KNOWLEDGE-ONLY MARINE POLICY

DOUGLAS CORMACK BSc. PhD.
formerly
Director, Warren Spring Laboratory, Dept of Trade and Industry, UK

Foreword

My Life-Long Interest in the Knowledge/Belief Dichotomy.
According to my mother 'I could talk before I could walk' because my father began to explain my immediate surroundings to me before I could do either. Again, when I became aware of my oldest cousin's claim that he wouldn't argue if he didn't know he was right, I questioned how he knew he was right, having already been aware of my father's usual comment on the politically opinionated: 'they don't know what to be at - who would have told them?' As with Socrates, however, he lacked the means of resolving such opinions/counter-opinions, while I had begun to recognise that nobody had yet provided such means. Later, I contrasted *The Book of Genesis* with *How Things Began* as broadcast for 11-12 year olds by *Scottish Radio for Schools*, and while being initially attracted to the Enlightenment and having discovered the *Free Thinker* as a sixteen year old, I quickly rejected its reliance on rationality *per se,* by discerning that both the religious and the non-religious were rational in so far as their respective conclusions were circularly compatible with their respective premises of belief/counter-belief. Yet again, I discerned that while Darwin's *Theory of Evolution* failed to explain species-diversity and was thus belief, the *Atomic Theory* of my school science explained chemical-diversity and was thus knowledge; and that while the self-styled Enlightened dismissed traditional behaviour codes as religious belief, I identified their knowledge-contents as attempts to harmonise individual selfishness with the hierarchical social cohesion essential to our group-species survival.

Thus, supported by my autodidactic awareness of the Dialogues of Socrates and of the Beyond of Pythagoras and Plato, none of whom differentiated 'knowledge' from 'belief', I concluded that these terms were no less synonymous in current academia than they had been in everyday speech since time immemorial; and that I might begin their differentiation by associating knowledge with progress in social-cohesion and physical-welfare, and regression in both with the irresolvable nature of belief/ counter-belief. Thus, having sought and found these differential associations in literature, philosophy, anthropology, sociology, history, economics, politics, etc, I discerned nonetheless, that the only differentiation recognised by their authorities was that they deemed their co-believers to be rational and their counter-believers to be irrational, and *vice versa*; and that nobody had informed these disputants that their differences in belief could be resolved only by the acquisition of relevant knowledge, the absence and the need for which, both participants and commentators remained entirely unaware.

Meanwhile I was acquiring the knowledge provided by *scientific method* through a first class honours BSc in chemistry with subsidiary mathematics, physics and microbiology, and a PhD in physical chemistry at the University of Glasgow, while extending my autodidactic knowledge of astronomy and cosmology. I then added elements of oceanography, geology and marine chemistry through a post-doctoral sojourn at the Woods Hole Oceanographic Institution in the USA, while seeking knowledge/ belief associations with progression/regression in US history, economics and politics in my spare time. Again, I discerned no recognition of such associations by any of their so-called authorities, the only recognised dichotomy again being that of rationality/irrationality, all resulting belief-consensual policy implementations being no more than restatements of their belief or counter-belief premises as in all belief/counter-belief systems of government since time immemorial. As to professional commentators on both history and current affairs, I recognised that while all of them discerned failures of government and suggested alternative policies of one kind or another, these were and are expressions of opinion/ counter-opinion, all of which perpetuate the associated debates without resolving them.

However, having been satisfied with the then current stage of physicochemical science, and having investigated its potential contribution to derivative and dependent sciences such as oceanography, I joined the UK Scientific Civil Service with the private objective of injecting scientific knowledge into governmental policy-making through the Warren Spring Laboratory (WSL) of the Department of Trade and Industry (DTI). However, I soon observed that governmental policy-making was dissociated from the scientific-technical knowledge being acquired by WSL in respect of chemical engineering, computerised process-control, materials handling, mineral processing, metal extraction, and national air quality monitoring; and that the knowledge acquired by R&D in these fields had no officially recognised role in policy-making, all of which was belief-consensual, regardless of knowledge, and thus regardless of reality. Later, as my career developed, I successively observed that while environmental work on industrial/automotive air-pollution abatement, on oil/HNS pollution prevention and response, on industrial and domestic waste recycling/disposal, and on contaminated land remediation was relevant to a growing public interest in environmental affairs, the knowledge being acquired thereon by WSL, had no effect on belief-consensual environmental policy-making.

Thus, on this experience from senior scientific officer (grade 8) to Director of WSL as chief scientific officer/under-secretary (grade 3) and from seven years experience as a grade 6 in the Marine Division at Departmental HQ, I concluded that so long as knowledge/belief remained undifferentiated, short-term party-political advantage would continue to be achieved by belief-consensual policies; that such party-specific policies would be successively implemented in ignored reality; that policy-makers and publics would continue to be unaware of the absence of knowledge in policy-making or of any need to acquire it for this purpose; that those who thus benefited from belief/counter-belief debate would oppose the knowledge/belief differentiation which would terminate it, even if such differentiation were possible; but that I might make it possible by demonstrating the compatibility of knowledge with reality and the incompatibility of belief with reality, reality itself being the only reference common to all.

In choosing to join WSL from the options offered after interview at our Embassy in Washington by the then counter 'brain-drain' panel, and in pursuit of my private objective of injecting knowledge into policy-making, I directed my early investigations in the chemical engineering division towards catalytic abatement of air pollution, the air pollution division itself being engaged in monitoring national air quality without being required to improve it. Thus, when central policy did require the marine pollution section of the chemical engineering division to be enhanced by creation of an additional division, I successfully applied to head it on my second promotion, my earlier oceanographic experience having coincided with the intended provision of a dedicated ship for the exclusive use of this new division. Here, I supposed, was a new policy-area into which I could inject new knowledge from the outset. Thus, I and my new division began to acquire new knowledge of the fate, effects, prevention and clearance of marine pollution on my assumption that ostensibly requested knowledge would speak for itself in refuting the beliefs which had been gaining ground with the public and with policy-makers since the *Torrey Canyon* incident of 1967. In retrospect, I now see this specific knowledge-acquisition as the **first stage of my campaign for knowledge-only policy.**

My Definitive differentiation of the Knowledge/Belief Dichotomy

With the knowledge thus acquired having been sequentially reported in the R&D reports of WSL and reviewed in my first book[1] of 1983 and in my second[2] in 1999 without effect on the environmentalist beliefs which were increasingly misleading policy-makers, I recognised that knowledge was failing to speak for itself; that belief was suppressing knowledge by being conflated/elided with it; and that this error could be corrected only by definitive knowledge/belief differentiation. Thus, my third book[3] of 2010, *The Rational Trinity: Imagination, Belief and Knowledge* recognised for the first time that reality stimulates our imaginations through our senses to beliefs transformable to positive or negative knowledge by evaluation of their compliance or non-compliance with reality, or to beliefs beyond this co-defined reality-evaluation in principle or in *pro tem* practice, but which cannot be accepted as knowledge in the absence of this reality-evaluation; that this reality-evaluation not only differentiates the knowledge/belief dichotomy, but also those of truth/falsehood, wisdom/folly, right/wrong and good/ bad; and that reality-evaluation of beliefs as specific hypotheses produced the knowledge which is our craftsmanship, science, technology and the knowledge-content of our traditional behaviour codes, while all else is belief/counter-belief or knowledge/belief mixtures which can now be differentiated into their knowledge- and belief-contents by noting the presence or absence of reality-evaluation, while reality-evaluation of hypotheses (beliefs) derived from available knowledge produces further knowledge.

Having thus resolved epistemology, it is now possible to differentiate the knowledge-contents from the belief-contents of metaphysics, religion, behaviour-codes, sociology, psychology, jurisprudence, literature, economics, politics and all other undifferentiated mixtures of knowledge/belief, thus differentiating their unifying knowledge from their divisive beliefs/counter-beliefs. Again, my third book recognises that opinion/counter-opinion is belief/counter-belief supported by partially selected facts/counter-facts neither set of which is conclusive knowledge because these so-called facts/counter facts have no established causal relationship to their supposed effects; that the only product of opinion/ counter-opinion debate, is an elective belief-consensus, transient from one debate to another in endless succession; that knowledge is thus differentiated from opinion and fact; that debaters merely re-state their premises while voters decide a belief-consensus; but that the knowledge-only contingency and incident-specific plans of this website were produced by the reality-validation of beliefs as specific cause-effect hypotheses by the designed experimentation by which I now define *scientific method*. Thus, we see more generally that knowledge, truth, wisdom, right and good 'work' in reality as do craftsmanship, science and technology, while belief, falsehood, folly, wrong and bad can only 'work' in reality by accident, while their otherwise accumulating errors, cause violence, revolution or war.

Nonetheless, enthusiasm for belief over the knowledge which refutes it, has been sufficient to produce financial subscribers for the continuing support of belief-propagating pressure groups; and to ensure that no employee of any environmentalist pressure group nor any subscriber ever visited WSL, or attended any of its knowledge-only training courses on marine pollution. However, with my newly definitive knowledge/belief differentiation offering the first ever means of curtailing this misplaced enthusiasm for belief, I opened the **second stage of my campaign for knowledge-only policy**, the terms 'knowledge-only' and 'belief-only' indicating the respective absence of belief and of knowledge.

My Knowledge/Belief Differentiation in Action.
Having accepted that knowledge had failed to speak for itself; and that consequently the **first stage of my campaign for knowledge-only policy** had failed to detach policy-makers from belief-only policy, I now assumed that my newly definitive knowledge/belief differentiation would be more effective, and on this assumption I entered the **second stage of my campaign for knowledge-only policy** by applying the knowledge/belief differentiation of my third book to re-present my first two books as a series of weekly articles in *Cormack's Column* of the Newsletter of the International Oil Spill Control Organisation (ISCO) from November 2011 to August 2014, and to re-present these articles as sequential documents to meetings 10 - 16 of the oil and hazardous substances (Oil/HNS) Technical Group (TG) of the Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO); to summarise these documents for meetings 67/68 of the MEPC itself; and for the October 2014 and April 2015 meetings of the International Oil Pollution Compensation Fund (IOPCF) Assembly and Executive Committee.

However, while none of these documents raised any dissention from delegates, and while I expected none, given the definitive irrationality of preferring definitive belief to the definitive knowledge which refutes it, I must admit that policy-makers have as yet shown little or no enthusiasm for my newly definitive knowledge/belief differentiation in practice. Nonetheless, the absence of overt dissention encouraged me to compile this website as the **third stage of my campaign for knowledge-only policy**, my knowledge/belief differentiation having been incorporated in the articles of *Cormack's Column* and these articles having now been re-edited and re-titled for this website for the purpose of persuading policy-makers and the general public of the need to terminate their preference for definitive belief over the now definitive knowledge which refutes it, though this termination runs counter to their education in rhetorically comparing, contrasting and construing the perpetually undefined.

Thus, in contrast to perpetual rhetoric, this website now definitively differentiates knowledge from its counter-beliefs and collates the former as a reference repository from which general contingency plans are developed for all aspects of casualty response and from which in turn incident-specific response plans can be developed by inserting incident specific values for the controlling physicochemical parameters identified in the contingency plan as applicable to predicting the fates and effects of all potential pollutants and to quantifying the outcomes of responses to them. Thus, with the International Spill Accreditation Association (ISAA) now offering to accredit response contractors and customer States as to their competence in using this knowledge repository and its knowledge-only contingency/ incident-specific plans, it is expected that the resulting compensation claims will be expeditiously settled in compliance with reality; that the repository will be enhanced with knowledge acquired from successive incidents; and that all individuals and parties interested in extending knowledge-only policy-making to other belief-consensual fields will visit website www.knowledgeonlypolicy.weebly.com and its specific subject-derivatives, as I successively establish them and list them therein.

1 Response to Oil and Chemical Marine Pollution, D. Cormack, Applied Science, 1983.
2 Response to Marine Oil Pollution - Review and Assessment, Douglas Cormack, Kluwer Academic, 1999
3The Rational Trinity: Imagination Belief and Knowledge, Douglas Cormack www.authorsonline.co.uk

Preface

Benefits of Knowledge/Belief Differentiation.
This website is a repository of the knowledge by which coastal States from the 1980s onwards could have identified the values of the physicochemical parameters which predict the fates and effects of all oil/HNS releases and the means of their cost-effective prevention and response, had they been able to differentiate knowledge from the counter-beliefs of self-appointed pressure groups. Thus, the general benefit of my definitive differentiation is that belief can no longer be misrepresented as knowledge by these groups, while the particular benefit is that the knowledge thus liberated from counter-belief now provides a knowledge-only contingency plan from which even fresh staff can prepare and execute incident-specific plans from which predictions made, decisions taken, accredited contractors employed, quantified results obtained, and costs incurred can be reported to the secretariats of the International Oil Pollution Compensation Fund (IOPCF) and P&I Clubs in fully documented form for expeditious settlement of claims, and to the secretariat of the International Maritime Organisation (IMO) for enhancement of the repository with knowledge acquired by direct observation at all successive incidents. By these means, the additional knowledge will refine and extend our existing quantitative knowledge as to the relationship between pollutant viscosity and the efficacy of current and future dispersant formulations and the respective efficacy of the various design principles of mechanical removal systems, at sea, on inshore waters and onshore.

This website recognises, however, that before any of these benefits can be realised, national policy-makers must recognise that they have thus far been captives of the knowledge-countering beliefs of self-appointed pressure groups; and that cost-effective response requires rejection of all such belief and acceptance of all currently available knowledge. Further to encouraging this knowledge-acceptance/ belief-rejection, this website recognises that belief in species-extinction/ecological-disaster currently prohibits or restricts dispersant-response to arbitrary distances from shore and/or to arbitrary water-depths, thus increasing the physical coating of shorelines and organisms which it ostensibly seeks to avoid; that it restricts recovery by prohibiting *in situ* discharge of co-collected and demulsified water, thus wasting storage capacity for removed pollutants and thus obstructing the pollutant-removal of which it ostensibly approves; and that it prohibits cargo/bunker transfer in safe havens, thus permitting single-tank release to become the total cargo/bunker release which it ostensibly seeks to avoid.

To emphasise the paradoxical nature of the consequences of this belief in species-extinction/ecological-disaster, this website recalls that these restrictions and prohibitions are counter to the long available knowledge that seawater concentrations arising from natural or induced dispersion are incapable of any such extinction/disaster however large the release or discharge may be; that the number of organism-deaths from physical-coating is insignificant compared to the numbers dying and birthing annually in the natural maintenance of species-populations; that consequently no extinction/disaster has arisen from any incident thus far; and that the acceptance of knowledge-only response and the rejection of belief-only restrictions and prohibitions would restore polluted localities to their pre-incident conditions more quickly and cost-effectively than beliefs counter to knowledge have permitted thus far.

Again, this website recalls that before this new knowledge-only approach can improve the current guidelines for claim submissions and selection of self-styled experts for their assessment, policy-makers and the general public must recognise that debate of opinion/counter-opinion is merely debate of belief-counter-belief supported by partially selected facts/counter-facts, neither set being debate-terminating knowledge; that there are as many opinions as there are opinionated ‘experts’; that debate produces only a belief-consensus; that no such consensual majority ever eliminates minority dissent, though it may suppress it; and that dissent over whether a response is ‘reasonable’ and ‘proportionate’ under the MARPOL Convention, is resolvable solely by knowing it to be reasonable and proportionate, belief/ counter-belief being conducive of no more than divisive debate.

Yet again, this website recalls that no dissent arose when this new knowledge-only approach was being serially presented to meetings 10-16 of the OPRC-Oil/HNS Technical Group of the MEPC of the IMO; that this absence of dissent was its first, though covert, recognition of the irrationality of preferring belief to the knowledge which refutes it; and that the rational inability to dissent from the summarising documents MEPC 67/19/INF.13 and 68/20/INF.6 and from documents IOPCF OCT14/4/6 and APR15/ 4/5 now leaves higher policy-makers no option but to accept overtly that any continuing preference for belief over the knowledge which refutes it would now be the irrationality of definitive madness.

This website thus recalls that until this definitive impossibility of dissent became observable within the IMO/IOPCF forum, policy-makers had been captive of the pressure-group belief in species-extinction/ ecological-disaster, despite the knowledge which refutes it having been publicly reported by such as the chemical engineering division of the UK Warren Spring Laboratory (WSL) consequent to the *Torrey Canyon Incident* of 1967; by the international training courses of the subsequent Oil/HNS Division of WSL from 1974 - 79; by its R&D reports from 1974 - 94; by WSL contributions to the biennial International Oil Spill Conferences from 1975-89; by the transmission of this knowledge through my chairmanships of the Response Manual Working Group of the IMO and of the Bonn Agreement Working Group on Operational, Technical and Scientific Oil Pollution Aspects (OTSOPA) of marine pollution; by my books of 1983 and 1999; and by the special editions of Elsevier’s Marine Pollution Journal which I issued from time to time as Journal Editor.

Thus, this website recalls that knowledge has indeed been suppressed by reiterative assertion of its counter-beliefs by self-appointed pressure groups; that these groups thus captured the exclusive attention of policy-makers and the general public; that this capture was maintained by presenting beliefs as scientific knowledge to those unable to differentiate scientific knowledge from the beliefs of pseudoscience; and that politicians have accepted all aspects of the ensuing belief-consensus as vote winners; and that the **first stage of my campaign for knowledge-only policy** had accordingly failed.

Again, given that the **second stage of my campaign** had not yet succeeded despite utilisation of my newly definitive knowledge/belief differentiation in *Cormack's Column* and in its associated documents to MEPC and its Technical Group, it became clear to me that my knowledge/belief differentiation and its consequences respecting response to marine casualty, would now require presentation in a single comprehensive form for the widest possible access; and that this would require a website accessible to politicians, policy-makers, commentators and the general public. This is that website. However, I also considered it fair to the individual members of those environmentalist pressure groups that I invite their leaders to reality-validate/reality-refute their beliefs to positive/negative knowledge as set out below; and that I accordingly invited their members to support the **third stage of my campaign for knowledge-only policy** which starts with this website.

My Invitation to Environmentalist Believers.

With preferment of belief over knowledge being made rationally impossible by my newly definitive knowledge/belief differentiation, and with no dissention having been voiced over the consequences of its use in my Newsletter articles nor in my presentations to the MEPC Technical Group, I invited the leaderships of belief-propagating pressure groups either to accept the knowledge that their belief in species-extinction/ecological-disaster had been reality-refuted by direct measurement of seawater concentrations of released oil and by the absence of such effects at all incident thus far; or to reality-evaluate it for themselves by comparing the numbers of organisms dying at incidents with those dying/ birthing annually in stable species-populations, by observing the rates at which shorelines denuded of organisms by oil and/or by cleaning, are re-colonised by their respective planktonic life-stages, by observing the rates at which boat-slips denuded of organisms for pedestrian safety are thus re-colonised, and by observing the rates at which weeded gardens are re-colonised by incoming seeds.

Again, I invited these pressure group leaderships to reality-evaluate their belief in anthropogenic global warming (AGW) with reference to our knowledge that the entire biomass of land and sea is maintained by abstraction of carbon dioxide from the atmosphere by photosynthesis and by return of this carbon dioxide to the atmosphere by contemporaneous biodegradation of these biomasses; that this biodegradation is interrupted solely by the absence of oxygen which converts intermediate biodegradation products to peat, natural gas, oil and coal; and that anthropogenic combustion of such 'fossil' fuels or their resumed biodegradation when released to the environment, returns to the atmosphere only part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through the global atmosphere and biomasses. Yet again, I invited these pressure group leaderships to reality-evaluate their belief in AGW with reference to our knowledge that carbonate rock is produced from atmospheric carbon dioxide by the Urey reaction with silicates in tectonic mountain-building and returns this carbon dioxide to the atmosphere by tectonic inducement of its volcanic degradation; and that were there no such volcanic-return, the atmospheric carbon dioxide necessary for life would have been sequestered as carbonate rock geological-ages ago.

Accordingly, I invited these belief-perpetrating pressure group leaderships to reality-evaluate hypotheses as to whether an increase in carbon dioxide return to the atmosphere by one of those cycles would result in an increase in abstraction by the other or both, to which end I suggested that hypotheses derived from horticultural knowledge of crop yields being increased by increasing the carbon dioxide content of controlled atmospheres would be a good place to start. As of now, this website records that no response has been made to these invitations and suggestions of 15 November 2012, despite the intended invitation having been announced at the prior MEPC meeting of 2012, though no response was expected of those who rely on belief *per se* rather than on its reality-validation or reality-refutation.

Comparison of the First and Second Stages of My Campaign for Knowledge-Only Policy.
With the **first stage** having recognised that policy-makers had been entrapped by belief-perpetrating pressure-groups since publication of Rachel Carson's *Silent Spring* in 1962, I anticipated the possibility of the knowledge reported in my first book[1] of 1983 being suppressed by belief-only opposition to its publication, even at the invitation of Elsevier. Indeed, I was aware that these beliefs had already caused the contingency plan of the new Marine Pollution Control Unit of 1979 to be largely a list of the so-called interested parties (pressure groups) who would be called to discuss any proposed response to incidents whether or not they accepted or rejected the knowledge which WSL had been paid by government to acquire, and which was thus being downgraded to a topic for opinion/counter-opinion debate. Thus, when DTI suggested publication by HMSO, I invoked the Elsevier invitation to preclude the editing of my text by administrative believers.

Again, to offset anticipated post-publication opposition from believers, the preface of my first[1] and second book[2] referred to the first six lines of the poem by S.G. Saxe, *The Blind Men and The Elephant* to indicate that while the blind men came to differing beliefs as to the nature of the elephant depending on which part of it they happened to touch, those approaching the nature of casualty-response without prior knowledge might be expected to come to differing assessments as to its nature depending on their pre-conceived beliefs/counter-beliefs. Thus, to avoid distracting accusations of attributing blindness to such believers, I sought merely to imply that the nature of casualty-response would be grasped only through knowledge of its controlling (cause-effect) parameters, my limited intention at that **first stage** being for knowledge to win rhetorically in whatever debates might ensue.

However, I was more confident that the knowledge/belief differentiation of the **second stage** would result in adoption of my knowledge-only contingency and incident-specific planning approach, debate now being definitively redundant; that the belief in species-extinction/ecological-disaster would accordingly be recognised as having been reality-refuted by measurement of exposure concentrations and by the absence of such effects at all incidents thus far; that the only significant consequences of releases would now be recognised as the transient and recompensed losses of fishery and/or amenity values; that the layer thinness of releases and discharges which limit seawater concentrations and thus preclude species-extinction/ecological-disaster would also be recognised as limiting response capability at sea to releases of about 3000 - 5000 tonnes under onshore winds; and that the resulting need for emergency removal of cargo/bunkers in safe havens to prevent releases of more than the IMO designed release of 5000 tonnes from a single impact-damaged tank would be recognised as fortuitously matching the thinness-limited capacity to respond to any slick at sea. However while there was no overt dissent from or debate about this knowledge-only approach, there has as yet been no rush to adopt and implement it.

The Third Stage of My Campaign for Knowledge-Only Policy.
The **third stage** is the creation of this website, driven by the lack of policy-maker urgency respecting the second stage, and encouraged by the current level of inter-delegate belief/counter-belief dissent within the MEPC respecting regulation of operational discharges and emissions from ships, and within the IOPCF Assembly respecting the submission and assessment of compensation claims, to the resolution of which my documents MEPC 67[4]/68[5] and IOPCF 14[6]/15[7] were specifically addressed.

As to this inter-delegate dissent, I recall that it first became overt over the costs of belief-only regulation of oil/HNS discharges and became covert only when the knowledge needed for compliance was later acquired and developed by WSL; that it again became overt when belief in species-extinction/ ecological-disaster insisted on zero discharge in so-called Special Areas, despite total cargo/bunker releases being incapable of any such effects; that dissent over ballast water regulation is now overt because belief-only approaches to its compliance have yet to be reality-validated; that dissent over emissions of sulphur, nitrogen and carbon dioxides, arises from the cost-implications of regulations which are merely belief-consensual in continuing to ignore the natural recycling of all life-essential elements through biomass and environment, those of sulphur, nitrogen, phosphorus, magnesium, iron etc, being co-photosynthesised from the environment and returned to it by biodegradation, as is carbon itself; and that this inter-delegate dissent is resolvable only by the knowledge which validates need and enables its satisfaction. Again belief/counter-belief dissent over claim submission and settlement within the IOPCF Assembly will be resolvable only by knowledge.

Thus, this **third stage** is directed to the adoption of my knowledge-only approach to incident response and to the resolution of inter-delegate dissention over claim settlement procedures and operational discharge and emission regulations. As to the prospect of success, I can report that while the belief in species-extinction/ecological-disaster previously suppressed all knowledge of the benefits of dispersant-use, the MEPC Correspondence Group on Dispersant Use reported its partial acceptance of these benefits to MEPC 68 in 2015. Thus, it has now accepted that the known concentrations of oil in seawater are insufficient to cause extinction/disaster; that dispersants are less toxic than oil at the concentrations of exposure; and that oil slick thickness which is the source of such concentrations is 0.1mm; that dispersed oil dilutes and biodegrades in the water column; and that dispersants prevent the physical coating of organisms and shorelines, and eliminate the need for removed pollutants to be processed: all of which is a part-acceptance of the dispersant knowledge contained in my documents to the Technical Group, the MEPC and the IOPCF Assembly, though the Correspondence Group made no reference to these documents. The Group, however, still calls for discussion (of opinions) as to the advantages/disadvantages of dispersant use to arrive at what it calls Net Environmental Benefit (NEB) at each and every incident, despite the advantages being known and the disadvantages being those of adherence to reality-refuted belief.

Thus, I invite global citizenry and IMO/IOPCF delegates to accept knowledge for policy-making in general, rather than the beliefs refuted by it; to reject in particular the reality-refuted belief in species-extinction/extinction/ecological-disaster and its paradoxical influences on response to marine pollution; to accept the knowledge which refutes this belief and removes its paradoxes; and to suspend the belief in anthropogenic global warming (AGW) and its costly responses until it is reality-validated, all we have as yet being the irresolvable debate common to all systems of belief/counter-belief[8].

1 Response to Oil and Chemical Marine Pollution, D. Cormack, Elsevier Applied Science, 1983.
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack Kluwer Academic 1999
3 The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack www.authorsonline.com
4,5,6,7: documents at Annex I.
8 www.knowledgeonlypolicy.weebly.com

Acknowledgements

WSL and Associated Staff.
I am pleased to take this opportunity to thank former colleagues in the Oil Pollution Division at Warren Spring Laboratory (WSL) for their acquisition of knowledge by what I now define as reality-evaluation of specific hypotheses as to the influence of physicochemical parameter values on the fates and effects of oil and hazardous noxious substance (HNS) releases, discharges and responses to them.

Thus, as with my first two books, I acknowledge the contribution of Mr. B. O. Dowsett, formerly my deputy head of division, for his unstinting support and for his development work on the Springsweep System and on the evaluation of all other design-principles for mechanical removal at sea; Mr. J. A. Nichols and Mr. H. Parker for work on dispersants and in particular on quantifying the parameters controlling their airborne application; Mr. H. Parker and Dr. F. Martinelli for remote sensing and dispersants; Mr. J. A. Nichols, Mr. B. Lynch and Mr. H, Parker for factors affecting the fate and effects of releases; Mr. D. H. Thomas, Mr. E. Wayment, Mr. N. Davia and Mr. R. Clark for oil removal in general; Dr. Margaret Lee for demulsification; Mrs. J. Smith and Mr. H. Sinnott for dispersant efficiency testing; Mr. J. F. Nightingale and Mr. N. Davia for all aspects of inshore water and shoreline clearance; Mr. T. Walsh, Mr H. Parker and Mr. N. Davia for oil/water separation and oil-in-water

monitoring; Mr. J. A. Nichols and Mr. N. Hurford for operational-discharge and casualty-release of HNS; Mr N. Hurford for oil : dispersant efficiency ratios; Mr. A. Cahit, Mr. G. Cripps Mr. L. Elliot and Mr. C. Wadden for general support of the division as a whole; and Miss R. A. Benstead for her office-management and capacity to type all division reports without recourse to the typing pool.

Thus, I acknowledge that these colleagues were the division from October 1974 until I joined the Marine Pollution Control Unit (MPCU) of the Marine Survey and Coastguard division of DTI as a founder-member in March 1979, later to be joined by Mr. B. O. Dowsett and Mr. B. Lynch who remained with the MPCU until their respective retirements. In addition, I am pleased to acknowledge the thanks due to the Stevenson-Clark officers and crew of our ship *Seaspring*, who with appropriate parties from the above division kept the ship operationally productive at sea for five days per week from June 1976 to March 1979 and thereafter at the increasing intermittency which necessitated her sale to the private sector as a standby North Sea response vessel; and to Nigel Brendish and John Churchill of Harvest Air for cooperation in developing the aerial dispersant-spraying technique.

I further acknowledge that prior to establishment of the MPCU, incident response at sea was led by the nearest port-located Principal Officer of the Marine Survey Service of DTI using the WSL-designed shipboard dispersant application systems as advised by appropriate WSL staff, while inshore/onshore clearance was led by the senior emergency control officer of the affected local authority, again as advised by WSL staff. However, having been invited to join the intended MPCU as its in-house scientist, and having expressed my preference for the new unit to be my WSL division and for it to manage both sea and shore response respecting the differing responsibilities of our department and those of the department of environment and local government, I acknowledge my acceptance of the initial invitation on the grounds that it would link the HQ unit to the knowledge repository which was the WSL division; that it would facilitate what I now see as the **first stage of my campaign for knowledge-only policy**; but that it took the intervention of the then Royal Commission on the Environment, for DTI to permit me to liaise with individual local authorities from my personal position within the new MPCU.

I further acknowledge that in March 1986, I was returned to WSL on promotion to deputy director in charge of its then four environmental divisions on marine oil/HNS pollution, industrial and domestic recycling/disposal, national air quality monitoring, and abatement of industrial and automotive emissions to the atmosphere, and in charge of personnel management for the whole laboratory. I also acknowledge, however, that the **first stage of my campaign for knowledge-only policy** had only been partially successful at HQ in that it had produced national stockpiles of, and service contracts for reality-validated response equipment; but that the contingency plan was written by departmental administrators thus ensuring that the use of the stockpiled and contracted equipment would be a matter of debate, heavily influenced by external environmentalist belief.

Nonetheless, as to the maintenance and further development of the WSL knowledge repository, I hereby acknowledge and thank those transferred or recruited to the Oil/HNS division during my time at HQ or after my return to WSL. Thus, as in my second book, I thank Mr. D. Albone, Mr. K. Colcome-Heiliger, Dr. A. Turner and Dr. T. Lunel for work on dispersants; Dr. I. Buchanan, Dr. Caroline Penn, Mr. M. Leech, Mr. W. Walker and Mr. D. Wallace for knowledge-only modelling; Mr. A. North for beach clearance; Dr. R, Swannell for bioremediation; Mr. P. Tucker for oil/clay flocculation and knowledge-only modelling, Miss P. Madhvi for rheology and surface chemistry; Mr. R. Clay for reviewing combustive oil removal; Mr. A. Tookey and Miss J. Carroll for remote sensing; and Mr. M. Sommervile for all aspects of practical release-response: all of whom, together with those thanked above, acquired knowledge and secured it in its WSL repository until retirement, resignation or transfer to UKAEA at Harwell as described below.

The WSL Environmental Science and Technology Agency.

With privatisation of government laboratories having been considered before my return to WSL, a Secretary of State (Lord Young) subsequently acknowledged that I was recovering the full cost of four environmental divisions with contracts for other departments when announcing his intention to close the four industry divisions run by my then fellow deputy-director at lower cost-recovery on industry contracts, and to transfer me and my four environment divisions to an as yet undisclosed location, thus closing the laboratory as an alternative to privatising it.

I further acknowledge, however, that this Secretary of State accepted my personal and independent plan to redeploy the staff of the four industry divisions on expanded and/or additional environmental R&D for funding largely by other than our department; that he appointed me business manager of the whole laboratory; and that he replaced my fellow deputy-director with Dr L. Goldstone from HQ as the physical-resource/personnel manager for the whole laboratory, whom I now thank for his unreserved collaboration and later support when, on my promotion to Director, I decided to have him as my single deputy-director. At this stage, in addition to my original four divisions, I already had two divisions on abatement of industrial emissions to the atmosphere, had converted those on mineral processing and metal extraction to one on the remediation of contaminated land, had distributed the staff of the former materials handling and computerised chemical-engineering divisions across the now seven divisions as appropriate to my business opportunities and had converted the chemical analysis section to a fully supportive division of this new divisional arrangement in what was now the WSL Environmental Science and Technology Agency, the first government laboratory to be given agency status: in all of which developments I acknowledge the outstanding contribution of Les Goldstone.

However, with the load-bearing pillars of our three-storey building having to be replaced because of metal corrosion within the concrete, and with our neighbour (GLAXO) offering to buy our site, I now acknowledge that the DTI Secretary of State (Peter Lilley) and the Treasury agreed to use the funds already approved for pillar-replacement together with those from sale of the site to build a smaller more cost-effective laboratory with fewer pilot-scale facilities as specified by myself and Les Goldstone, in a nearby town to avoid home-relocation of staff. Nonetheless, the apparent success of this **first stage of my campaign for knowledge-only policy** was only superficial. Despite the new laboratory and its pilot-plant having been accordingly designed, foundations laid, and walls rising, despite our business profile having attracted international contracts from the US EPA and The Netherlands Rijkswatterstaat, and despite my publicly reported annual profits on our lowering charge-out rates having initiated management buyout proposals from two venture-capital associations, the Secretary of State (Michael Heseltine) cancelled the re-build, retained the funding, and sought to transfer our business with whoever would agree to re-locate, to the Harwell site as referenced above. Thus, given the success of our knowledge-only business, it must be concluded that such closure of WSL was a belief-only decision.

Having successfully concluded our existing contracts without financial loss to DTI by our programme of internal staff-transfers to compensate for staff-resignations prior to closing the laboratory for demolition and site-decontamination I have to acknowledge that I declined the offer of transfer to Harwell or to DTI HQ and requested early retirement while continuing to wonder whether he who ‘could not see the need to build a new laboratory in this day and age’ was perhaps pleased to close a knowledge-only environmental laboratory while belief-only environmentalist lobbies and belief/ counter-belief think-tanks were being created. Indeed, the UNPCC had begun to promulgate its belief in anthropogenic global warming in response to which I had conveyed my carbon dioxide recycling mechanism (Preface) to the Central Policy Division of DTI. Thus, I must acknowledge that belief-only policy had terminated the **first stage** of my internal campaign for knowledge-only policy**.**

Negative Effects of Staff-Change Frequency and Incident Infrequency.
Here, I acknowledge that the absence of significant incidents in UK waters from the late 1970s to the closure of WSL in June 1994 coupled with total replacement by then of the founding-staff of the MPCU, left no-one capable of attempting a knowledge-only policy respecting the *Sea Empress Incident* of February 1996; that this lack of knowledge-retention turned a text-book opportunity for cargo/bunker transfer of all but an initial grounding-loss of some 3000 - 5000 tonnes of cargo in the entrance to Milford Haven, into the further loss of 69,000 - 67,000 tonnes from re-floating/re-grounding on successive tides before the casualty was brought to a Haven terminal for discharge of the remaining 58,000 tonnes; and that this incident fully justifies my long-stated need for the preservation of knowledge irrespective of staff-change frequency and incident infrequency. Thus, the creation of my knowledge repository and its knowledge-only approach to contingency/incident-specific planning as a website, is the **third stage of my campaign for knowledge-only policy,** the **second stage** having been the re-casting of the WSL acquired knowledge in terms of my later knowledge/belief differentiation .

It must also be acknowledged, however, that this website will be unavailing if knowledge continues to be suppressed by belief; and that liberation from this suppression is essential given that the reality-refuted belief in species-extinction/ecological-disaster prohibited timely discharge of the *Sea Empress* to its destination refinery, prohibited *in situ* discharge of co-collected and emulsion-processed water, insisted on all such processing being conducted at authorised premises such as refineries, thus slowing the overall rate of pollutant removal, prohibited dispersant-use within the Haven and outside until pollutants were wind-driven offshore, and thus resulted in belief-only claims for a 72,000 tonnes release rather than in knowledge-only claims for the initial release of 3,000 - 5,000 tonnes.

Thus, the poor utilisation of response knowledge from the *Torrey Canyon* to the *Deepwater Horizon* incidents inclusive, must be acknowledged as more than adequate encouragement for acceptance of the **third stage of my campaign for knowledge-only policy** now secured against staff-change frequency and incident infrequency by access to, and adoption of the knowledge repository and knowledge-only contingency/incident-specific planning approach provided by this website.

Beyond the divisional staff who contributed knowledge to this website, I take this opportunity to thank the staff of the other divisions of my then Warren Spring Laboratory for their contribution to environmental knowledge-acquisition in general. In recognition and memory of them all, I hereby acknowledge my aspiration to achieve ultimate success for the **third stage of my campaign for knowledge-only policy** respecting the environment in general and all other fields of belief-only policy by exemplary extension, an endeavour which will be fully successful only when national governments adopt policies of knowledge-acceptance/belief-rejection and promulgate them through the UN System[8]. Thus, I am pleased to acknowledge the recent move towards knowledge-acceptance/belief-rejection by IMO Member States respecting dispersant use: a small and partial step, but one which augurs well for overall success in the maritime and all other fields of current belief-only policy[8].

As to the specific need for knowledge-only policy respecting marine casualty releases, and operational discharges and emissions from ships, I am confident that policy-makers now have no rational alternative other than to accept this website as the knowledge repository from which knowledge-only contingency and incident-specific plans can be derived for mutual use by all coastal States, response contractors, and the secretariats of the IMO, the IOPCF and the P&I Clubs, and from which the regulation of operational discharges and emissions from ships can be re-assessed on the knowledge which must replace belief.

1 Response to Oil and Chemical Marine Pollution, D. Cormack, Elsevier Applied Science, 1983.
2 Response to Marine Oil Pollution- Review and Assessment, Douglas Cormack, Kluwer Academic Publishers, 1999.
3 The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack www.authorsonline.com
4, 5, 6, 7: the documents at Annex I.
8 www.knowledgeonlypolicy.weebly.com

WEBSITE INTENTIONS

In light of the foregoing Overview, Foreword, Preface and Acknowledgements, the first intention of this website is to create support for the replacement of belief with knowledge in policy-making by public recognition that debate of belief/counter-belief arises from the absence of knowledge and is maintained by suppressing knowledge or by ignoring the need for further knowledge acquisition; that debate- generated belief-consensus is not knowledge of reality and thus ought not to be implemented in reality without reality-evaluation to positive knowledge for acceptance or to negative knowledge for rejection; that all previously implemented belief-consensus in all areas of policy should be observed either to have worked in reality as positive knowledge or to have failed as negative knowledge; and that in future, electorates ought to be asked to prioritise knowledge-only policy-options for implementation within resource limits, the term knowledge-only denoting the absence of belief/counter-belief (articles 1 - 38).

The second intention is to exemplify marine pollution prevention and response as a candidate for such resource limitation. Thus, the preamble to this website (articles 39 - 49) presents the knowledge ignored by belief respecting the impacts of releases from ships, oil-wells and land-sources, while contrasting the physicochemical knowledge which controls fates and effects of operational discharges and accidental releases, with resource-wasting beliefs in toxicity, in spurious mathematical modelling, and in further investigation of the combustion of oil on sea surfaces.
The third is to provide a readily accessible repository of all available response knowledge on evaporation and dispersion of discharges and releases; on fates, effects and biodegradation; on dispersant application and its viscosity-dependent effectiveness at sea and onshore; on the possibilities for more effective dispersant formulations; on remote sensing and sampling techniques for releases; on viscosity-dependent/design-dependent effectiveness of dispersant and mechanical removal techniques at sea and onshore; on downstream processing of removed materials; on recycling/disposal incapacities; and on the need for cargo/bunker transfer as revealed by the *Sea Empress* incident (articles 50 - 115).

The fourth is to show that the foregoing knowledge has been suppressed by counter-belief; and that this suppression respecting ecology and anthropogenic global warming can be terminated only by my newly definitive knowledge/belief differentiation (articles 116 - 129). The fifth is to show that the need for knowledge supremacy respecting casualty-response can only be satisfied if knowledge is thus definitively differentiated from belief in response planning, in the training and accreditation of responders, and in waste management and energy generation in general; and that while knowledge enables prediction of outcomes, belief is incapable of any such prediction (articles 130 - 155). Thus, the sixth intention is to show that the above knowledge repository is fully incorporated in my new knowledge-only contingency plan; that all future incident-specific response plans can be created by substituting incident-specific values for the physicochemical parameters identified in the contingency plan (articles 156 - 162) while the seventh is to show that the MEPC has been thus informed respecting casualty response and the regulation of operational discharges and emissions from ships; and that the IOPCF Assembly has been thus informed respecting claim settlement (articles 163 - 177 and Annex I).

Again, Annex II is intended to show the wider context within which the foregoing knowledge was acquired, while Annex III is intended to show the future rate and extent to which the knowledge and counter-beliefs cited in this website are being respectively accepted or rejected by Member States of the IMO and the IOPCF Assembly. At this point, further documents are separately in preparation to announce the availability of this website to these bodies and its specific relevance to each of them.

With this website having identified the benefits of differentiating knowledge from belief in respect of operational discharges, emissions and accidental releases to the marine environment, and having identified the general benefits of this differentiation in www.knowledgeonlypolicy.weebly.com, I intend to apply this differentiation in a series of further websites to demonstrate the benefits derivable from knowledge-only policy-making in other specific fields of socio-political belief/counter-belief.

THE KNOWLEDGE REPOSITORY: PREAMBLE

Harmonisation of Technology and Marine Environment

Article 1

I start by recognising that reality-validated knowledge is definitively in harmony with reality and that the harmonisation of technology and environment requires reality-validated knowledge of both. Thus, I recognise that belief in species extinction/ecological-disaster is definitively disharmonious with the reality-validated knowledge that while oils may cause organism-death and commercial-loss, species-extinction/ecological-disaster has never arisen from any incident thus far; that this particular belief has thus been reality-refuted repeatedly from the *Torrey Canyon* to the *Deepwater Horizon* incidents inclusive; and that the regulation of marine transportation will not be harmonious with the environment until environmental knowledge is accepted and environmentalist belief is rejected by policy-makers.

Thus, from my newly definitive differentiation of the knowledge/belief dichotomy, we know that while some individuals per species may be killed per incident, belief in lasting-damage to species let alone to the ecosystem, remains belief; and that were believers to compare the numbers killed per species per incident, with the numbers born/dying annually in the maintenance of species populations, all residual doubt would be removed and knowledge would replace countering-beliefs respecting species-specific and ecological effects in general. Again, the physical-coating of individuals within species is dependent on their known habits. Thus, moulting auks temporarily confined to the sea-surface, habitual waders, and species which habitually dive from the surface to feed, are at greater risk of individual deaths than are those which dive from the air only where and when fish are not hidden by oil slicks. Indeed no dead birds were seen at the Ekofisk Blow-out of 1976 and none were seen flying in the area while the slick persisted. Again, as to ecological damage at the base of the food chain and upwards, we know that there are no ill-effects from dispersed oil droplets which are habitually biodegraded by micro-organisms whose standing populations increase with proximity to chronic oil-sources and natural seepage. Yet again, while ecological effects might be expected where shore-located organisms have been covered by oil, we know that even such shores are re-colonised as effectively as scrubbed boat-slipways or weeded gardens, while the seawater concentrations arising from natural or induced dispersion of floating slicks are known to be orders of magnitude below those needed to produce toxic effects.

Further to bio-oxidative degradation by micro-organisms at the bottom of the food chain, we know that all vegetative-matter is photosynthesised from atmospheric carbon dioxide and returns to carbon dioxide and water on post-mortem biodegradation; that all animals and humans respire food-matter to carbon dioxide and water while alive and biodegrade to these molecules when dead; and that localised oxygen-deprivation interrupts this biodegradation to form peat, natural gas, petroleum and coal. Thus, we know that biodegradation of oil droplets in the sea and combustion of 'fossil' fuels, return to the atmosphere the carbon dioxide which would otherwise have returned earlier had its biodegradation not been interrupted. Indeed, we also know that tectonic plate movement continuously raises mountain ranges with silicate abstraction of atmospheric carbon dioxide to form carbonate rock by the Urey reaction; that this carbonate is subsequently eroded and river-transported to the marine sediments; and that these are sub-ducted beneath continental margins with associated volcanic release to the atmosphere of their formative carbon dioxide.

Thus, while beliefs in oil-related species-extinction/ecological-disaster are reality-refuted by direct observation of seawater concentrations and of re-colonisation rates, steps could be taken towards reality-validating or reality-refuting belief in anthropogenic global warming (AGW) by comparing the increase in carbon dioxide emissions since the industrial revolution with the possible increase or decrease in carbon dioxide emission or abstraction in one or both of these natural cycles. The point at issue is not whether global temperatures rise or fall: we know they do from the geological record of successive cold and warm ages of millions of years duration and of intermediate periods of more moderate variation. The point at issue is whether or not anthropogenic activities during the industrial age of some two centuries or even a few decades can have had, or will have, any effect relative to these natural effects. Alas, such reality-evaluation of specific hypotheses derived from the belief in AGW has been precluded by the capture of policy-makers in its correctly named belief-consensus, there having as yet been no reality-validation or reality-refutation of this belief: hence the interminable AGW debate.

Article 2

As to the acquisition of knowledge on the fates and effects of accidental releases and operational discharges of oil/HNS to the marine environment, Warren Spring Laboratory (WSL) was unique in having authorisation to release oil/HNS at sea and onshore for investigation of fates, effects and evaluation of responses to these effects, and in having its former ship-chartering arrangements replaced with the fully dedicated ship *Seaspring* from June 1976. Nonetheless, while the knowledge thus acquired was published in a series of unrestricted reports and summarised in my first book of 1983, and while my second book of 1999 included an analysis of the extent to which this knowledge had been suppressed or lost as exemplified by response to the *Sea Empress* incident of 1996, neither of these books caused the counter-belief in species-extinction/ecological-disaster to be rejected despite their having shown that the resulting exposure concentrations were insufficient for such effects, and that no accidental release, let alone any operational discharge, had thus far caused any such effects.

Indeed, from its outset, the newly constituted WSL oil/HNS division of 14 October 1974, was motivated by knowledge of the interruptions of commercial amenity-enjoyment and fish-marketing rather than by belief in species-extinction/ecological-disaster. Indeed, the division was surprised to find that this refuted belief could override the known benefits of dispersing oil at sea to prevent its coating of individual organisms; of dispersing it from shorelines to facilitate re-colonisation; and of safe haven cargo/bunker transfer to prevent greater release from subsequent weather damage in exposed locations. Nonetheless, despite dispersants and mechanical recovery being known to provide only small-scale response-capability in comparison to the magnitude of total cargo/bunker release, beliefs antagonistic to safe haven use prevailed until the *Sea Empress* incident of 1996 caused the subsequent *Donaldson Enquiry* to acquiesce with the knowledge-only case for safe havens presented in my book of 1983 and with my analysis of the consequences of its absence at this specific incident, both of which I presented to the Enquiry *via* the postal service and subsequently included in my second book of 1999.

As to building on existing knowledge of oil components and of individual chemicals, the WSL division selected the physicochemical parameters of density, viscosity, surface tension, volatility, solubility, solidification and reactivity, as being relevant to whether releases would sink, float, spread, disperse, evaporate, dissolve or react with air and/or water. Thus, pollutants were classified for potential response as evaporating floaters, non-evaporating floaters which disperse or dissolve, sinkers which disperse or dissolve, or solidifiers which float or sink whether soluble or insoluble. As to gravity-induced spreading of floaters under the influence of viscosity and surface tension, it was already known that the resulting slicks had very low thickness and inversely high areas for the evaporation, dispersion and solution which effect natural surface-clearance; that the inversely low thicknesses would ensure low concentrations per unit volume of air and of water, per unit area of surface; that these low thicknesses would limit seawater and atmospheric concentrations derived from them and reduce the encounter rate for removal and dispersion by any conceivable means; and that while the encounter rate of dispersant-spraying equipment could be increased by mounting it on aircraft rather than on ships, ship-speed would itself need to be reduced to about 1 knot to avoid escape beneath the towed mechanical-removal unit. At this early stage Fay had already produced his equation for viscosity/surface tension controlled spreading as $D = (\sigma^2 t^3 / \rho^2 v)^{1/4}$ where D is the slick diameter, σ the surface tension coefficient, ρ the density, v the kinematic viscosity, and t the post-release time (article 31).

As to confirmation of this equation, the WSL team measured equilibrium slick thickness to be around 0.1mm as predicted by the equation, for which the encounter rate of a 1m wide unit travelling at 1 knot would be $0.18m^3$ (tonnes) per hour and pro rata. Thus, while evaporation, dispersion and/or solution proceeds over every square metre of the entire area, the concentration in every bottom cubic metre of atmosphere or top cubic metre of sea can be no more than 100 parts per million and less for rates slower than instantaneous and less again on dilution to higher altitudes and lower depths, while dispersant-induced and/or mechanical removal rates apply only to very small fractions of the total slick area. As to the effects of dispersants on organisms, marine biologists knew that the kerosene carrier was more toxic than the surfactant at equal concentrations; that their separate or combined toxicity could be measured only at concentrations orders of magnitude higher than those arising from application rates scaled to slick thickness and encounter rates. Indeed, when water replaced kerosene in the later concentrate dispersants, their toxicities could only be measured by adding oil to them at exposure concentrations three to four orders of magnitude higher than those induced by operational dispersant-use and for longer times than those of operational exposure. Thus, despite this knowledge, so-called toxicity testing continued under mixing conditions likely to ban the most effective formulations while approving the least effective (articles 47 - 49).

Article 3

In the meantime, the WSL team showed from the known distillation profiles of individual crude oils that all components with boiling points above 250°C would evaporate from slicks within a few hours to reduce them by up to 30% by weight while the un-evaporated remainder could form water-in-oil emulsions of increasing viscosity as water-contents rose to about 80%. Again, the team showed by observing the lifetimes of slicks that their natural removal rates being proportional to area and hence to the amount present, could be expressed as half-lives determined by their viscosities, thus enabling the quantities likely to reach shore to be estimated from the time required to arrive there under known conditions of wind and current. A further consequence of this knowledge was that the quantities naturally evaporating and dispersing dwarfed anything achievable by dispersant-use or mechanical removal, thus confirming the benefits of minimising/preventing releases from ships and wells, of removing cargo and bunkers in safe havens, and of capping wells expeditiously to minimise the physical coating of shorelines and of individual organisms. Indeed, from 1994 until the advent of direct costs, I applied this knowledge of evaporative loss and dispersive half-life to adjudicate salvage awards by comparing the quantities stranded with those which would have stranded had the salvor not prevented the latter by his removal of cargo and bunkers (articles 42, 105 &106).

Beyond this thickness-induced limitation of encounter-rate, the importance of release prevention is further confirmed by the knowledge that wave height and pollutant viscosity reduce slick removal rates below encounter rates; and that pollutant viscosity similarly reduces natural dispersion rates and those induced by dispersants to below their encounter-rates. Thus, while skimmer and pump might be quoted as having a design-capacity of 100 tonnes per hour, this is vastly in excess of the encounter rate of $0.18m^3h^{-1}$ (tonnes per hour) per metre swath width per knot of travel in a slick thickness of 0.1mm even if viscosity and wave-height are not adverse. Thus, even if the boom mouth is 100m wide the skimmer encounter rate is only $20m^3h^{-1}$, while the recovery rate averaged over two boom-towing ships and one recovery ship is $< 7m^3h^{-1}$ per ship (article 70).

Again, with the recovered pollutant containing up to 80% water to say nothing of the co-collected free water, it is not surprising that incident reports rarely include the quantities of oil recovered at sea, these being usually derisible in comparison with the recovery capacity nominally deployed. However, encounter rates are higher for slicks pressed against shores by wind and subsequently stranded by the ebbing tide, though this advantage is often diminished by the high viscosities of post-release emulsions and by the need to break them to 'recycle' their oil content, a process also required at sea to maximise oil storage capacity by discharging this water-content together with the co-collected free water, though such *in situ* discharge is now prohibited by the belief in species-extinction/ecological-disaster which has now designated such water as a controlled waste requiring this oil-water separation to be conducted only at authorised sites such as oil refineries. Again, the processing of stranded emulsions has the disadvantage of co-collected beach materials, though dispersion of the lower-viscosity emulsions into the surf would be the obvious solution were it not prohibited by the belief in extinction/disaster despite such being absent even when such residual emulsions have naturally dispersed just prior to stranding.

Thus, even if dispersion and mechanical removal techniques are operated in full knowledge of their strengths and weaknesses, we know that their operational capacities match only the smallest releases; that reliance must be placed on natural evaporation and dispersion for reduction of the larger, with dispersion/removal techniques being applicable only to the residual amounts eventually threatening coastal activities, preferably released only from damage to a single tank; and that the main effort and expenditure must be on limiting casualty releases in the first place. However, we also know that adoption of knowledge-only assessment, prevention and response has been prevented by belief in species-extinction/ecological-disaster and by beliefs which encourage reliance on equipment and techniques wholly inadequate for other than the residuals from the few thousand tonnes released from single tank rupture on collision or grounding; that such beliefs must be replaced with the knowledge of natural evaporation and dispersion being the more beneficial the greater the release; and that human intervention can deal with no more than small release-residuals .

Article 4

As a consequence of the previously cited knowledge, the oil and shipping industries and their regulators must accept that their belief-only reliance on inherently limited release-response equipment will result only in continual demands for ever-greater equipment holdings and in ever-greater embarrassment when these fail to achieve what belief expects; and that their best option is reliance on knowledge-only preventative technology. Again, the shipping industry would be well-advised to insist that responders to accidental releases from ships must utilise the knowledge available for reduction of releases, the regulators themselves having relied solely on belief-only response to releases and having set regulations on belief-only limits for operational discharges and emissions from ships, and on belief-only adequacies for shore-side reception of operational wastes from ships.

Further to accidental releases, the respective industries and their regulators must now recognise that inadequate response has been publicly acceptable only because the belief in species-extinction/ ecological-disaster has never been realised in any incident thus far; that had it been observed in reality, the inadequacy of response would have been high-lighted; that compensation ought henceforth to be paid only for realistic commercial loss and knowledge-only response; that it ought not to paid for the consequences of belief-only interference with contracted responders and not for the belief-driven equipment miss-use which prolongs and intensifies the afore-mentioned commercial losses; that in-house national knowledge and/or accredited knowledge-only contractors must henceforth be employed in release limitation and response; and that the growing response costs per tonne released must thus be reversed. Further to contractors, it must be recognised that those involved in inland, river and lake spills have been comparatively free from belief-only interference in their continual development of cost-effective responses which complement the knowledge-only marine shoreline and inshore water responses earlier produced by WSL R&D staff.

Again, with no overt dissention having arisen when I progressively informed the Technical Group of the Marine Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO) of my new knowledge-only approach despite governments and publics alike having been previously captured by the belief-consensus of environmentalist NGOs, I invited these NGOs through ISCO on 15 November 2012 to reality-validate or reality-refute their beliefs in species-extinction/ecological-disaster and in anthropogenic global warming (Preface) and I have taken the subsequent absence of any response from them as recognition of their embarrassment at overtly preferring beliefs to the knowledge which refutes them while covertly avoiding the risk of themselves demonstrating this reality-refutation.

Article 5

Further to harmonising technology with the marine environment by knowledge-acceptance/belief-rejection, the WSL programme, on oil/HNS releases, discharges, fates, effects and responses, took account of the knowledge which enables industry to refine crude oils to product oils; to synthesise individual chemicals including the so-called hazardous/noxious substances (HNS); to transport all such products; and to use them as received or to convert them to yet other products. Again, it took account of the knowledge which enables industry to respond to operational discharges and accidental releases within and from industrial premises by such means as separation from substrates by sorption, pumping, or excavation/dumping; neutralisation with appropriate reagents; recycling by addition to normal or other processing; by biodegradation or combustion to the carbon dioxide and water from which all organic materials are initially produced by photosynthesis.

Thus, with the oil and chemical industries being unable to do any of the above in the absence of tabulated knowledge of the values of physicochemical parameters involved, the WSL division identified those which control the fate and effect of operational discharges/emissions and of casualty-releases to the sea, and which determine the appropriate techniques and equipment for prevention, limitation, and response. Thus, the division classified crude oil components, oil products, and HNS as evaporating floaters, non-evaporating floaters which dissolve or disperse, and sinkers which dissolve or disperse with or without reaction with air and or water as in article 2, while the relationships between temperature, evaporation-rate, concentration, and explosive envelops are determined by known values as in article 3.

Thus, total evaporation of a volatile liquid can only be prevented by attainment and maintenance of its saturation vapour pressure in the air above it, this being possible only when an enclosed space contains sufficient depth of liquid for this pressure to be reached before it evaporates totally. Again, while the total quantity available for open-air evaporation from unit area of surface is proportional to the layer thickness, the vertical dilution of the vapour with un-contaminated air prevents attainment of its saturated vapour pressure, ensures decreasing concentrations with increasing height as long as the liquid layer continues to exist, and thereafter ensures that these concentrations become more uniform with height, and tend to zero throughout the air column, which in this context, is of unlimited volume per unit area of surface.

Thus, we know that the quantity available for evaporation per unit area of surface is proportional to the layer thickness; that while this can be substantial in confined spaces onboard ship, released volumes on water surfaces have layer thicknesses dependent on the rate of surface-spreading; that these rates and thicknesses are dependent on viscosity and surface tension of the spreading layer; that both these parameters have low values for volatiles thus ensuring rapid and extreme thinning of their slicks to zero thickness; that lateral wind movement further reduces concentration; and that whether evaporation is in confined spaces or in the open air, the resulting concentrations and their timescales can be calculated from known evaporation rate, layer thickness, saturated vapour pressure, volume of enclosed space and open air dilution rates (article 2).

Article 6

Having previously considered the air concentrations of volatiles in articles 2, 3 and 5, this article considers the upper and lower explosion limits which are respectively the concentrations of the volatile for which there is insufficient oxygen or insufficient vapour for explosion to occur. Thus, while concentrations above the upper explosion limit are brought within the so-called explosive envelop by ventilation, those within it are rendered non-explosive by the ventilation which brings them below the lower explosive limit. Again, the temperature at which the lower explosive limit coincides with the saturation vapour pressure of a liquid is known as its flashpoint which means that flashpoints within the ambient temperature range present an explosion risk while flashpoints above 62°C are considered safe in confined spaces. Nonetheless, the risk of explosion is not zero even in the open air when the evaporation-rate exceeds the vertical dilution-rate and when the quantity of liquid is sufficient for the lower explosion limit to be attained in a sufficient air-volume. Thus, while production of an explosive mixture in a column of air say 1cm high would require a sufficient layer thickness and confinement, those of spilled liquids on un-confined water surfaces catch fire rather than explode, this knowledge being the basis of attempts to burn oil on water surfaces even though the volatiles which burn would evaporate anyway and may burn without completely combusting or even igniting the less volatile, given the extinguishing heat-sink of the underlying water (articles 35 - 38).

As to the layer-thickness/concentration relationship, we know that nonane (nine carbon atoms) evaporates totally from a 0.1mm layer in 3 minutes and from a 1mm layer in 30 minutes to produce concentrations in the bottom cubic metre of the atmosphere of 100ppm or 1000ppm assuming no vertical dilution; that with compounds up to those with nine carbon atoms accounting for 20-25% of all crude oils, the air-concentrations from these respective layer thicknesses would be one fifth to one quarter of those from 100% nonane; that with compounds of up to six carbon atoms (hexane) accounting to for about 5% of all crude oils, the air-concentrations from these respective layer thicknesses would be about one twentieth of those from nonane; and that with the lower explosive limits for nonane and hexane being 0.74% and 1.1% respectively, the volatiles from fresh crude oils may burn when ignited while explosions are only possible in confined spaces onboard ship.

Thus, we know that sufficient knowledge has long existed on which a general knowledge-only contingency plan could have been produced for releases of crude oils, oil products, and HNS; that this plan could have related the physicochemical parameters of density, volatility, viscosity, surface tension, solubility, solidification and reaction/explosion in water/air to the fates/effects of sinking, floating, spreading, evaporation, natural dispersion, solution, dilution in air and water; to the stranding of half-life residuals; to the coating of individual organisms within identified species; to the likely interruptions of commercial coastal activities; and to the techniques and equipment best suited for minimising the interruption and maximising the rate of resumption of these activities.

Again, we know that such a knowledge-only general contingency plan could long since have related physicochemical and fate/effect parameters to the known efficiencies/inefficiencies of the preventive techniques of well capping and cargo/bunker transfer; that such a plan could have compared the efficiencies/inefficiencies of viscosity-dependent dispersant treatment and of viscosity- and wave-dependent mechanical removal with the known rates of natural evaporation, dispersion and solution; that such a plan could have permitted the insertion of incident-specific values for all the parameters relevant to any specific incident; and that such a planning approach could have been created at any time since the early 1980s, had the knowledge by then acquired by WSL not been suppressed by the belief in species-extinction/ecological-disaster which WSL had already reality-refuted by its measurements of slick thickness and associated water column concentrations.

Article 7

Further to the WSL approach, we have also known for thirty-five years that while volatile HNS and oil-components escape to the atmosphere with comparable ease, natural dispersion of non-volatile HNS is generally much faster than that of non-volatile oil-components, the former having lower viscosities and lacking the natural surfactants which produce water-in-oil emulsions of even higher viscosity, and thus greater resistance to natural dispersion. Thus, HNS with viscosities ≤ 100cSt have dispersion half-lives similar to those of oil distillates such as kerosene and diesel at ≤ 4 hours, while soluble HNS are likely to dissolve in ≤ 4 hours. Again, just as evaporation of volatiles continues in the open until complete or until stopped by attainment of saturated vapour pressure in enclosed spaces (articles 5 and 6), solution of soluble HNS continues until a saturated solution is attained in the underlying water. Thus, in the sea, the total quantity dissolved per unit area is proportional to the layer thickness which is inversely proportional to the total area of floating or sunken HNS. Thus, whether HNS removal is from water surfaces by dispersion or solution from fully spread layers, the resulting concentrations are initially low (10-20ppm) and become increasingly lower as dilution proceeds by diffusion and turbulence (article 2) while those dissolving without spreading would produce initially higher, but more localised concentrations prior to dilution by the ever-present diffusion and turbulence (article 2).

Again, as to sunken HNS, dissolution and dispersion are subject to the same considerations, though the thickness and area of the sunken layer depends on the configuration of the underlying seabed, while its persistence as a layer depends on localised surface : volume ratio. Thus, as with floating layers, the resulting seawater concentrations of HNS are dependent on dissolution and dispersion rates from the water-interface, while its greater thickness in the hollows of the sea-, lake-, or river-bed enable mechanical removal rates to exceed those attainable with fully spread floating layers.

Further to the viscosities of HNS, the WSL R&D programme of the mid 1970s identified only fifteen with viscosities ≥ 5cSt, the highest of which being mono-isopropanolamine (750cSt), branched-chain alkyl benzene sulphonate (600-700cSt), di-isopropanolamine (200cSt at 45°C) and straight-chain alkyl benzene sulphonate (80 - 100cSt). Thus, the vast majority of floating HNS evaporate, dissolve or disperse rapidly with mechanical removal being impossible and dispersants being unnecessary. Again, in the mid 1970s, only twenty solidifiers were identified as remaining liquid or solidifying within the global sea-temperature range or as remaining solid to higher temperatures, the latter being phthalic anhydride (melting point 131°6C), chloro-acetic acid (63°C), di-isopropylamine (44°C), hexa-methylenediamine (41°C) and phenol (40.9°C).

Again, it was concluded as of the mid 1970s, that the quantities of packaged HNS which could enter the sea were much less than those from the integral cargo tanks of bulk shipment which in turn were less than from the bulk shipment of crude oil; and that while packages containerised on deck do enter the sea and may subsequently strand, the contents are not released unless the container and/or internal packages are damaged. Thus, as with oil releases, it behoves environmentalists to reality-validate/ reality-refute their beliefs at the seawater concentrations of organism-exposure to individual HNS in the real environment.

Article 8

The hazard from the shipboard carriage of packaged goods is more to the crew than to the environment. Thus, certain packages are carried on deck to maximise atmospheric dilution of casualty-related releases, while below-deck exposure can be reduced by active ventilation with due regard for the danger of diluting high concentrations of potentially explosive gas/vapour into the their explosive envelop. In addition, vapour concentrations can be calculated from the quantity released, its saturation vapour pressure and the enclosed volume into which it is released, while commercial analysers/explosion-meters are readily available (articles 5 & 6).

Again, while toxic and explosion limits are accessibly tabulated for all HNS, the use of these tables requires consideration of both quantity and concentration (article 6). As to the former, however, we know that toxicities tabulated as LC_{50} values might not be toxic at actual concentrations of exposure; that, for example, a square metre of slick of thickness 0.1mm can produce no greater concentration than 100ppm in the top cubic metre of the water column or bottom cubic metre of the atmosphere column, even were the transformation to be instantaneous with no subsequent dilution; that it is the actual concentrations of phase transition and subsequent dilution which determine actual toxicity of dispersants, oils and HNS in the open environment (articles 2 & 3); but that in enclosed spaces, the wearing of protective clothing and breathing apparatus should always err on the side of safety.

Yet again, it may be concluded that HNS which evaporate, disperse or dissolve after spreading on the sea surface, are as uncollectible as the oil-components which naturally evaporate and disperse; that the highest dispersion rates and resulting concentrations of non-soluble HNS are mostly of viscosities comparable to that of diesel oil and thus disperse as quickly; that the concentrations of volatile and dispersible/soluble HNS and oil-components in the atmosphere and the sea are initially low at a few ppm and rapidly diluting; that while such oil-component concentrations are non-toxic, the LC_{50} values of identifiable HNS may be compared with these of the oils to evaluate their potential toxicities in the marine environment, though the subsequent dilution/biodegradation of both is inevitable. Yet again, it may be concluded that sunken HNS will behave similarly, though recovery of the slower to disperse/ dissolve, will be easier the thicker the localised layers; that gas releases will produce higher localised concentrations than do vapours from volatile liquid surfaces and depending on their concentration-related toxicity/explosion hazards, will require delineation of unsafe areas pending atmospheric dilution to safe concentration levels.

As to bulk substances stranding in the solid state, these may be collected for ‘recycling’ or disposal depending on their physicochemical and toxic properties. As to stranded containers and packages, the damaged may be disposed of as are waste-chemicals in routine industrial practice, while the undamaged can be routed to their intended recipients or re-routed to alternate recipients; that, the best option, as with oil cargoes and bunkers, is to transfer

HNS cargoes to safety to avoid further release at the casualty location; that the belief in species-extinction/ecological-disaster must always be reality-evaluated against known concentration-toxicity relationships; and that this is the best way to ensure public acceptance of the impossibility of recovering that which has evaporated, dispersed or dissolved according to its unavoidable physicochemical properties (article 1).

It must be recognised that the values of the relevant physicochemical properties which control the fates and effects of released oils and HNS and which determine our response to these releases and our efforts to limit them, have always been available from their respective industries. Thus, from the mid 1970s, WSL was using this available knowledge of density, distillation-profile, viscosity, pour-point/melting-point, solubility, and concentration-toxicity relationships in the R&D programme by which it enabled itself to predict whether any particular release will sink or float, evaporate or not, disperse quickly or slowly, be liquid or solid, dissolve quickly or slowly, and be toxic or not at exposure concentrations, this being a further use of the knowledge by which the respective industries refine, synthesise and transport their raw materials and products and by which they respond to on-site and inland releases which have similarities to shoreline response in respect of the permeability and undulation of substrates. Again, from the late 1970s, WSL informed itself on how the emergency services conduct tank to tank transfers and the over-drumming of damaged containers, and how they and the respective industries use air-quality monitoring equipment, protective clothing and breathing apparatus, while administrations have paid scant attention to this knowledge in their belief-only involvement in what they are pleased to call their environment protection.

Article 9

While policy-makers have neither acquired nor used any of the knowledge identified in articles 1 - 8, and while they remain ignorant of the method by which further knowledge is acquired as and when necessary, they believe that their arbitrary regulation has a role in the progress made by industry through its acquisition and use of the knowledge which is craftsmanship science and technology. Thus, while the industrial knowledge which progresses in response to known need, ran from wind to engine propulsion, through load-lines, collision-avoidance and life-saving in respect of marine safety and its associated knowledge-only regulation, arbitrary regulation for so-called environmental protection either suppresses or ignores knowledge. Thus, while in the 1960s, the chemical engineering division of WSL began to investigate the means of minimising operational discharges of oil from ships and for removing the residuals of such discharges from amenity shorelines by acquiring knowledge as to the performance of shipboard oil-water separators and of shoreline applications of dispersants, policy-makers extended the early results of the latter to residuals stranding from the total release of cargo and bunkers at the *Torrey Canyon* incident of 1967, an extension which subsequently gave rise to the anti-dispersant and pro-removal beliefs which now suppress application of the knowledge of both; and which suppress knowledge of the former to the extent of reducing the oil-contents of operational discharges to an arbitrary zero in arbitrarily designated Special Areas; and to the extent of maintaining the belief-only fear of HNS; all of which has long since been refuted by readily available knowledge (articles 1 - 8).

Thus, having been promoted to head a newly constituted division dedicated to oil and chemical pollution prevention and response at WSL on 14 October 1974, and having thereafter made significant knowledge-only progress through my R&D programme, I considered knowledge to be triumphing over belief as I was later to define these terms (Preface). Thus, when in 1979, our then Department of Trade and Industry (DTI) indicated its intention to create a Marine Pollution Control Unit (MPCU) in its headquarters division of the marine survey and HM Coastguard services, ostensibly to augment the ship-borne dispersant spraying arrangements developed by WSL in 1972 with the new techniques and equipment developed and reality-evaluated by my division since late 1974, I proposed that my division be the new MPCU. While this proposal would have merged our R&D programme and our collective operational experience of all previous UK incidents, and of some elsewhere from 1967 - 1979, with our experience of providing international training courses at home and abroad since late 1974, I recognised that it could not of itself provide a permanent knowledge repository, given the redeployment of staff which would follow the foreseeable completion of the WSL programme; and that while its transfer to the marine survey and coastguard division would still be subject to the staff changes of government service, it might be institutionalised within the latter's continuous provision of marine services.

Thus, having accepted the invitation to join the new unit as its 'chief scientist' in the expectation that our recently acquired knowledge might triumph over belief to the extent of its preservation within an MPCU contingency plan, I soon found that belief would remain paramount. Indeed the use of 'control' rather than 'response' in the title of the new unit was a clue to its intended nature. Thus, it became clear that the unit's contingency plan would not maintain the knowledge of the WSL division beyond the division's life; because the 'plan' would merely list the names and telephone numbers of the so-called interested parties for discussion of opinions/counter-opinions (belief/counter-beliefs) as to the actions/ inactions to be taken in particular incidents as these arose; and that while such a list might be a useful annex/appendix to a plan, it would not of itself be a plan such as an agent for knowledge-only policy would have written for maintenance of knowledge within a response unit subject to staff changes even within an otherwise continuous service. Indeed, a generalist administrator wrote it, as appears to have been the case in all other administrations then and since.

Thus, in light of the observed inadequacy of administrative oil spill response, and fear of chemicals in general, we must consider why such knowledge-omitting documents were/are written, and why/how they must/can be corrected to knowledge-only documents. In doing so, we must recognise that our future welfare depends on the harmonisation of technology and environment through knowledge of both; and that this requires reality-validation or reality-refutation of the environmentalist beliefs which otherwise cause disharmony between scientific-technical knowledge and belief-driven pressure-groups, regulators, politicians and public, a disharmony resolvable only by my newly definitive knowledge/ belief differentiation (Preface and articles 1 - 8).

Article 10

Further to the UK contingency plan, it should have been obvious to DTI that the WSL division was the only interested party with the first-hand knowledge which had ostensibly given rise to the new MPCU; that 'advice' given by other interested parties would either be second-hand endorsement of this WSL-knowledge, or its counter-beliefs offered by those with no relevant knowledge; that the overarching belief in species-extinction/ecological-disaster would oppose the use of dispersants and support mechanical removal in ignorance of their respective strengths and wealnesses (article 3); and that all meetings of the so-called interested parties would thus debate opinions/counter opinions, i.e. beliefs/ counter-beliefs supported by partially selected facts/counter-facts, neither set of which would be sufficient to terminate debate to other than a belief-consensus which could alter daily (Preface).

It should also have been obvious that the new MPCU and its contingency plan would be concerned only with the control of sea-going response contractors; that its staff and contractors would stand-down when the pollutant stranded; and that no parallel unit would be established for shoreline response, this having been devolved to individual local authorities thus left to their own devices. Therefore, I proposed a national stockpile of shoreline response equipment specified by the WSL division as a back-up for individual local holdings and for myself to liaise with local authorities faced with strandings, but I was successful in this proposal only when the then Royal Commission on the Environment endorsed it.

As to why national contingency plans do nothing to preserve knowledge against the frequency of staff changes and the infrequency of incidents, and consist only of the contact numbers of external belief-only protagonists in sufficient numbers to suppress knowledge, it may be hypothesised that the belief-consensus which thus emerges is intended to absolve central government of responsibility for the outcome of incidents at sea and onshore, a hypothesis which appears to be reality-validated by all official incident reports from that of the *Torrey Canyon* to that of the *Deep Water Horizon.* As to how this shirking of responsibility is to be rectified, it should long since have been obvious that the Powers of Intervention conferred on coastal States by the MARPOL Convention implied the need for these States to know how such intervention would be implemented and for industry, insurers and the general public to encourage their governments to prefer knowledge over belief in the conduct of all future incident response, with debate being restricted to the prioritisation of knowledge-only options, if debate be required at all.

Thus, any national contingency plans worthy of the name, must preserve knowledge relevant to response at sea and onshore, and must identify the quantifications needed to create knowledge-only incident-specific action plans for which governments must take responsibility (articles 4 & 8). Such contingency plans must therefore identify all of the physicochemical parameters relevant to fates, effects and response needs and satisfactions for all releases in all circumstances. Again, they must provide a template for quantifying specific incidents by insertion of incident-specific values for the parameters relevant to determining incident-specific fates, effects and responses; for determining whether response is possible, necessary or unnecessary; for selecting appropriate response options, and for maximising their cost-effective application. Yet again, such contingency/incident-specific plans must provide a template for recording the results obtained by the actions taken in all incident-specific responses, and for recording any additional knowledge acquired at specific incidents in respect of the cost-effectiveness of the techniques and equipments used as functions of the physicochemical pollutant values, wave heights, and shoreline types presented by specific incidents, such recordings being intended to facilitate the preparation of compensation claims for expeditious settlement by IOPCF and P&I Club secretariats and to progressively enhance the knowledge repository by reportage though the IMO secretariat.

As to why such contingency/incident-specific plans must be created, we know that failure to do so will only increase the socio-political difficulties already confronting the oil and shipping industries and their insurers; that success in doing so will harmonise industry with public expectations, and technology with the environment on the basis of knowledge common to all; that otherwise the environmentalist belief in species-extinction/ecological disaster will continue to harm the individual organisms and the commercial amenity and fishing interests it purports to protect, while the belief in anthropogenic global warming will continue to increase the cost of the benefits conferred on humanity by technology; and that correction of this perversity requires media, publics, policy-makers and politicians to be made aware of the invitation now extended to the environmentalist lobby to reject the former belief as having already been reality refuted and to reality-validate or reality-refute the latter belief as its contribution to the harmonisation of technology and environment commended by this website.

Ecological Comparison of Ship, Oil-Well and Land-Source Releases

Article 11

Environmentalists have been invited to reality-evaluate their belief in species-extinction/ecological-disaster (Preface), to confirm for themselves that the seawater concentrations and the numbers dying in incidents have never been high enough to cause such effects; and to acknowledge that global land and marine biomasses ecologically synthesise and biodegrade all organic molecules from and to carbon dioxide in the known biological carbon-cycle of both sea and land (Preface and articles 12 and 26).

In the land-based cycle, ecosystems continuously introduce organic molecules to the sea by river runoff and atmospheric rainout, while others are continuously produced by the marine ecosystem itself to move up the food chain or to sink as intermediate biodegradation products to deeper waters to sustain ecosystems at greater depths or to return to surface waters by the up-welling which makes continental shelves more productive than ocean depths. Thus, primary marine production arises from carbon dioxide by photosynthesis in the light-penetrating euphotic zone where phytoplankton species undertake the role of land plants, while chemosynthetic bacteria synthesise organic molecules from carbon dioxide by deriving energy from oxidation of such as the ammonium ion, molecular hydrogen or hydrogen sulphide rather than from photons of sunlight, and while heterotrophic bacteria use pre-formed organic food sources in the secondary production of the marine food chain which in the absence of light sustains ecosystems down to the seabed thousands of metres below the euphotic zone.

Given this heterotrophic reliance on pre-existing organic material, we might expect such bacteria at the base of the marine food chain to utilise petroleum components, the precursors of which would have been a food source during their earlier passage to the seabed for anaerobic burial and subsequent formation of natural gas, petroleum and coal. Indeed, population densities of heterotrophic bacteria in coastal waters are higher than at sea in proportion to their respective petroleum concentrations. Again, while releases of geologically produced petroleum expose organisms to a wider range of hydrocarbon classes and to a wider range of homologues within each class than are present in their food-source precursors, any negative effects of the former are limited by the low concentrations of their solution or droplet dispersion in seawater. Yet again, while low molecular weight hydrocarbons of petroleum origin could have potentially narcotic effects and while low molecular weight petroleum aromatics could be toxic if their concentrations could be high enough, both are rapidly lost to the atmosphere by evaporation. Moreover, while the higher molecular weight poly-nuclear aromatic (PNAH) compounds do not evaporate, those absorbed by organisms are rapidly secreted unchanged or as recognisable metabolites on exposure to clean water, *i.e*. they are in equilibrium with the surrounding water and are not incorporated within the structure of the organism, though they may taint shellfish if not depurated prior to consumption whether their source be land run-off, ship discharge/release, or natural seepage.

Again, while petroleum-release provides a wider range of compounds other than those of purely biogenic origin, it may be concluded that current marine life is the product of all sources of organic material produced in and added to the sea; and that this life has been self-sustaining despite all natural seeps of petroleum during marine geological/biological time. However, while concentrations of organic compounds in water can be high enough for their oxidative/biogenic degradation to deprive aquatic organisms of oxygen (e.g. accidental milk-releases to rivers), and while concentrations of other nutrients can be high enough to upset ecosystems by increasing the population of some species to the detriment of others, as occurs with algal blooms in rivers and coastal waters, we may conclude that such phenomena are not associated with oil releases because their seawater concentrations are never high enough. In any case, excess growth cannot be attributed to toxicity.

Thus, while avoidance of the physical-coating of individual organisms and the associated reduction of fishery and amenity-enjoyment values, justifies the costs of preventing the causative oil releases, it may be concluded that the costs of post-release response are justifiable only in proportion to the commercial loses thus avoided; that attempting to prevent dispersion into the sea is as unjustifiable as attempting to prevent evaporation to the atmosphere; and that while removal of floating oil may prevent the coating of organisms otherwise subject to coating, its dispersion is beneficial/neutral to water column organisms at the base of the otherwise unaffected food chain. Thus, the environmentalist lobby is invited to consider whether further reality-refutation of its belief in species-extinction/ecological-disaster is needed in light of such knowledge as the above (Preface).

Article 12

As to quantification of the potential fates and effects of oil inputs to the sea from land and ship sources, we already know the former inputs to be greater than the latter, while the latter receive more environmentalist attention than the former, though neither have so far produced the species-extinction/ ecological-disaster expected by environmentalist belief. Again, we know that operational releases from ships have been steadily reduced by progressive introduction of tank washing with crude oil rather than water; by collection of the washing-oil in a single tank and loading the next cargo on top of the washings (the LOT system); by dedicating some cargo-tanks to ballast-carriage and by segregating ballast-tanks from cargo-tanks to avoid all danger of mixing and thus discharging oil with water; and by improvements in oil-water separation prior to bilge water discharge.

Thus, while such as the *Torrey Canyon* and *Deepwater Horizon* incidents distort annualised figures for oil tanker and offshore well inputs, the reduction in operational discharges and releases of oil to the sea from ships is confirmed by the annual estimated inputs shown in the following Table.

Source (million tonnes)	1973	1981	1989
Tanker Operations	1.080	0.700	0.159
Bilges and Bunkering	0.500	0.300	0.253
Marine Terminals	0.003	0.022	0.030
Dry Docking	0.250	0.030	0.004
Tanker Accidents	0.200	0.400	0.144
Non-Tanker Accidents	0.100	0.020	0.007
Total	2.133	1.472	0.597

As to comparison with annual oil inputs to the sea other than from ships, the Table below shows the estimated inputs from offshore oil production, land-source oil, and natural petroleum seeps for 1978.

Source	million tonnes, 1978
Offshore Production	0.06
Coastal Refineries	0.06
Industrial Waste	0.15
Municipal Waste	0.30
Urban Runoff	0.40
River Runoff	1.40
Atmospheric Rainout	0.60
Natural Seeps	0.60
Total	3.57

Again for comparison with the above, the Table below shows annualised estimates of natural organic and hydrocarbon production in the sea, hydrocarbon production by forests, and geological seepage.

Source	million tonnes annually
Total Phytoplankton	86,000
Phyto-Hydrocarbons	26
Forest Hydrocarbons	13 - 432
Hydrocarbon Seepage	0.60

Thus, we know that natural hydrocarbon production by marine phytoplankton and forests on land are many times greater than inputs from marine transport, from offshore oil production, and indeed from both combined (above Tables). Admittedly, emissions from growing trees are relatively unstable in air and sunlight as are petroleum volatiles. Nonetheless,, even if 99% were oxidised to carbon dioxide and water in the atmosphere and only 1% reached the sea, it would be a substantial quantity in comparison with the individual anthropogenic inputs and their totals (above Tables). In addition, it should be noted that while there are no estimates of the total natural runoff of organic compounds from the decay of all land-source flora and fauna, this must be very substantial prior to its ultimate biodegradation to carbon dioxide and water or to its 'fossilisation' as natural gas, oil and coal before their combustion as fuel completes what would otherwise have been their natural transformation to carbon dioxide and water. Indeed, petroleum is estimated to accumulate at a rate of 1400 million tonnes per annum while the very much greater quantities of its un-fossilised photosynthetic precursors are the basal components of the marine and land-based food chains and biomasses. Thus, environmentalists are invited to reality-validate or reality-refute their beliefs in species-extinction/ecological-disaster and in anthropogenic global warming (AGW) in light of the above knowledge and of that presented below on the relative intensity of oil inputs, none of which cause species-extinctions or ecological disasters (Preface).

Article 13

Though total anthropogenic hydrocarbon inputs from shipping, offshore exploration/production and land-source operations are less than those photosynthesised by and for marine species prior to organism death, biodegradation, photo-degradation and recycling, and probably less than those contributed to coastal waters by atmospheric rainout from land-source vegetation (article 12), their relative input-intensities must be the determinants of their relative significance. Thus, we find that those from anthropogenic land-sources are greater than those from shipping or offshore activities *per se*; that these land-source inputs directly to a river are more intense than those thus conveyed to the sea; and that bulk-releases to water surfaces are more intense than are discharges of water containing dispersed oil droplets whether to rivers or seas.

Again, we have already noted that the intensity of bulk releases is reduced by their prior spreading on water surfaces; that 100m^3 spreads over 1km^2 to a thickness of 0.1mm; that the intensity of input per m^2 is proportional to the layer thickness and not to the volume released; and that dispersion of a 1m^2 layer of 0.1mm thickness can input no more than 100ppm to the top m^3 of the water column. Conversely, oil discharged as droplets in water may form surface slicks if the droplets resurface at size-dependent rates according to Stokes' Law, though in such cases the resulting slick thickness is unlikely to reach 0.1mm because droplets too small to surface for retention in an API or ship-borne gravity separator are unlikely to surface in the sea, natural turbulence in the latter being greater than in the former (articles 18 - 21).

Again, having already noted that surface slicks disperse as droplets small enough not to resurface we can also note that the ensuing concentrations are much lower than 100ppm even in the top m^3 because dispersion is slow in inverse proportion to viscosity and because the larger droplets resurface; and that the intensity of input is progressively diminished by subsequent dilution of the dispersed droplets through ever greater depths of water while the thinning slick produces ever smaller droplets under constant levels of wave-induced agitation. Thus, having noted that discharges of water containing oil droplets may form slicks of various thicknesses, and that whether discharged thus or released in bulk, oil eventually disperses as droplets by subsequent wave-agitation, with maximum possible relative intensities of oil inputs to the sea per km^2 of sea surface being as tabulated below for the range of increasing slick thicknesses observable by the eye's colour differentiation (article 62).

Approx. Thickness	Approx. Volume/Area
0.02μm	0.02m^3/km^2
0.1 μm	0.1m^3/km^2
1.0 μm	1m^3/km^2
50.0 μm	50 m^3/km^2
0.1mm	100 m^3/km^2

Having now related oil input intensities to volume/area ratios observable from the thinnest slick upwards, all of which are independent of the volumes released, I now refer to the concentrations of oil actually measured under wave dispersed slicks. Results obtained as early as 1973 by the UK Ministry of Defence gave concentrations between 0.1 and 0.2ppm over a period of 24 hours under a slick of Kuwait crude discharged for this purpose, while later, the WSL team measured concentrations under a gas-oil slick (S.G 0.85 and boiling range 200-260°C) at depths between 1.5 and 10.5m as being 0.46 to 0.23ppm, these slicks having been 0.1mm thick. Later, similar investigations with Ekofisk oil gave concentrations ranging from 2.11 to 0.2ppm at depths from 2 to 15m over a period of 21 hours while the slick itself lost about 20-25% of its weight by evaporation in 2 hours and about 30% in 8hours.

Again, at the Ekofisk Blow-out of 1976, WSL measured concentrations of oil in the depth range of 1-4m, 50 hours after the well was capped as being in the range of 0.245 to 0.005ppm (5ppb) as the degree of sheen-visibility decreased with increasing distance of 3 to 20 nautical miles from the source-platform, while the subsequent surface clearance by natural dispersion was observed to be consistent with a half-life of 10-12 hours as had earlier been observed by WSL for deliberate releases of Ekofisk oil. Thus, it was early concluded that the concentrations of non-volatile oil components naturally dispersed in sea water are low because of rapid spreading and slow dispersion; that the latter is slower still, the more viscous the oil; that Ekofisk oil is among the most rapidly dispersing crude oils; and that species-extinction/ecological-disaster must arise from releases of such oils if it is to arise at all, the input-intensity being greatest for the most rapidly dispersing oils.

The Toxicity Delusion

Article 14

While concentrations of oil components under slicks have been measured down to 5ppb as they dilute to even lower background levels in the open sea, the standing concentrations in coastal waters from land-source inputs are known to be around 10ppb, *i.e.* 0.01ppm, with no observable species-extinction or ecological-disaster. Again, while physical coating by oil slicks can have deleterious effects on individuals in a relatively narrow range of identifiable marine species, dispersed oil in the water column enhances the food-source of species at the base of the marine food chain, is filtered and later depurated in equilibrium with seawater concentrations by organisms higher in the food chain, or is otherwise neutral to them (articles 11, 12, 26 and 47 - 49).

Indeed, no attempt has been made by environmentalists to reality-evaluate their beliefs in species-extinction/ecological-disaster with reference to the concentrations of oil components actually present in seawater. Again, while fish eggs and larvae exhibited lethal and sub-lethal effects immediately beneath oil slicks at the Ekofisk Blowout, fishery biologists of the then Department of Agriculture and Fisheries for Scotland (DAFFS) concluded that these have no effect on subsequent adult populations, and that adult fish themselves are unaffected by such incidents unless they sustain surface-coating detrimental to their saleability by being drawn through surface slicks in net-recovery. Again, as noted earlier, LC_{50} values for *Crangon crangon,* can only be measured at concentrations orders of magnitude above those arising from oil releases (articles 2, 8 and 13) .

The alternative approach of attempting to establish a population base-line against which to evaluate pollution effects at specific incidents also indicates an absence of species-extinction/ecological-disaster. Thus, the annual assessment of commercial fish stocks shows variation brought about by annual variation in recruitment of young fish to the stock and variation in adult death rates none of which require explanation in terms of effective pollution levels, though they do show that any such effects are insufficient to raise a signal above the noise levels of natural variation. Thus, we see that oil releases have no significant effect on plankton which is, in any case, in continuous production; no significant effects on fish eggs and larvae, few of which reach maturity in any case; no negative effects on commercial fish stocks; and hence no ecological effects on the interrelated species of the food chain. Thus, the above pollution levels can have no effects on fish stocks comparable to those tolerated by the so-called conservation policy which discards the by-catch to keep landings within stipulated tonnage limits in yet another example of the mistaken preference for belief over knowledge.

Again, while netted-fish would be non-marketable if coated with oil by being drawn through surface slicks, and while shellfish coated with stranded oil on shorelines are similarly non-marketable, we must consider the anti-marketing effect brought about by dispersed-oil tainting or fear of tainting. As to fish, it has long been known that those caught in the presence of naturally dispersed oil at the Ekofisk Blow-out showed no tainting when submitted to taste-panel evaluation by DAFFS. As to sub-surface filter-feeding shellfish which inadvertently collect oil droplets, these are normally depurated of all particulate/ droplet material in clean flowing-water prior to sale. Thus, not only is there no evidence of species-extinction/ecological-disaster by oil-release, it appears that public belief in such extinction/disaster is encouraged by the banning of fish/shellfish sales, and that such banning is due more to the fear of tainting than to actual tainting.

Further to the measurement of LC_{50} values for test organisms in stipulated exposure times, it has been noted that such test concentrations are chosen more to provide a result within the working day than to reproduce the concentrations to which the results are supposed to apply, as has already been seen for the toxicity testing of oil and dispersants (article 8). More realistic workers had, however, begun to evaluate the toxicity of waste-discharges by measuring the effect of the discharge itself on the *in situ* organisms exposed to it. In this approach these organisms are exposed to the full range of components in the discharge at their actual concentrations rather than to individual LC_{50} values which bear no useful relationship to exposure concentrations. In any case, salt marshes physically coated by continual or continuous discharges from inadequate onshore oil-water separators, have recovered naturally when more efficient separators were installed. Again, determination of the critical body residue (CBR) is now considered more realistic than reliance on the LC_{50} approach. Thus the CBR approach determines the whole body concentrations needed to show toxic effects by measuring body residues and corresponding exposure concentrations up to the critical levels of both.

Thus, the CBR rationale alone, is sufficient to indicate that oil concentrations arising from the dispersion of oil slicks at sea are extremely unlikely to produce lasting effects of any kind, let alone species-extinction/ecological-disaster, given that the measured LC_{50} values for oil and dispersants combined, are orders of magnitude greater than those actually measured at sea prior to their dilution to background levels while biodegrading to carbon dioxide and water (articles 2,8, 26 and 47 - 49).

Article 15

Before turning to the effects of floating and stranded oil on individual organisms, we must reality-evaluate the belief that our consumption of shellfish exposes us to carcinogenic poly-nuclear aromatic hydrocarbons PNAH (article 11) despite fishing bans and depurations. Again, knowledge is more reassuring than environmentalist belief. Thus, knowing that PNAHs are ubiquitous in being among the combustion products of such organic materials as wood, garden-rubbish and tobacco, we also know that their seafood-content accounts for no more than 2-3% of our total consumption; and that there is no evidence for oil-source PNAHs being the cause of cancer in marine species themselves at actual levels of exposure, let alone for cancer being caused by ingestion of cancerous tissue.

As to the surface-coating of individual birds with floating oil, we know that this is the most obvious biological consequence of oil release; that ingestion of oil by the bird in attempting to clean its plumage can cause internal damage, while heat loss through reduction of thermal insulation of the plumage is said to be the main cause of death; that nonetheless no species has been driven to extinction by oil release; that the best way to evaluate the significance of the numbers dying by oiling would be to compare them with the numbers dying and being born annually in maintaining species numbers at current levels; and that, thus far, no such studies have been reported, though the Royal Commission on the Environment did report in 1981 that bird species were generally on the increase despite all discharges/releases. In any case, we know that the species most liable to oiling are those which wade and bottom-feed, those which dive from the water surface to catch fish, and those which remain flightless on the sea surface during the annual moult; and that the species least at risk are those which dive on fish seen in flight and which do not dive where fish are hidden from sight by floating oil, though these observations have yet to be admitted by environmentalists.

As to the oiling of individuals in other marine species, we know that those which leave and re-enter the sea to and from shorelines, are at greater risk than those which are permanently in the sea; that there is a paucity of reported oiling for the latter; that, in any case, the significance of oil-related deaths for all species could be evaluated as for bird species (previous paragraph); and that the grey seal population had been increasing dramatically in the fifty years prior to the 1981 Report of the Royal Commission on the Environment, despite the elevated levels of marine oil release in world war II.

As to sedentary shoreline species, we know that oil slick thicknesses increase as their areas decrease on being pressed against shores by onshore wind prior to stranding as the tide ebbs; that shoreline surf may disperse such slicks into higher droplet concentrations than occur at sea; that such surf may contact droplets with subsequently sinking sediments thus enabling contact with sediment-burrowing species; that such contact with thick layers may result seabed mats close to shore; and that such layer thicknesses greater than those encountered at sea can coat and kill sedentary organisms. However, we also know that such oil will ultimately biodegrade whether or not attempts are made to remove it; and that the shore will subsequently be re-colonised as boat-slips scrubbed of organisms in the interests of pedestrian safety are re-colonised from their planktonic life-stages, or as weeded gardens are re-colonised from wind-borne seeds.

Thus, whether affected species are mobile or sedentary, comparison of impacts on their individual members with their capacities to recover lost numbers and to re-colonise denuded shorelines shows little cause for belief in permanent local damage, let alone species-extinction/ecological-disaster. Again, comparison of natural cost-free population restorations with the commercial losses associated with fishing bans and interruptions in amenity-enjoyment, show that regulation-driven increases in costs per tonne of recovered oil are as unjustified as are the beliefs in species-extinction/ecological-disaster which drive these costs ever upwards; that the costs incurred in current spillage response would be more profitably incurred in preventing oil release by cargo/bunker transfer; that response costs should only be incurred to the extent of their resumption of commercial activities at greater than natural rates; and that fishing bans should be based on knowledge of need rather than on reality-refuted belief.

Thus, it may be concluded that the invitation to reality-evaluate environmentalist beliefs (Preface) will show whether environmentalists can accept the supremacy of knowledge and thus assist in harmonising technology with the environment, or whether they will always prefer disharmonious belief/counter-belief debate to the harmony of submitting contesting beliefs to reality-evaluation.

Water-Immiscibility and Shore-Side Separation

Article 16

Having recalled the invitation to environmentalists to provide knowledge of how species-extinction/ ecological disaster could be caused by droplet dispersions of water-insoluble oils and HNS at concentrations limited by the thinness and slow dispersion or solution of their fully spread layers on the sea surface, I now review knowledge of how contact between two immiscible liquids causes droplets of one to be distributed in the other and how such distributions are relevant to pollution prevention and response. In general, droplets of the immiscible substance (the dispersed phase) can be distributed in water (the continuous phase) or droplets of water (the dispersed phase) can be distributed in the immiscible substance (the continuous phase), the former being referred to as a dispersion of oil-in-water, and the latter as an emulsion of water-in-oil, respective examples being olive oil in aqueous vinegar or mayonnaise (water in olive oil).

It is known that energy is required to overcome cohesive surface tension because droplet creation is an increase in total surface area of the now distributed phase; that such distributions are consequently unstable; and that they tend to revert to their respective continuous phases by droplet coalescence with dissipation of the energy which previously imposed the distribution. In the case of oil dispersions in water, coalescence rates are slow to non-existent when the average inter-droplet distance is large. However, as the larger oil droplets migrate upwards by density difference (Stokes Law), the coalescence rate increases as they become more densely packed beneath the growing upper phase, and it increases again as they coalesce with its under-surface. In contrast, the water droplets in emulsions are quasi-stable only in the presence of added or naturally occurring components which inhibit water-droplet coalescence however closely packed they may be. In the case of crude oils, it is known that such components as asphaltenes and wax prevent coalescence of water droplets by locating at their interfaces, and that such emulsions may be stable enough for their coalescence to be effected only chemically or thermally. Thus, the rate of droplet coalescence is increased by adding surfactants which counter the coalescence inhibitors naturally present, and/or by heat which dissolves these inhibitors from droplet surfaces into the continuous oil phase while reducing the viscosity of the continuous phase which otherwise impedes droplet migration within it.

Dispersions and emulsions are well known elsewhere. In the chemical industry, the removal of an organic solute from solution in water to solution in the organic solvent or the removal of an immiscible dispersed phase from water, is often achieved by agitating an organic solvent with the solution or suspension to maximise the infer-facial surface area of the organic solvent to maximise transfer to it prior to its coalesce as a separable continuous phase. Thus, for quantitative analysis of dispersed oil in water, the above process makes use of fluorisol or chloroform as the organic solvent. Again, while the food and pharmaceutical industries prepare many products for sale as stabilised emulsions, they are careful to minimise energy input when subsequent separation of droplets of product from the excess continuous phase is required. Thus, the smallest droplets of so-called secondary dispersions are avoided because they are more reluctant to separate by droplet migration and coalescence than the larger droplets of so-called primary dispersions. Again, while the smallest droplets promote emulsion stability they also increase viscosity thus requiring a balance to be struck between desired product stability and the flow properties desired in use.

As to the oil and shipping industries, the desire is to avoid creating dispersions and emulsions and to separate them from the excess water when they unavoidably form. Thus, while oil which leaks from machinery or from storage tanks on shore can mix with site drainage water, and while such leaks and small spillages onboard ships can mix with bilge water, such mixtures are now passed through oil-water separators prior to retaining the oil and discharging the water. Again, while cargo tanks were initially water-washed prior to ballasting with clean water, the resulting oil-in-water dispersion had to be gravity-separated within each intended ballast tank for combined retention in one designated 'slop' tank. At the end of the ballast voyage, cargo loading could then proceed into clean empty tanks, into ballast tanks after clean ballast discharge and on top of the slop tank oil. A further development dissolved cargo-tank residues in crude oil to reduce the oil-water contact inherent to the earlier system. Later, specific cargo tanks were identified solely for ballasting while new-builds were required to have segregated tanks and separate pumping systems for cargo and ballast operations, thus making all earlier oil-water contact needless and ultimately impossible (article 12).

Article 17

The velocity at which the dispersed oil/HNS phase droplets migrate upwards in the continuous water phase, U, is given by Stokes' Law for streamlined conditions (Reynolds' Number < 2) by Newton's Law for turbulent conditions (Reynolds' Number > 500) and by an Intermediate Law between these limits, all of which enable separation rates to be predicted as a function of droplet-sizes, continuous-phase viscosities, and phase-density differences. Again, if a lowest size droplet is specified for a gravity separator and its calculated migration velocity is U, the time t taken for it to rise from the bottom inlet to the upper water-phase boundary at height h above the inlet is given as $t = h/U$, this being the separator residence time required for all droplets above and including the specified minimum size to migrate to the phase-boundary. This enables the cross-section area and length L, of the standard API (American Petroleum Institute) gravity separator to be calculated for removal of droplets down to a specified minimum size for a known flow rate per unit cross-section area V, because $L = V/t$.

Thus, with the surface area determined as above and increased by 65% to allow for short-circuiting and residual turbulence, separation of droplets down to 150 μm can be achieved in a residence time of 30-45 minutes with delivered oil-contents in the parts per million (ppm) range, though actual values depend on the oil quantity initially present as yet smaller droplets. A typical shore-based installation capable of thus treating 600 tonnes of effluent per hour could measure 35m x 6m x 2m. However, the equations, referred to above as Laws, show that performance is enhanced the greater the density difference between the oil and water, and the lower the water viscosity, these advantages being achieved by inserting heating coils which thus permit smaller droplets to migrate to the surface than would otherwise do so. Again, the elevated temperatures and gas-bubble release in oil production from wells, not only lowers viscosity but also sweeps oil droplets upwards to coalescence. Indeed, gas is often introduced to gravity separators by injection or dissolving under pressure prior to release to simulate the action of natural gas. Again, lowered-viscosity facilitates drainage of the water-film which separates droplets from the floating oil phase prior to coalescence with it. Thus, while drainage might otherwise take seconds or minutes, subsequent coalesce is a matter of milliseconds.

However, given that droplet coalescence is significant only in the region of high droplet concentration beneath the growing oil phase and with this phase itself, separator volume can be reduced by decreasing the distance of droplet-migration and increasing the area of oil-phase growth by installing a series of parallel tilted plates within the basic API separator under which droplets more quickly concentrate and coalesce with the growing oil layer beneath each oil-wetted plate prior to moving along their undersides to the top of the separator, though such internal modifications do not extend coalescence from the droplet-size range of primary dispersions to that of secondary dispersions.

Nonetheless, the chemical, oil and shipping industries separate secondary dispersions (hazes), in which the droplets are small enough for the turbulence of Brownian Movement to prevent gravity migration, by having recourse to beds of granular or fibrous materials wetted by water rather than by the oil droplets which adhere to them and grow by subsequent droplet collisions to sufficient size to be sheered off by viscous drag to rise and further coalesce as in a gravity separator. Again, oil retention filters wetted by the oil droplets rather than by water are available, though these tend to block by accumulation of the retained phase. Thus, both are used only for removing secondary dispersions downstream of the primary gravity separator. Again, in shore-based effluent treatment, final purification is achieved in traditional filter-beds of gravel which self-coat with appropriate and naturally present micro-organisms which biodegrade the oil to carbon dioxide and water just as they biodegrade dispersed oil droplets in the water column at sea.

Onboard Separation

Article 18

Having noted that segregation of ballast tanks had removed the need for tank-washing at the cost of reducing cargo capacity; and that shore reception facilities equipped with API gravity separation and downstream biological treatment were intended for otherwise unavoidable water-oil mixtures (article 17), I now review the process by which the efficiency of shipboard gravity-separation was increased for operational bilge-water discharge.

As early as 1960, WSL staff had shown that bilge discharges were mostly water, the oil-content in the relatively prolonged middle period of discharge being about 30ppm on average; that the oil-content of the final period was in the percentage range from inclusion of the oil which had been floating in the bilge prior to and during the middle period; and that the initial period was again in the ppm range from inclusion of the oil which had coated the discharge-piping during the previous final period. The following Table exemplifies the oil-contents for these respective periods.

Case	Initial Period, ppm	Middle Period, average ppm	Final Period %
1	46	10	1.7
2	165	20	15
3	25	8	11
4	209	90	11

Again, with respect to the then practice of ballasting fuel tanks, WSL staff investigated in 1962 the percentages of 3000 second Redwood No 1 fuel oil present as droplets < 254 μm in water-oil mixtures after passing through the range of pumps identified in the following Table.

Pump	% < 254 μm at 10 tonnes h^{-1}	% < 254 μm at 6 tonnes h^{-1}
Triple Screw	12	3
Single Vane	20	4
Double Vane	21	1
Rotary Gear	22	5
Reciprocating	24	9
Hypocycloidal	40	11
Diaphragm	-	12
Disc and Shoe	56	36
Centrifugal	56	56
Flexible Vane	-	98

It should be noted that a droplet size of 254 μm is considerably greater than the 150 μm taken to mark the presence of secondary dispersions (article 16). Nonetheless, theoretical considerations suggest that seagoing gravity separators are unlikely to coalesce droplets < 254 μm. Again, calculation shows that a pump producing > 2% of oil droplets < 254 μm with an inlet oil concentration of 5000ppm (0.5%) would produce an outlet concentration greater than the then IMO discharge limit of 100ppm. Thus, with all pumps except the centrifugal producing more of the larger droplet sizes by de-rating to 60%, and with the latter being the most prevalent at sea despite their high percentage production of droplets < 254 μm, it was obvious that the arbitrary IMO limit of 100ppm of oil in water discharges from ships would not be met; and that to measure the degree of non-compliance, the WSL investigators would have to measure the actual performance of the then current shipboard gravity separators.

Article 19

When WSL investigated the nature of the task facing shipboard gravity separators for fuel-tank ballast discharges in 1962, the nine comparisons of input and output for separators fed by centrifugal pumps were as shown in the following Table.

Inlet Concentration %	Outlet Concentration ppm

0.12	625
0.17	477
0.19	140
0.39	242
32.60	300
44.20	579
69.10	768
78.20	881
91.70	615

In all cases, the outlet concentrations were greater than the 100ppm stipulated by the IMO even when the inlet concentrations were as low as 1200 to 1900ppm (0.12 to 0.19%). This suggested that the performance of then currently approved gravity separators was being influenced by droplet size to the extent that they could never meet the stipulated limit whatever the inlet concentration might be. Accordingly, WSL investigated the scope for limiting pump-induced dispersion of oil in water by comparing the degree of dispersion created by a centrifugal pump (article 18) with that of a positive displacement pump, and by eliminating their respective degrees of oil-dispersion by operating them in suction-mode. The results obtained with a then typical shipboard gravity separator are shown below.

Inlet Concentration, ppm	Outlet Concentration for pumps and modes of pumping, ppm		
	Centrifugal	Positive Displacement	Suction Mode
200	70		3
400	90		-
1000	90		14
3000	-		16
6000	-		4
8000	225		14
10000	-		15
12000	-	100	-
20000	-	170	13

As to modes of operation, the pumps either fed the separator with the mixture of oil and water thus creating small droplets or they sucked the mixture into and through the separator thus avoiding creation of small droplets. The tabulated results show that in the suction mode, both pumps allow the separator to achieve outlet concentrations of ~ 15ppm and below for the above inlet concentrations; that with the centrifugal pump in normal mode the separator ceases to achieve concentrations < 100ppm at inlet concentrations above 1000ppm; that the positive displacement pump breaks through the 100ppm limit at inlet concentrations above 12,000ppm; and that the suction mode is best whatever the pump type.

However, given that this typical shipboard separator would be unlikely to comply with the IMO discharge limit of 100ppm for inlet oil concentrations above 12000ppm (1.2%) with any type of transfer pump in the non-suction mode; and given that pumping in the suction mode was encouraging only up to inlet concentrations of 2% oil as tested, it was necessary to evaluate separator performance for inputs from 100% oil to 100% water, technology being a matter of knowledge and not of belief.

Article 20

Having submitted a shipboard gravity separator to the preliminary evaluation reviewed in article 19, WSL (H. Parker, T. Walsh) constructed a test rig with circulating capacity of 100 tonnes per hour according to the IMO specification of two test oils, of a test sequence, and of alternate methods of oil-in-water analysis, the specified oils being a fuel oil of viscosity 950 seconds Redwood No 1 at 37.8°C and a light distillate (diesel) oil of specific gravity ~ 0.83 at 15°C.

After filling the test equipment and separator with water and exposing it to a flow of 100% oil for 5 min to saturate all internal surfaces, the oil content is reduced to 0.5 to 1.0% oil in water for 15 min before evaluating performance at this inlet concentration by taking three outlet samples for analysis at prescribed intervals over a 30 min period before flow is stopped and air allowed to enter. A further settling period at 25% oil is then followed by another 30 min evaluation in which three analysis samples are taken as before. Thereafter, 100% oil is input for 5 min prior to taking a further sample, while another is taken in a 15 min period after which the oil flow was stopped. Then followed a sequence of 25% oil for 15 min alternating with no oil for 15 min with one sample being taken at the end of 3 hours. Throughout, an observation window was used to check the general operation of the equipment. The above cycle was then repeated with the light distillate except for the 3 hour automatic sequence. Sample analysis was by infrared absorption or by visible/ultraviolet after extraction into fluorisol or chloroform respectively (article 16).

Now, given that preliminary investigations had suggested that shipboard gravity separators would not meet the IMO limit of 100ppm without additional downstream coalescence and/or filtering (articles 17 and 19) and given that the importance of droplet size was confirmed by de-rating feed pumps from 1000 rpm to 600 rpm to produce larger droplets (article 18), the WSL team now obtained the results tabulated below when evaluating the performance of a 10 tonne per hour separator without/with downstream coalescence and with its feeder pump running at 600 rpm and at 1000rpm.

Sample No	Oil Inlet %	Oil Outlet ppm			
		600 rpm		1000 rpm	
		No Coalescer	Coalescer	No Coalescer	Coalescer
1	0.5		2.5		4
2	0.5	135	2.5	870	5
3	0.5		2.5		4
4	25		8.0		7
5	25	630	4.8	2335	23
6	25		2.5		77
7	100		2.5		33
8	Zero		2.5		69

Thus, we know that pump de-rated coalescence is still insufficient to comply with the 100ppm limit. On the other hand, the following Table shows the results obtained for another 10 tonnes per hour separator without and with downstream coalescence *and* filtering.

Sample No	Oil Inlet %	Oil Outlet ppm	
		No Coalescence/Filtering	Coalescence/Filtering
1	0.5		2.5
2	0.5		2.5
3	0.5		2.5
4	25		2.5
5	25	1932	2.5
6	25		3.75
7	100		2.57
8	Zero		2.5

Thus, we know that the lower limits of 15ppm and even 5ppm are met by a combination of downstream coalescence and filtering, though the gravity stage ought to be protected from inappropriate pumps and modes of pumping to maximise the life of the downstream units while the highest oil-content mixtures are best discharged to shore-reception wherever possible.

Article 21

Given that a shipboard gravity separator with downstream coalescence/filtration units operating at 10 tonnes per hour, discharges oil concentrations < 5ppm, regulators are invited to note that this amounts to < 50g of oil per hour or < 5g per nautical mile at a ship speed of 10 knots; that such discharges are subject to further dilution on contact with the sea; that the residual droplets therein are generally too small to coalesce to surface slicks; and that any slick arising from the larger droplets is inconsequential.

Again, regulators are invited to note the oil phase separated by ship-borne gravity separators and oil-laden coalescence/filter units have to be retained on board for disposal to shore-reception facilities as mandated by the MARPOL Convention of 1973/74; that this implies provision of adequate onshore reception capacity for ‘recycling’ and/or final disposal of all ship-source oil wastes, and of API or modified API separators to reduce the oil-content of ship-source oil-water mixtures to acceptable levels for water discharge to coastal waters (article 11); but that the adequacy of such facilities is treated as yet another matter of belief/counter-belief debate, IMO having published guidelines rather than regulations on the provision of such reception and processing capacity by coastal States. Thus, despite the adequacy/inadequacy of such capacity being directly related to known port traffic patterns and cargoes, and of the known costs of using them, adequate capacity provision by coastal States is non-mandatory.

Meanwhile, MARPOL 73/78 banned oil discharge from tankers and from all ships above 400 gross registered tonnes in designated Special Areas, the bidding for such status requiring the involved coastal States to submit evidence to IMO of the availability of port reception facilities in compliance with the relevant MARPOL guidelines. In addition, IMO established a Working Group on the inadequacy/ adequacy of reception facilities in specific ports and on the requirements of existing and projected Special Areas worldwide. However, regulators are hereby invited to compare the degree to which these levels have harmonised technology with the marine environment, and to compare the degree to which shore-reception facilities have harmonised or are yet to harmonise with the environment in individual ports, so that this latter harmonisation will reduce the frustration of seafarers in keeping with 2010 having been declared the Year of the Seafarer by the then Secretary General of IMO.

As to maintaining the effectiveness of installed shipboard oil-water separators, there were two options. One was to install type-tested separation equipment to the required standard, say of delivering < 5ppm oil in the discharge, while relying on maintenance procedures to secure compliance thereafter. The other was to sample the discharge for regular/continuous analysis by equipment which itself requires maintenance. As to type-testing (articles 19 and 20), we know that the IMO test specification for oil-water separators could be satisfied by onshore laboratory analysis of samples obtained by solvent extraction of the oil from the water as can also be applied to API separator discharges onshore, while shipboard sampling and analysis has to be done online in the absence of shore-based laboratory facilities. However, with either approach, dispersed oil-droplets in water have to be sampled and quantitatively analysed under conditions in which they are gravity-separating at rates dependent on droplet-size or have already separated to two continuous phases in the discharge pipe.

Thus we know that representative sampling of the total flow is more difficult than it would be were the oil to dissolve in water; that even if a representative sample of the mixture is obtained, it still consists of dispersed oil-droplets in water and is again separating to continuous phases prior to analysis; and that even if the mixture is stably dispersed in the shipboard technique as opposed to the laboratory technique of dissolving in a separable solvent (article 20), optical turbidity or UV fluorescence measurements in the former will still give calibrated concentrations dependent on droplet size distributions; and that even if mechanical homogenisers are incorporated, the resulting droplet size will depend on oil viscosity. Again, while instrument manufacturers have addressed these shipboard difficulties in various ways, it could be concluded that greater reliance could be placed on routine maintenance of oil-water separators type-tested by more reliably arranged sampling and by more reliable analysis of oil as a solution in an organic solvent as specified by IMO for type-testing; and that this would eliminate responsibility for online sampling/analysis and analyser-maintenance being borne by the already over-burdened seafarer.

Rheology of Dispersions and Emulsions

Article 22

Having reviewed knowledge of immiscible droplet dispersion into water and re-coalesce to separate continuous phases and the relevance of this knowledge to the natural dispersion of oil slicks and to the prevention of oil-discharges (articles 16-21), I now review knowledge of water droplet dispersion into immiscible liquids to produce emulsions, and their re-coalescence to separate continuous phases, and the relevance of this knowledge to dispersion or removal of floating emulsions and to post-removal emulsion-breaking prior to ‘recycling’ of the oil-content even when it would biodegrade as a dispersion.

While dispersions of oil-in-water are subject to migration and coalescence to a continuous oil phase when the oil-droplets are > 100 - 200 μm in diameter, and to turbulent dilution to ever wider dispersion when the oil-droplets are < 200-100 μm, emulsions of water-in-oil are much more stable with water- droplets being 1-10 μm in diameter and water-concentrations being up to 80%, the latter being consistent with the theoretical limit for close-packed spheres. Again, while dispersions of oil in water have the viscosity and pumping-ease of water itself, the viscosities of water-in-oil emulsions increase beyond that of the oil as the fractional water content increases with associated pumping-difficulties.

Most of the work on the flow properties of water-in-oil emulsions in general, has been done with the dispersed phase simulated by solid particles of 1-10 μm in diameter, the latter avoiding the tendency of some emulsions to break into two continuous phases while being investigated. Such investigation shows that when actual or simulated two-phase systems are caused to flow, the streamlines of the continuous phase curve round the droplets or particles of the dispersed phase rather than remaining parallel, this distortion being manifest in the observed increase in viscosity in systems where the droplets or particles are too far apart to influence each other directly. However, as the concentration of the dispersed phase increases, the degree of streamline-distortion around one droplet begins to influence the degree of streamline-distortion around a neighbouring droplet. Again, at still higher concentrations, neighbouring droplets may form duplets and triplets which immobilise the continuous phase transiently, or permanently at higher concentrations, with progressive increase in viscosity. Again, at yet higher concentrations, the film of continuous phase between dispersed droplets is compressed when two or more droplets approach or glide across each other, a situation which calls for the application of lubrication theory. Ultimately, as concentration increases further, viscosity-increase is due to flow-induced changes in droplet packing arrangements.

In addition to the above fluid-dynamic interactions, it is necessary to consider mechanical interactions in which momentum-transfer arises from the collision of droplets, the frequency of which depends on droplet concentration, the effect of Brownian movement on the smallest droplets, and the effect of the shear-rate applied to induce bulk-flow. Again, it is necessary to consider mechanical friction forces between droplets during flow and short-lived turbulence arising from changes in packing arrangement.

At this point, one might question whether such considerations are more appropriate to solid particles than to liquid droplets, and whether such close contact of droplets would be possible at the highest water contents observed in water-in-oil emulsions without the said droplets coalescing and thus breaking the emulsion in all cases. In theory, a hexagonal close-packed array of spheres provides a volume fraction of 72% while a cubic close-packed array gives 52%, these values comparing favourably with water-contents of 70-80% observed for crude oil emulsions and of 40-50% for the water-contents of fuel oil emulsions. In addition, coalescence of the water droplets is prevented in such cases by the surrounding layer of asphaltenes and wax which permitted their dispersion in oil in the first place. Again, the above fluid-dynamic considerations explain the Newtonian emulsions for which measured viscosity is independent of the shear-rate applied to induce flow, while the above mechanical considerations explain the higher water-content non-Newtonian emulsions for which measured viscosity varies with shear rate as it does for sauces which pour only after shaking, for non-drip paints at zero shear rate and for some of the oil-in-water emulsions which concern us here.

Article 23

While attempts had earlier been made to relate emulsion viscosity η to viscosity of the continuous phase η_c and the fractional content of the dispersed phase ϕ by equation 1: $\eta = \eta_c (1 + a\phi)$, a literature survey conducted by WSL (Miss P. Madhvi) found it to hold only for values of $\phi < 0.05$ with *a* remaining constant at 2.5, while attempts to gain agreement between measured and calculated viscosities for higher values of φ by introducing higher powers and additional coefficients had only limited success. Thus by replacing the $a\phi$ of equation 1, with $a\phi + b\phi^2 + c\phi^3 + \ldots$, it was found that for *a* at 2.5, values of *b* ranged from 1.4 to 12.7 and values of *c* were again wide-ranging, though rarely used. However, for water-in-oil emulsions, the review valued *a* at 2.5 and *b* in the range 0 to 9.7. In contrast, the exponential equation $\eta = \eta_c e^{k\varphi}$ has shown good agreement with measured values for Cold Lake and Epping crude oil emulsions for values of ϕ ranging from 0.01 to 0.40, though the viscosities of these emulsions were very shear-dependent at higher values of ϕ and had a tendency to break at shear rates of 100 s^{-1}. Thus, while evermore complicated expressions have been suggested for higher values of ϕ, the equation of Ackermann and Shen agrees well with the literature data survey up to $\phi = 0.50$, while that due to Frankel and Acrivos agrees for $\phi > 0.50$, but shows deviation for $\phi < 0.50$.

Though the effort to produce a single equation to predict the viscosity of emulsions from the intrinsic viscosity of the continuous phase and the fractional water content has been only partially successful, it has produced further insights as to the difficulty of doing so. Thus, we suspect that the viscosity of the dispersed phase affects the measured viscosity of the emulsion by an interaction between the continuous and dispersed phases not accounted for by the considerations previously outlined; and that the droplet- size distribution plays a part, as do the presence and concentrations of the emulsifying agents, the nature and properties of the emulsifying film around the droplets, and the possible presence of hydrocolloids and particulate solids. To simplify matters, D. Cheng (head of materials handling at WSL) suggested that for any given system a simple polynomial in the form $\eta/\eta_c = (1 + a\phi + b\phi^2 + \ldots)/ 1 - (\phi/\phi_{max})^{1/3}$ is adequate, provided the purpose is interpolation between measured values, that measurement of values is extended as needed, and that no extrapolation is attempted beyond the measured range.

As to interaction between the continuous and dispersed phases, Taylor as early as 1928 had suggested that the dispersed phase would behave as rigid spheres only when the diameter of the droplets was less than a critical size and he replaced the coefficient for *a* in equation 1 with $(\eta_d + 2/5\ \eta_c)/(\eta_d + \eta_c)$ where η_d and η_c are the dispersed and continuous phase viscosities respectively. Clearly when the former is very much larger than the latter this expression reduces to equation 1. However, when they are similar, continuous external flow causes fluid circulation within the droplets which in turn reduces the flow distortion around them and thus the measured viscosity. Of course, this model assumes that any emulsifier film around the droplets will not isolate them from interaction with the external flow.

Further to the demonstration of droplet-size effects, Leviton and Leighton found no effect in the size range 0.7 to 3.0 μm in dilute water-in-oil emulsions while Thompson *et al* found that in the size ranges below 20 μm and below 40 μm for 20% and 50% water-in-oil emulsions respectively, the viscosity increased with decrease in droplet size but was independent of size above these ranges. However, an adsorbed film will increase droplet size at any size but will have the greatest effect the smaller the droplet and would thus be expected to increase viscosity as droplet size decreases. Again, Coulomb forces would be expected to increase viscosity at these lower sizes. Overall, however, emulsions are not uniform dispersions and so the mean droplet size d_m is a mean of the actual size distribution, making it possible to have the same d_m for different size distributions, thus confusing attempts to demonstrate size effects.

Article 24

Despite previous uncertainties of relating emulsion viscosities to those of the continuous-phases and the volume-fraction of the dispersed phase, Mackay successfully established this relationship for Alberta and six other crude oil emulsions using the Mooney equation : $\eta/\eta_c = \exp\{2.5\phi/(1 - \phi/\phi_{max})\}$ for water contents ranging from ϕ at

25% to ϕ_{max} at 80%. As to emulsion formation by wave agitation, Mackay suggested the rate of water-uptake to wind speed to be: $d\phi/dt = K(1 + u)^2 (1 - \phi/\phi_f)$ where u is wind speed and ϕ_f is the volume-fraction finally attained.

Again, WSL (B. Lynch) investigated the influence of asphaltene-content on the viscosities of a range of crude oil emulsions after sea-surface exposure had produced water-contents of 60% as tabulated below.

Crude Oil	Asphaltene Content, wt %	Emulsion Viscosity, cP
Ekofisk	0.037	740
Brent	0.046	910
Forties	0.090	1200
Thistle	0.24	1000
Ninian	0.46	2130
Heather	0.72	4500
Iranian Light	1.54	2979
Kuwait	2.04	26500
Safaniya	3.75	20000

It is clear from the above that while other constituents of these crude oils may be exercising a lesser influence on emulsion viscosity at constant water-content, that of the asphaltenes appears strong in all of them. Using these results, Buchanan at WSL, derived the relationship between η_f and asphaltene-content, A_c, as: $\eta_f = 10^{3.87}\sqrt{A_c}$, from a log-log plot of these parameters. Again, through his modified Mooney equation: $\eta = 224\sqrt{A_c} \exp(2.5\phi)/(1 - 0.654\phi)$ he showed satisfactory conformity between its calculated viscosities and those previously measured for a range of corresponding water-contents.

In subsequent articles, I return to this wave-induced increase in emulsion viscosity over that of the parent oil, in reviewing its effect on natural rates of slick dispersion, on spillage recovery from sea and shoreline surfaces and on the separation of their oil-contents. Meanwhile, I recall that some emulsions form only with difficulty if at all; that others are unstable to the extent of requiring solid particle simulation for some comparative investigations (articles 16 & 22). Again, I recall that emulsion formation requires energy input and facilitation by suitable emulsifiers; that emulsions nonetheless separate spontaneously with energy dissipation; and that time-related stability varies from one emulsion to another (article 16)). In general, however, five processes contribute to emulsion breakdown: creaming, in which the droplets rise or sink by differing in density from the continuous phase and thus come closer together; flocculation, in which three-dimensional droplet clusters accrete to separation only by a thin film of the continuous phase; coalescence, in which this film drains to permit small droplets to form larger droplets; Ostwald ripening, in which a widening distribution of droplet size occurs; and phase inversion, in which the dispersed phase becomes the continuous phase and *vice versa*.

In assessing progress through these stages, droplet sizes can be estimated by light-scattering and microscopic methods while stabilities can be compared by accelerated life-testing in the ultra-centrifuge to which Stokes' Law applies as: $u = (D - D)d^2\omega^2R/18\eta$ where ω^2R replaces g in the standard equation, ϖ being the angular velocity of the centrifuge and R being the rotation radius of the sample.

Article 25

The variable stability of water-in-oil emulsions is relevant to the observed persistence of oil slicks at sea, to the efficiency of dispersant and mechanical recovery operations, to the ease of breakdown on exposure to warming by sunlight when floating on calm seas and when stranded on shorelines, and to the ease of breakdown when treated with demulsifiers in the course of downstream processing.

As to stability, we know this to be dependent on surface-active molecules which are attracted to water at one end and to oil at the other and so locate at the interface between the dispersed phase droplets and the continuous phase, a behaviour also exhibited by some finely-divided solids insoluble in both phases. The simplest surface-locating molecules are those of soaps and detergents which disperse oils as droplets in water. In general, the hydrophilic end consists of ionising groups which may be cationic or anionic or even in some cases non-ionic, while the hydrophobic end consists of alkyl or aryl hydrocarbon structures. Thus, water droplets can be dispersed within oils by macromolecular emulsifying substances such as methyl cellulose lignosulphonate, while such as asphaltemes and waxes can act as emulsifiers by precipitating from oils as very fine crystals to be retained at interfaces by surface tension forces. Thus, crude oils and even some product oils are complex enough to provide a range of natural components capable of creating water-in-oil emulsions with the energy input provided by wind-induced waves. Indeed, the asphaltenes are themselves of two classes, being either normal alkanes which crystallise/precipitate at hydrophilic/hydrophobic interfaces or aromatic or even naphtheno-aromatic compounds which locate at these interfaces by molecular adsorption from solution.

Berridge *et al* investigated the stability of emulsions for a range of crude oils, heavy fuel oils and light distillates by allowing them to spread and thin to uniformity on a flat solid surface. Emulsions stable enough for such purposes were obtained for all the crude oils investigated with the exception of Brega and Nigerian Light which were classified as borderline. Residual (heavy) fuel oil also formed stable emulsions but none were formed by kerosene, gasoline or diesel oils, while that formed by lubricating oil was not stable. It was also observed that stability correlated with asphaltene and vanadium contents but not with wax or sulphur contents or with neutralisation number, emulsions of the high asphaltene oils being stable for many months. Again, Bocard and Gatellier found that while low-asphaltene/low- viscosity oils such as Nigerian Light did not form stable emulsions, some higher viscosity oils did so, independent of asphaltene content. Yet again, MacGregor and McLean reported unstable emulsions with Libyan Seria, Algerian Zorzatine and Nigerian Medium, all having asphaltene contents < 0.15%.

Further to the role of wax, Bridie *et al* removed it from Brent crude to show that the de-waxed oil could not form emulsions until the removed wax was replaced. It was also shown that emulsion stability depended on the physical state of the wax, by causing it to dissolve or crystallise in differing size distributions by heating and cooling Kuwait crude oil to differing extents and at differing rates prior to emulsifying it. Again, it was found that pour-point suppressants increase the ease of oil pumping by modifying the physical state of the wax-content to the form which inhibits emulsion formation; that wax removed from lube oil is light in colour while that from crude oil is black; and that the asphaltenes which otherwise blacken removed-wax are themselves pour-point suppressants.

Yet again, it was found that Kuwait crude contained 6.6wt% asphaltenes and 9.8wt% paraffin wax; that its emulsion contained 68% water with a droplet diameter of 5 to 10 μm and a viscosity of 2.3×10^5 cP; that when the asphaltenes and wax were removed the resulting emulsion shed 93% of its water-content in 15 minutes; that the same result was obtained with the asphaltenes removed and the wax retained; that with the wax removed and the asphaltenes retained the resulting emulsion lost 86% of its water content in 15 minutes; that replacement of both gave the original emulsion characteristics; and that when 50% of the black asphaltene/wax mixture from the Kuwait crude was added to a lubricating base-oil which would take up only 1% water in attempts to emulsify it, the resulting emulsion had a water-content of 54% and droplet diameters of 0.03 to 0.01 mm, while with addition of 100% the resulting values were 67% and < 0.01mm.

Again, when Thomson *et al* removed crystalline wax and other solids by centrifuging they showed that the subsequent emulsions shed 100% of their water-content in 24 hours after being centrifuged at 0°C and 20°C; that they shed 70% in 24 hours after being centrifuged at 35°C; that 55 % was shed in 24 hours by the un-centrifuged sample; and that when the solids removed by centrifuging at 35°C were added to the un-centrifuged sample to increase the solids-content of the original oil, the stability of its subsequent emulsion was further increased.

Relevance of Rheology to Oxidative Biodegradation

Article 26

Having reviewed knowledge of the formation and stability of water-in-oil emulsions as influenced by the presence or absence of the natural emulsifiers of crude and product oils, I now review knowledge of the emulsifiers additionally produced by oxidation of oils post-release.

Thus, while stable emulsions could not be produced with fresh Brega and Nigerian light crude oils (article 25) post-release weathering resulted in stable emulsions with water-contents ranging from 67-74%. In addition, it was separately shown that Arabian light crude oil produced oxygenated products to the extent of 0.08% after 132 hours exposure to ultra/visible radiation in the 300-450μm waveband with a peak at 365μm. Again, Arabian and Zorzatine crude oils formed unstable emulsions unless previously photo-oxidised; that Statfjord crude oil did not form emulsion in the dark but did so on being illuminated with a dysprosium lamp; that emulsion formation is generally inhibited by addition of carotene, a known inhibitor of the photo-oxidation of petroleum; and that addition of tetra-decanal, selected as typical of an oxidised petroleum compound, enabled emulsions to be formed in the dark. In addition to photo-oxidation, it has been shown that auto-oxidation occurs through free-radical chain processes; that both are catalysed by high-valence metal ions such as vanadium; that free-radical chains can be terminated by sulphur compounds; and that polymerisation of petroleum components can produce macromolecules known to be emulsion stabilisers.

Again, bacteria oxidise petroleum components just as they oxidise all components of the post-mortem degradation of higher organisms to carbon dioxide and water. Indeed, this is the mechanism of oil-spill bioremediation. Thus, bio-oxidation produces the same or similar emulsion stabilisers as do photochemical and auto-oxidation processes. In all cases, single end-group oxidation of long-chain oil components produces the combination of hydrophilic and hydrophobic pairings which characterise emulsifiers. In contrast, however, hydrocarbon polymerisation produces tar balls which are slow to oxidise internally for lack of oxygen penetration, though their oxidative surface degradation continues even as it does for road-tar surfaces. Again, similar oxidation of short-chain components produces derivative alcohols, aldehydes, ketones, carboxylic acids and amino acids. Yet again, oxidation of individual carbon atoms of the longer chain hydrocarbons produces polysaccharides while amino acid polymerisation produces polypeptides, both of which are ecosystem food sources which will themselves undergo oxidative degradation to carbon dioxide and water through the above shorter-chain intermediaries, all of which processes are thus non-toxic to the organisms involved.

Thus, having previously seen that the volatile components of oils which disperse into the atmosphere as molecules and the non-volatile components which disperse as droplets into the sea, are both oxidised to carbon dioxide and water; we now see that while dispersion of water-in-oil emulsions as droplets into the sea may be slower than that of the non-emulsified oil, the oxidation which stabilises these emulsions goes on to increase the solubility of oil components in water and ultimately to degrade all of them to carbon dioxide and water without increasing their toxicity in the meantime. Indeed, we know that this oxidation is that which degrades all marine organic debris unless interrupted by the oxygen depletion which causes petroleum to form from this debris in the first place. Thus, we see that there is little in the above knowledge to support the environmentalist belief in species-extinction/ecological-disaster being synonymous with marine oil release, and that the physical coating of individuals within identifiable species falls far short of species-extinction, let alone ecological-disaster (articles 14 and 15).

Relevance of Rheology to Mechanical Removal and Downstream Processing

Article 27

Having seen that emulsion formation and stability depend on the density and viscosity differences between continuous and dispersed phases and the degree of wax crystallisation in the parent oil phase, it is to be expected that temperature-rise in affecting all of these parameters will in turn affect emulsion formation and stability. Thus, having reviewed the oxidation which stabilises oil-in-water emulsions prior to degrading them to carbon dioxide and water (articles 22 - 26), I now review our knowledge of the relationship between temperature variation and emulsion formation/stability as it affects mechanical removal of emulsions from water surfaces and shorelines, and the downstream separation of oils from their water-in-oil emulsions.

As to the controlling parameters, it is known that the density difference between the water and oil phases in emulsions usually increases with increase in temperature; that water viscosity decreases by 3% per 1°C rise in temperature while for many crude oils the decrease is 10% per 1°C; and that consequently this increase in density difference increases droplet migration rate while the relative lowering of viscosity in the continuous oil phase will increase collision rates thus de-stabilising the emulsion. It is found that these changes in stability are temperature dependent only over the small temperature range of 10-20°C above the lower ambient, the emulsion-breaking discontinuity following in the temperature range of 30-50°C. Again, the emulsion-breaking temperature can be reduced by admixture of demulsifiers, these containing surfactants counter to the emulsifiers present in the oil. However, the viscosities of water-in-oil emulsions being high, this admixing requires substantial energy inputs usually supplied by forcing the emulsion through a static mixer by high-pressure pumping and continuous/pressurised injection of the demulsifier.

Again, it has been found that emulsions form more rapidly and are more stable, the lower the ambient temperature; and that the higher the viscosity of the crude oil the more stable its water-in-oil emulsion. As a specific example, it has been found for Brent crude that the heavier (more viscous) the fraction, the higher the water-contents of the ensuing emulsions;; that in all fractions the water-contents decrease with increase in the temperature at which emulsion formation takes place; that the temperature limits at which these fractions formed emulsions of 60% water content almost coincided with their respective pour points; and that these temperature-effects were consistent with both initial viscosity and the ratio of dissolved to crystalline wax as previously reviewed. Further to this ratio, it has been found by thermal microscopy and polarised light that no wax crystals were present above 50°C, at which temperature, emulsions cannot be formed, or at which they breakdown if formed at lower temperatures.; and that the slowly cooled oil produced large crystals and relatively unstable emulsions while rapid cooling produced small crystals and much more stable emulsions.

In contrast, it is known that low-density/low-viscosity oils such as light refined products from kerosene to diesel and some crude oils such as Breda do not produce emulsions, or if they do, these are unstable unless they contain asphaltenes and wax to significant extents. Again, while stable emulsions generally have high water-contents, this *per se* is less a stability factor than is the small droplet size which usually accompanies it. Thus, the very stable Tia Juana and Gach Saran emulsions had estimated average diameters of ≤ 1μm while the Brega and Nigerian light emulsions had larger droplets and least stability, though again droplet size *per se* may be evidence of stability rather than the cause of it. Thus, stable emulsions can have water contents from 20-80% water present as very small droplets, yet be perfectly stable as droplets size increases with increasing temperature-induced coalescence until reaching the discontinuity of ultimate separation to continuous phases..

Article 28

I now review rheology in relation to viscosity changes as emulsions age in storage tanks after collection on calm warm seas, or on warm shorelines. Such knowledge accumulation has arisen because of interest in the stability of a growing number of emulsion-based commercial products. As reviewed earlier, interaction between droplets produces aggregates which internally immobilise the continuous phase giving rise to increased viscosity as measured at low shear rates, while at higher shear rates the aggregates are disrupted with a decrease in measured viscosity and an effective increase in ϕ to $f_s\phi$ because the continuous phase previously trapped within the aggregates is now released, the precise value of f_s depending on the number of droplets previously in the aggregates, droplet size, droplet double-layer thickness and the magnitude of the disrupting shear rate. However, when droplet coalesce occurs it produces a gradual increase in mean droplet size and accompanying change in the limits of the droplet size distribution and thus it is possible to calculate the decrease in viscosity from comparing its associated droplet size data with that of the fresh emulsion in any given case.

This procedure is based on the Newtonian contribution to viscosities measured at infinite shear η_∞ which arises from interaction between droplets of mean diameter d_m at a mean separation distance of a_m such that further increase in shear rate produces no further decrease in the contribution from non-Newtonian viscosity, this distance being given by the equation $a_m = d_m \{(\phi_{max} /\phi) -1\}$. The procedure then plots the viscosity data for both the fresh and aged emulsion to show that a_m influences η_∞/η_0; that both sets of data follow the same curve; and that the only aging process which exerts a measurable effect on viscosity decrease is the progressive increase in d_m. The procedure then calculates the rate of droplet coalescence C_g from the observed change in the number of droplets per unit volume of emulsion (related to d_m) over sufficient days using a Coulter counter, the coalescence rate then being calculated by the equation $N_t = N_0 \exp(- C_g t)$ where N_t is the number of droplets/ml of emulsion at time t after formation and N_0 is the corresponding number in the freshly prepared emulsion.

Typical results are that after about 70 days aging the upper limit of droplet size distribution does not exceed 5μm with at least 80% of the droplets having diameters ≤ 1.5μm. However, many emulsions exhibit an initially rapid coalescence before a slower rate is maintained for the remainder of the aging process, this initial rate being generally found only in emulsions containing the smallest, most quickly coalescing droplets, the presence of which can explain why some emulsions can have differing viscosities for apparently the same d_m. Again, while coalescence is spontaneous, it requires activation energy E which depends on droplet charge, the nature of the stabilising layer, and the rupture and drainage of the inter-droplet film of continuous phase, the relationship between activation energy E and the temperature-dependence of coalescence being the equation: $d_t^3 = d_0^3 + 8kT\phi_t /\pi\eta_0 \exp(- E/RT)$, all symbols having their usual significance.

Thus, we see that the rheological knowledge underlying the manufacture of commercial emulsions is applicable and has been applied to the water-in-oil emulsions inadvertently created by natural wave- or pump-induced agitation of the separate phases of oil and water; that such application shows why some crude oils and products do not form water-in-oil emulsions; that others differ in stability once formed; that the viscosity of fresh oil is increased by emulsion formation; that viscosity reduces with aging towards breakage to separate phases; that the emulsions of some oils are stable enough to require intervention to break them and that such intervention requires the forceful admixture of demulsifiers and/or the application of heat; and that such heat may on occasion prevent/limit emulsion formation on calm/warm seas and or destabilise them on warm shorelines.

Relevance of Rheology to Dispersant Formulation and Use

Article 29

Having reviewed knowledge on the formation and stability of emulsions, I now review knowledge of its relevance to the dispersion of floating oil and emulsions into underlying water through wave-agitation.

As we have seen, energy is required to produce droplets from a continuous liquid phase because work W has to overcome the surface tension force per unit area $\aleph$ to increase the surface area of the bulk phase to that of the total surface area of the droplets according to the equation $W = \aleph A$. However, the diameter d of the ensuing droplets is related to viscosity η by the equation $d = k\eta^n$ where k is a constant related to the mechanism of shear application while n has a value close to 0.5. Again, the initial droplets formed from a continuous phase may subsequently break into smaller droplets though this requires further deformation under further shear application which in turn requires work dependent on surface tension, $\aleph$, and viscosity, η. Thus, the inter-surface tension of two liquids A and B is related to their separate surface tensions by the equation $\aleph_{AB} = \aleph_A + \aleph_B - 2(\aleph_A\aleph_B)^{1/2}$.

The surfactants naturally present in oil or those of added dispersants reduce the inter-surface tension of the immiscible oil-water system so that the available wave energy increases the dispersion rate by dissolving in the oil and/or diffusing to the droplet-water interface, one end of the surfactant molecules being oleophilic (lipophilic) and the other hydrophilic. Thus, surfactant molecules have or can be designed to have lipophilic/hydrophilic balances (LHB) with values ranging between 0 and 20. However, those occurring naturally locate at the water-oil interface of the water droplets within water-in-oil emulsions and are thus trapped within the droplets within the emulsions and are not lost to the sea, while those of dispersants locate external to oil or emulsion droplets and are thus likely to be lost to the sea, though such loss is without consequence when these droplets subsequently disperse far enough from the remaining slick and from each other to avoid re-coalescence. Thus, it is essential that dispersants are applied to slicks and not to the seawater on which they float and that they remain with the slick long enough to promote droplet formation and droplet separation before being lost to the sea.

However, further investigation has shown that surfactant concentration at equilibrium/near-equilibrium on droplet surfaces, Γ, and concentration in the surrounding water, c, are related to surface-tension reduction according to equation $\Gamma = 1/RT\ d\aleph/d\ln c$; that the diffusion rate to the droplet interface at the start of the dispersion process keeps pace with interface creation during deformation of the bulk phase; that this may not be sustained after droplet formation; that consequently the concentration at the droplet-surface is usually below the equilibrium value; and that the continuous bulk phase intended for dispersion becomes increasingly depleted of surfactant as the process continues to possible cessation.

Again, the mechanism of droplet formation involves interfacial rheology in that the viscosity of the continuous phase resists the shear stress in the plane of its surface which would otherwise sustain the deformation necessary to initiate droplet formation, this deformation being opposed by the pressure difference across the interface Δp which is related to the principal radii of induced curvature R_1 and R_2 of the interface boundary by the Laplace equation $\Delta p = \aleph(I/R_1 + 1/R_2)$ so long as shear stress $T = \mu dv/dt$ in the droplet-forming region does not exceed Δp.

Thus, we know that the greater the difference between the viscosity of water and the viscosities of oils and their emulsions, the greater their resistance to dispersion as droplets; and that while dispersants may facilitate droplet formation and hence the dispersion of oils and water-in-oil emulsions, this facilitation diminishes with viscosity increase as does the ease of pumping in removal of either oil or emulsion.

Article 30

On the basis of the knowledge reviewed in article 29, we know that the mechanism of droplet formation is the shearing of one continuous liquid against a contacting continuous liquid; that the denser liquid pushes into the less dense as an accelerated spike, while the latter enters the former with lower acceleration and finally a constant speed as a blunt finger; and that the interface thus becomes a region in which ‘threads’ and ‘fingers’ of one liquid are moving into the other. Again, we know that these elongations become subject to sinuous and varicose deformations; that these become unstable and finally break into droplets; that the former applies to threads of constant radius which deform sinusoidally before breaking into small droplets; that the latter applies to fingers which deform through varying radius (varicose) into large droplets. Yet again, we know that an initially formed droplet may deform through ever-thinner prolate spheroids (ellipses rotated about their major axis) to a thread which will break sinusoidally to produce droplets smaller than the parent droplet; and that an initially formed droplet may deform through ever-thinner oblate spheroids (ellipse rotated about minor axis) to a thin disc which through destabilising surface disturbances or through irregular deformation into depressions and protuberances will produce droplets smaller than their parent. Though this field has been pursued through consideration of turbulence related capillary ripples and Raleigh-Taylor/Kelvin-Helmholtz instabilities, it may be concluded that inter-phase droplet formation depends on differences in density, surface-tension and viscosity between the phases.

On the above basis, we know that wave-induced shearing causes floating oil to disperse into the underlying water as small droplets the vertical separation distances of which increase with time as they dilute to background levels while the larger dispersed droplets concentrate through upward migration to re-coalesce with the un-dispersed surface phase; that meanwhile this same wave-induced shear causes water droplets to disperse into the floating oil within which they increasingly concentrate to a finite limit; that initially the dispersion of oil into water proceeds at a greater rate than the dispersion of water into oil; that nonetheless the initial oil slick residues progressively become water-in-oil emulsions of increasing water-content; that the emulsion has a higher viscosity than the initial oil; and that consequently the volume of the slick increases as its water-content increases to its natural limit while its rate of dispersion decreases as the viscosity of the initial oil increases to the viscosity of the emulsion at its maximum natural water-content which at 80% equates four times the oil-content.

Again, on the above basis, we know that an applied water-carried dispersant will need to penetrate the oil or emulsion slick for its surfactant components to facilitate its dispersion as droplets; that hydrocarbon-carried dispersants could more easily penetrate by solution in the oil phase; and that penetration by either mechanism is more inhibited the higher the viscosity of the oil or emulsion layer. Yet again, we know that those crude oils and light distillates which have low initial viscosities and do not form water-in-oil emulsions, have the highest natural and dispersant-induced dispersion rates and removal pumping rates; that some of these crude oils may form water-in-oil emulsions when some of their components oxidise on exposure to air and light to form emulsion stabilisers not naturally present in the fresh oil (article 26), while other crude oils and heavy fuel oils already contain natural emulsifiers; and that the ensuing water-in-oil emulsions have natural and dispersant-induced dispersion rates and removal pumping rates inversely proportional to their viscosities.

Yet again, while we know that fresh oils can lose up to 30% of their weight at evaporation rates and extents depending on their distillation profiles (articles 3, 5, 6 and 31 - 33) we now also know that the non-volatile fraction can increase its weight by up to 4 times depending on the water-content of its water-in-oil emulsion. Thus, while dispersant efficiency for a given quantity of oil can be reduced by increase in its emulsion viscosity, the quantity of the latter presenting itself to mechanical removal is four times greater than its residual oil-content and may be difficult/impossible to pump. Again, while we know that pandering to environmentalist beliefs in non-existent toxicity (articles 14, 15 and 47 - 49), caused kerosene-based dispersants to be replaced with water-based formulations, we now also know that this replacement increased the rate at which the surfactants of the latter are lost to the sea before effecting slick dispersion, and eliminated the kerosene of the latter which had previously reduced the viscosity of the continuous oil phase and thus increased the rate at which water-in-oil emulsions were broken and/or dispersed into the sea.

Discerning readers will have noticed that I use the term ‘remove’ rather than ‘recover’ the latter being favoured by the environmentalist pretence that oil removed from seawater or shorelines can be cost-effectively ‘recycled’ rather than ‘wastefully’ and ‘toxically’ dispersed, while the only oil capable of cost-effective recovery is that transferred from casualties to avoid release to seawater and shorelines in the first place (articles 43 - 46 and 60 - 61).

The Natural Fate of Released Oil/HNS

Article 31

By way of preamble, the foregoing articles showed the harmonisation of technology and environment to be possible only through knowledge of both; compared the respective annual magnitudes of ship, oil-well and land-source releases of oil; dispelled the toxicity delusion; described the nature of water-immiscible systems in terms of rheology; compared onboard and shore-side oil/water separation; compared dispersions and emulsions in terms of rheology; and demonstrated the relevance of rheology to oxidative biodegradation, to dispersant formulation and use, and to the downstream processing of that which is mechanically removed. Again, by way of preamble, the foregoing articles reviewed the increases in emulsion viscosity which reduce the efficiency of dispersants and of pumped removal by the presence of natural emulsifying components or by their natural oxidative acquisition as for crude oils, or which fail to produce emulsions as do many oil products and all liquid HNS which thus do not increase their viscosities and which thus retain their initial dispersion and removal pumping rates.

Thus, with this introductory knowledge onboard, I now review our knowledge of the natural fates and effects of released oils/HNS in terms of their floating, sinking, spreading, movement on wind and tide, windrow formation, extent of evaporation, emulsification, dispersion half-lives, chemical/biological oxidation, and possible combustion: all but the last having been investigated by WSL through actual releases of oil and HNS. With this knowledge having been accepted, its application to successive incidents will further refine it and successively enhance the knowledge repository of this website respecting the relationship of incident-specific viscosity values to dispersion half-lives, the relative effectiveness of dispersant formulations, the potential benefits of premixing dispersants with oils during release in well failures (articles 60 -61), and the relative effectiveness of dispersant formulations and of the various design-principles of mechanical-removal to pollutant viscosity values (articles 156 - 162).

As to fate and effects, the first attempt to predict spreading rates and extents by Blokker was based on gravity-induced spreading being moderated by viscous inertia. However, while agreeing with this approach for Phase I spreading of instantaneous high volume/high layer thickness releases, Fay proposed his own Phase II spreading for thinner layers which though still gravity-driven were now moderated by viscosity *and* surface tension, while for his Phase III spreading of the thinnest layers, surface tension became the predominant influence (article 2). Calculations thus showed that for Phase I spreading to be sustained for one hour an instantaneous release of thousands of tonnes would be required; that the thicknesses of Phase III spreading were in the micron range as they are when the smallest dispersed droplets are migrating to a clean surface and coalescing there as in operational discharges through gravity separators and coalescence-filters (articles 16 - 21); and that Phase II spreading predominates at thicknesses of around 0.1mm, prior to natural emulsification, dispersion, and biodegradation, as in releases such as arise from shipping casualties and oil-well failures. This predicted thickness of Phase II spreading was confirmed to be ~ 0.1mm by WSL with trial releases of Ekofisk oil at sea in 1975 and at the Ekofisk blow-out of 1976 (article 2) by measuring the oil quantity per unit area by absorption into polystyrene pads of known area followed by extraction in chloroform and quantitative analysis, the quantity and the pad area thus giving thickness.

As to the value of D in the Phase II equation: $D = \{(\sigma^2 t^3)/(\rho^2\eta)\}^{1/4}$ Fay had found the expected diameter, D, to be the dimension orthogonal to the wind direction, and that he had to apply to D a factor K in the wind direction which varied between 1 and 10 in a series of observations conducted on spills ranging in size from 3.5 to 16 tonnes, from 4 to 11 tonnes and for one of 20,000 tonnes, whereas WSL explained the variable K by observing that as slicks move downwind, their under-sides shed dispersed droplets of which some of the larger re-surface behind the upwind slick-edge, thus giving an appearance of surface-spreading, but to a thinner layer than that from which they originated, that this elongation is thus due to downwind slick-movement and upward droplet-movement, not to spreading *per se*; and that the range of observed values for K beyond unity is due to wind-induced movement of slicks which are spreading across the wind in accordance with K being unity. Indeed, when the WSL team measured ‘spreading’ in high enough wind speeds, a value of 10 for K was achieved while the cross-wind value remained unity.

The effect of wind and tide on slick-movement was further investigated by the WSL team in the northern North Sea (62° N and 0° W) in an area of residual north easterly current (066°) of about 1 knot and in a tidal area of the southern North Sea at 52° 10′ N and 2° 40′ E. It was expected, by analogy with drift observations for other floating objects, that oil slicks would move as the vector sum of 100% of the tide and 3% of the wind vectors. In the first location over a 9 hour period the slick was observed to move on an average heading of 050° in compliance with 100% and 2.8% of the respective vectors. In the second location over 5.5 hours, assumption of 100% of the tide vector, gave successive wind vector %ages of 4.3, 4.0, 3.3 and 1.8 (average of 3.1). However, with drift angles of 0-22° to the right of wind direction being predicted for mid-latitudes of the northern hemisphere as supported by Teeson's investigations with floating cards, and with small errors in the tidal current vector manifesting themselves as deviations from the wind direction and *vice versa* in the oil experiments, WSL saw little point in straining for greater accuracy given that local wind speed and direction cannot be accurately measured let alone predicted (forecast) for sea-areas. Thus, for all practical purposes, WSL accepted 100% and 3% of the tide and wind vectors as sufficiently accurate for prediction of slick movements correctable by direct observation as part of incident response.

Article 32

Prior to the WSL observation of slick elongation by the resurfacing of dispersed droplets behind wind-driven slicks, Irving Langmuir, theorised during a transatlantic voyage in 1927 that the wind-aligned parallel ribbons of foam, seaweed and other floating debris which he observed, might be explained by the existence of wind-driven subsurface circulation cells. Later, he demonstrated by experimentation in Lake George that these circulation cells did exist and that they accounted for the observed phenomenon, and because these cells act as a localised counter to the generalised spreading of oil, I now review their consequences for release removal and dispersant application.

The circulation system consists of large horizontal cylindrical cells of water lying parallel to each other and at a small angle to the wind direction with adjacent cells rotating in opposite directions to produce narrow ribbons of down-welling where downward moving edges of adjacent cells meet and ribbons of up-welling where the moving edges of adjacent cells separate. Thus, water is continuously brought to the surface to diverge to regions where it leaves the surface in such a way as to bring buoyant material to the surface to remain there in parallel alignment. Again, a change in wind direction will sub-divide existing ribbons to form others aligned to the new direction. Nonetheless, it has been shown that spacing between these so-called windrows in metres is five times the wind speed in metres per second or 2.5 times the wind speed in knots, though spacing tends to stabilise at intervals of 20-30, 36-40 and 48-52 metres these being the diameter ranges of the horizontal circulation cells. However, while such windrows would be unlikely to form at the layer thicknesses of Phase I spreading, they are observed to form in the fully spread oil slicks of Phase II *i.e.* at layer thicknesses of the order of 0.1mm which are thus thickened in parallel rows, while slicks of Phase III disperse to droplets too small to resurface.

As to mechanical recovery, however, we see that a windrow of 3-5 metres in width produced by rotating cells of 20 -52 metres in width results in windrow thickness enhancement by up to a factor of 10; that this enhancement is averaged back to the un-windrowed thickness by the oil-free ribbons between the windrows; and that the collection booms of mechanical recovery systems need swath widths of little more than 5 metres to encounter layer thicknesses up to 10 times thicker than those of Phase II spreading, while avoiding useless sweeping of the oil-free surface between one windrow and another. Again, the formation of oil-in-water emulsions increases the Phase II layer thickness of 0.1 mm to 0.4 mm for water-contents up to 80%, though storage capacity for recovered oil is now required to allow for the volume of this water-content in addition to the free-water invariably removed with the oil or its emulsion. Again, if windrows are to be sprayed with dispersant, it is necessary to know the dispersant : oil ratio for efficient application to the swath width and its layer thickness of say of 0.1mm and 1.0mm respectively, or to recognise the need for multiple applications.

Again, as to mechanical recovery, we see that single ship operations with relatively narrow boom openings of say 5 metres (15 ft) would encounter a windrow of 3 - 5 metres width and of the order 1.0 mm thickness which for 80% water-content emulsions would encounter say 2.4 - 4.0 tonnes of emulsion per hour at 1 knot, of which only 0.6 - 1.0 tonne would be oil. In practice, by the time *Seaspring* reached the scene of the Ekofisk blowout the windrows were of narrow and uneven width, suggesting more than one realignment in the varied wind directions prevailing from the start. Thus, it was found that an early version of what became the Springsweep single-ship system consisting of a tension-line boom of 10 metre (30 ft) swath-width, an *ad hoc* floating hose-end and a deck-mounted 3.5 inch Spate pump removed 9 tonnes of 70% water-content emulsion per hour after correction for free-water, suggesting that the average layer thickness was the 0.1mm of phase II spreading.

Thus, with this comparison of theoretical removal rates with the observed rate at the Ekofisk blow-out, WSL opted for single-ship boom operations and focussed on selection of a pumping system of the highest possible viscosity tolerance, alternatives involving booms being towed by two ships with a third to recover pollutant, being judged comparatively ineffective and needlessly costly on the above data (articles 70 - 89).

Article 33

The rate and extent of evaporative loss from the surface of oil slicks is dependent on the vapour pressures of volatile components and the concentrations to which they are present in the oil, while for individual HNS, the rate of total evaporative loss depends on their individual vapour pressures, such physicochemical data being essential to the oil and chemical industries and therefore readily available. While wind speed and ambient temperature might have been expected to affect extent of evaporative loss, this expectation is not realised in practice. Again, high winds might have been expected to create airborne droplets, and while such aerosols were observed in the extremely high winds and breaking oily-surf of the Braer Incident, these are no more likely than sea-spray because viscosity is higher for continuous oil slicks than for open water. However, as to the possibility of vapour encapsulation in solid oils, WSL compared the evaporative-loss/distillation-characteristics of Beatrix and Ekofisk crude oils, checked for comparative temperature/wind influence on both, and compared the physicochemical properties of both which might influence vapour encapsulation by Beatrix oil.

The comparative distillation characteristics are as tabulated below.

Boiling Range °C	% Weight	
	Beatrix	Ekofisk
5-100	7.8	7.0
100-160	4.4	11.1
160-250	13.5	15.1
250-300	25.0	19.0
350	49.3	46.5

The weather conditions for summer and winter trials at sea with released Ekofisk oil are as tabulated

Date	Tonnage	Wind Speed knots	Air temperature, °C	Sea Temperature, °C
July 1975	0.5	12	18.4	11.6
June 1976	10.0	2-3•	17-20	11.0
Jan 1977	10.0	15	3-4	7.0

•8-10 knots for first two hours

The percentage evaporative weight loss for the above conditions for July were about 25% after 6 hours with no further change in the next 2 hours while for the June and January conditions a loss of 25% occurred in the first 2 hours. However, for the July trial, the 25% lost in the first 2 hours increased to 30% in 6 hours. Nonetheless, it may be concluded that all components with boiling points between 5 and 250°C evaporated within 6 hours regardless of variations in ambient temperature and wind speed.

Again, temperature variation for sea trials with Beatrix oil was as tabulated below.

Date	Litres	Wind Speed knots	Air Temperature °C	Sea Temperature °C
May 1977	200	10	13	11
March 1978	200	12	7	6

Over both of these trials the percentage weight loss increased from 3% after 0.4 hours to 13.2 -15.5% from 2.3 to 7.8 hours, though results were variable in the early stages with 3% and 6% at 1.2 hours, 5% and 6.8% at 1.5 hours and 6.8% and 12% at 1.8 hours having been recorded. It was concluded that while the distillation characteristics of both oils are similar, the 25.7% of Beatrix oil components with boiling points between 5 and 250°C evaporate more slowly than the 33.2% of Ekofisk components in this boiling range; and that this difference in rate is due to encapsulation of volatiles in the former, the properties possibly relevant to encapsulation being as tabulated for both oils below.

Property	Beatrix	Ekofisk
Viscosity (cSt) at 20°C	80	9.3
Pour-point (°C)	20	-12.0
Wax Content (% weight)	18	6.5
Asphaltenes (% weight)	0.06	0.03

Thus, we see that Beatrix crude oil is solid at ambient temperatures below 20°C while Ekofisk crude remains liquid to - 20°C; that the encapsulation of volatiles is due to solidification most probably caused by the high wax-content of Beatrix oil; and that the slow release of volatile components would need to be allowed for were such oils as Beatrix to be collected after release. For liquid oils however, it may be concluded that components boiling below 160°C will be lost from slicks in 1-2 hours while those boiling below 250°C will be lost in 6 -8 hours.

Oil Combustion in Cargo Tanks Investigated

Article 34

Following the early work reviewed in article 33, Stiver and Mackay derived an equation relating evaporative loss to slick thickness, wind speed, temperature, time and the available distillation data for individual hydrocarbons and hydrocarbon mixtures. However, this equation adds little to the general observation that all oil components and individual HNS having boiling points < 250°C evaporate completely within a few hours from the layer thicknesses (~ 0.1 mm) of Phase II spreading, a phenomenon which substantially reduces the need for dispersant treatment and/or mechanical removal.

However, the presence of volatile oil components produces combustible mixtures, the combustion of which progressively volatilises higher boiling fractions to further combustion, a possibility which sustains the efforts made by others to achieve the complete combustion of oil slicks at sea which if successful would reduce/eliminate the need for dispersant-use and/or mechanical removal. I will review these efforts in articles 35 - 38. In the meantime, I review the efforts made to combust oil in ships' tanks to prevent further release to the sea, as was attempted in the *Torrey Canyon* incident of 1967.

Thus, while predicting that heat-loss to the underlying sea could terminate slick-combustion, it was recognised that this would largely be avoided in ships' tanks even in the presence of water-bottoms. Again, it was predicted that the oxygen for combustion could be in short-supply in tanks, and would be non-existent when initial combustion rendered the tank-atmosphere inert. Thus, the investigation was directed towards the means of supplying sufficient oxygen to complete the combustion in undamaged tanks or to maintain it to the point of water-bottom extinction in damaged tanks.

Accordingly, investigation of the means of supplying sufficient oxygen to sustain combustion after deliberate ignition showed that in a six metre deep tank with one opening in the top and one in the top of a side and with each accounting for 10% of the top area, Kuwait crude oil could be burned at a surface-regression rate of 0.15 m^3h^{-1}; and that were such convective-venting to be arranged in all tanks of a casualty, it would be possible to burn-off most of the cargo. However, it was recognised that the internal oil level would need to be reduced below the lower lip of the side opening by means other than combustion before this opening could be made; that there is little scope for side-openings in the freeboard of a fully laden or partly submerged tanker; that such side-openings could not be made in centre tanks; and that the potential for combustion with deck-openings alone should be investigated.

With these predictions having been made from the initial investigation, the UK's Rocket Research Establishment proceeded to show that the combined effect of two deck openings accounting for 14% of the tank-top area provided sufficient oxygen ingress and combustion product egress to sustain the above combustion rates and extents; that as revealed by suitably located thermocouples, the burning oil causes a high temperature zone to advance down through the tank contents; that on reaching a water bottom this hot zone could produce a violent eruption of burning tank-contents; that such eruption may occur when the hot zone reaches a tank bottom itself; and that such may occur unpredictably even while the hot zone is within the remaining oil volume.

Attention then turned to investigation of the circumstances in which the necessary tank-top openings could be achieved by explosive surgery, though it was concluded that were the casualty to remain above the waves long enough for arrangements for such surgery to be made and to permit the subsequent combustion to reach completion, it would in all probability be long enough to transfer both cargo and bunkers to another ship or ships; that any future work towards understanding the mechanism of explosive eruption of burning cargo should be directed to the relevance of this phenomenon to the safety of fire-fighting onboard ships which have accidentally caught fire; and that the intentional combustion of the contents of cargo and bunker tanks cannot be a routine operational technique as could have been predicted at the outset.

Oil Combustion on Water Surfaces Investigated

Article 35

Apart from their combustibility, organic compounds are unstable in air and sunlight and will eventually degrade through chemical oxidation, photo-oxidation and bio-oxidation (biodegradation) to the carbon dioxide and water from whence they were initially photo-synthesised to the global biomasses of flora and fauna, though the absence of oxygen may interrupt this biomass biodegradation and fossilise the residue as natural gas, oil and coal. As reviewed in previous articles, we know that photo-oxidation begins in oil slicks to form emulsifiers in those oils which otherwise would not form water-in-oil emulsions; that this oxidation continues with the dissolution of naturally dispersed oil and emulsion droplets from slicks; that oxidation of the oil components of such droplets by heterotrophic bacteria promotes their growth at the foot of the marine food chain as does their oxidation of the non-oil components arising from the natural post-mortem degradation of all flora and fauna in the carbon recycling without which neither marine nor land-based ecosystems would exist (Preface and articles 14, 15 and 26); and that such microbial degradation is the so-called bio-remediation of polluted shorelines as will be reviewed in article 99.

However, in addition to these slow oxidation processes at ambient temperatures, we know that oil components of which some are also classified as HNS will also oxidise at higher temperatures as in the investigation of tank-contained combustion reviewed and rejected in article 34. Nonetheless, the accidental combustion of cargo oils continues to encourage others to investigate intentional combustion of oil slicks. Accordingly, a review of the accidental onboard combustion and intentional combustion of trial oil slicks was conducted by WSL (Mr R. Clay). The former review of accidents recalled that the VLCCs *Atlantic Empress* and *Aegean Captain* caught fire after colliding in the Caribbean with the latter being subsequently offloaded in Curacao while attempts to cool the former with continuous water spraying during eight days' towage to seaward culminated in a major explosion on the tenth day, in subsequent smaller explosions, and in final sinking without release of oil to the sea; that later the same year, the *Burmah Agate* collided with an anchored bulk-carrier four miles off Galveston setting fire to both, after which oil continued to burn for ten weeks before the remainder was off-loaded; that an explosion occurred during cargo transfer from the *Mega Borg* to the *Framura* in the Gulf of Mexico in 1990; that this was followed by more explosions and intense fire; and that explosion and fire occurred when the *Aegean Sea* grounded in the approach to Corunna in 1992.

Thus, while the head-space air in cargo tanks is displaced with the nitrogen and carbon dioxide of the ship's engine exhaust to remove the risk in the process known as inerting, damage to the tanks, particularly by collision, permits ingress of air to form an explosive vapour mixture which only needs a spark, which may also be provided by collision, to set it off. Again, with openings sustaining the oxygen ingress required to sustain combustion and with released oil burning on the sea surface, many have investigated the possibility of slick combustion being a response technique, despite it being already known that such combustion would cease when heat loss to the underlying water extinguished it; that continuous combustion would need boom-provided encounter rates; that such booms would need to be fire-resistant; and that evaporation of volatiles and emulsion formation would reduce the prospects for combustion at increasing distance from source.

Nonetheless, it was argued by some that Arctic conditions may be reduce the tendency to spread and thus to present thicker layers for longer than in warmer temperatures; that thicker slicks in calm conditions may be expected to emulsify more slowly than normal; that combustible thickness may be maintained by compression against ice-edges acting as zero-cost booms, resistant to the fire-damage which afflicts even high-cost fire-resistant booms; and that slick combustion might thus be made a spill response technique for Arctic conditions despite its inherent difficulties.

Article 36

With accidental combustion of cargo oils having given rise to investigation as in articles 34 and 35, it also gave rise to intentional burnings at a number of incidents. Thus, at the *Arrow* incident of 1970, intentional burns were achieved with difficulty on beaches and on slicks in Chedabucto Bay, Nova Scotia. Again, some 2,000 gallons of a 15,000 gallon fuel oil release were burned when *Barge B-65* grounded in Buzzards Bay, Massachusetts in 1977, and some ice-trapped Bunker C was burned after the *Othello/Katelysia* collision in Tralhavet Bay, Sweden, in 1979. However, as to burning on beaches, WSL found that melted/unburned oil penetrated the underlying beach material unless the oil was first removed from the beach for combustion in a burner designed for this this purpose (article 102).

Meanwhile, investigations by others of ignition-response and flame-spreading rates were showing that the most volatile oils were the most susceptible to ignition and subsequent combustion; that prior loss of volatile components and emulsification had an inhibiting effect on both; that burning rates of between 1,400 and 6,300 litres per square metre per day and surface regression rates of between 2 and 3mm per minute were nonetheless achievable, though this surface regression rate decreased rapidly when layer thickness decreased below 5mm due to heat-transfer to underlying water and ceased to be sustainable at thicknesses around 1-2 mm; and that small and mesoscale burning in open pans were suggesting that regression rates of about 3.3mm per minute could be achievable independent of surface area. Such thicknesses and regression rates cannot, of course, be achieved with slicks free-spreading on water.

With combustion efficiency defined as the ratio of oil finally removed to the amount initially present per unit area, the efficiencies derived from small scale pan experiments are dependent on initial thickness. Thus, while a 2mm thickness burning down to 1mm is a 50% efficiency, a 10mm burn to 1mm is a 90% efficiency. On this basis, it was shown that test oils emulsified to 25% water-content gave a burning efficiency of 80-90%, while at 50% water-content they gave 70-80% and at 75% water-content their efficiencies fell from 35% to 5%. Again, at mesoscale, a fresh Louisiana crude gave a 90% efficiency for the primary burn, while kerosene addition enabled the residue to burn also.

However, while the layer thickness requirements for these surface regressions and burn efficiencies are compatible with the burning of oil in ships' tanks given adequate ventilation, cargo/bunker transfer remains by far the preferable option. Again, while the circumstances in which 5mm oil layers would be routinely encountered are difficult to visualise (Phase II spreading thickness being 0.1mm) and while arrangements could be made to apply dispersants at encounter rates appropriate for 1mm thick layers, it is difficult to visualise their being effective on burnt-out residues.

Nonetheless, Dome Petroleum undertook a major oil burning trial in the Beaufort Sea in 1979/80 in which an under-ice discharge of $19m^3$ in winter, became sandwiched in the thickening ice sheet and began to appear on the ice-surface during the spring melt, and was finally localised to the extent of 85% within a 50 metre radius of the initial discharge point prior to ice break-up. It was estimated that 50% of the re-surfaced oil, none of which had emulsified, was combusted with 95% efficiencies being recorded in individual melt pools. Trials have also been conducted on water surfaces where ice cover is significant. Thus, fresh and weathered samples of Prudhoe Bay crude oil at ice coverage ranging from 75-90% achieved 60 - 80% burning efficiencies, though these decreased with increased evaporative loss and emulsion water-content. Again, the layer thickness needed for combustion increased as water temperature decreased.

Yet again, it was found that Norman Wells crude oil would burn in the channels (leads) which appear as the ice sheet opens up; that the fresh oil would burn to a layer thickness of 0.6 mm, while for highly weathered oil, it ceased at 3mm; that wind-herding to thicker layers against ice-edges in leads suitably oriented to wind direction was beneficial, with burning efficiencies up to 90% being achieved; that ignition was equally effective at the upwind and downwind edges of wind-herded oil; and that evaporative losses of up to 20% did not affect the burning efficiencies of Norman Wells oil.

However, the adsorption capacity of snow for oil depends on the properties of both snows and oils. Loose dry granular snow has a capacity for Prudhoe Bay crude of 40 - 70% by volume as measured after melting. Once ignition had been achieved the oil layer thickness in the melt region was controlled by the rate of oil release, the area of the melt-water pool and the spatial distribution of the wind-herded oil within the pool. Once started, maintenance of combustion required the melting process to compensate for the oil removed by burning. Burning efficiencies of 90 - 99% were achieved with crude oil and diesel, with evaporative loss being inhibited by the snow, emulsification being inhibited by the absence of turbulent energy, and with ease of ignition being dependent on the oil-content of the snow.

Article 37

Further to the ignition of floating oil layers, the review by R. Clay found for small-scale tests that the low flashpoint Hibernia B-27 crude oil ignites more easily than the high flashpoint Hibernia C-96; that both can be ignited 12 hours after release; and that B-27 emulsion with a water-content of 80% ignites with similar ease to C-96 emulsion with a water-content of 25%. Again, trials with other oils of varying properties have shown in general, that medium crude oils might be ignited up to 48 hours after release with water-contents up to 40%; that heavy crude oils might be ignited with water-contents up to 20% after the same time; and that, if ignition can be initiated, it may propagate beyond the ignition zone by progressive thermal-breakdown of emulsion.

As to design of ignition devices, the basic requirements are for a gentle but hot flame to burn close to the oil/emulsion surface for maximum heat transfer; for a shield to prevent wind from extinguishing the initiating flame; for the initial flame to burn long enough to achieve self-sustaining combustion of the oil/emulsion; and for the initiator to be helicopter-deployable in locations where ice conditions may be unsafe for pedestrians. A variety of devices have been produced to meet these requirements. For example, the Pyroid and the Dome Igniters are intended to be thrown on to the slick after activation of a timing mechanism, while the Helitorch is suspended from the helicopter and remotely controlled to deliver burning gelled-gasoline or diesel oil onto the slick surface. Again, continuous lasers have brought a portion of slick to its flashpoint temperature for vapour ignition by a pulsed laser.

In addition, fresh crude and both gelled and liquid diesel oils have been considered as localised additives to slick surfaces to assist in initial ignition and a number of wicking agents have been tested, the latter having included phenolic foam, peat-derivatives and polypropylene, though none had shown significant advantage. Again, while early tests with diesel oil have been described as encouraging, the initiating flame can be extinguished by wind speeds of $10ms^{-1}$. Resistance to flame-extinction having thus been noted as a design requirement, the Pyroid device consists of a pyrotechnic sandwiched between two flotation layers to produce a ring of fire of 2,000°C and a burning time of 2 minutes. It is $25cm^2$ by 13cm and weighs 2kg. Again, the Dome device consists of a wire basket of solid propellant and gelled kerosene slabs between two metal floats which provide 1,300°C for 10 seconds followed by a less intense 10 minutes. It is 30 x 18 x 11cm in size and weighs 0.5kg.

As to the products expected from oil slick combustion, the carbon dioxide amounts to 90 - 95% of the total if we exclude water vapour, while the others are elemental carbon or soot together with nitrogen oxides and sulphur dioxide; unburned hydrocarbons such as benzene, toluene and xylene; products of incomplete combustion such as carbon monoxide, aldehydes, ketones, acids, and esters such as acetates; and the heavy metals vanadium and nickel. Dioxans and dibenzofurans have not been detected. Typical volume fractions in relation to carbon dioxide are reported as 4% (1/25) for carbon monoxide and 0.04% (I/2500) for NO_x of which 0.015% (1/6500) is NO. The sulphur dioxide fraction depends on the variable sulphur-content of the oil but may be taken as 0.0416% (1/2400) for an oil sulphur-content of 0.1% and *pro rata*. The concentrations of unburned hydrocarbons are lower than would have resulted from natural evaporation without combustion, while those arising from incomplete combustion are in the ppm range prior to natural dilution. The heavy metals are similarly in the low ppm range with most being in the unburned tarry residue and only a little in the soot which also includes some of the unburned polycyclic aromatic hydrocarbons which may be present in oils themselves to the extent of 0.001 - 1%.

Article 38

The WSL review of oil slick combustion by R. Clay, suggests that smoke (soot) is the most significant product. The smoke yield from experimental fires directly determined by use of filters, indicate 10 -15% yields from large fires which thus produce highly visible (optically dense) plumes for which opacity K = kV/m where k is the light extinction coefficient per metre, V the volumetric flow rate through a duct above the combustion area, and m is loss rate of fuel mass. The consequence of this relationship is that were smoke produced by 1gm of combustible to be collected over an area of $1m^2$, the light incident on this area would be completely blocked for $K=1m^2g^{-1}$. On this basis the average value of K for Alberta Sweet crude was found to be 0.87 m^2g^{-1} and for Prudhoe Bay crude it was 0.96 m^2g^{-1}. However, while smoke production increases with decrease in air supply, measurement on heptane pool fires of diameter 0.3 to 6.0 metres suggest that from base to flame tip the entrained air is five times the requirement for complete stoichiometric combustion though the smoke production clearly shows combustion to be well-short of such completeness.

So far we have been reviewing knowledge of combustion products close to the source where their effects are most intense. Assessment of wider effects, however, requires consideration of the subsequent transportation and associated dilution of these initial effects as their plume moves down- wind from its source. This smoke plume has a circular or elliptical cross-section as it rises above the combustion zone because of its buoyancy which in turn is caused by its gas/vapour density and soot content. However, as the plume rises its buoyancy decreases because it entrains the surrounding cooler air until finally at a certain height it begins to fall as cooling continues while it moves downwind from its source. During this period, crosswind vortices within the plume distort its circular/elliptical cross-section into a kidney shape while its crosswind vertical width continues to increase until its lower regions make contact with the sea or land surface.

Computer simulations are reported as showing that the area of surface contact may extend over hundreds of kilometres for a burn area of $100m^2$. For meso-scale burns, air contaminations by combustion gases was found to reach acceptable levels at 500 metres downwind while particle contamination levels were acceptable 150 metres downwind, though deposition of particles within that distance is far from uniform with local deposition rates being correspondingly difficult to predict. However, with smoke particles below 10 microns attracting much attention because of their ability to deposit in the lower respiratory regions, efforts have been made to reduce smoke formation in the intentional burning of oil slicks.

To this end, laboratory experiments have shown that chemicals such as ferrocene (bis-cyclopentadienyl iron) and its derivatives reduce smoke formation by 70 - 94% when added to oil to the extent of 2 - 4% by weight depending on oil type. While the soot production from burning hydrocarbons is highest for aromatics and decreases from them through branched paraffins, cycloalkanes and straight-chain paraffins, soot reduction by ferrocene is highest for aromatics and branched paraffins. However, ferrocene additions < 2 - 4% are ineffective because it sublimes at 100°C and so is lost at burning oil temperatures which are typically in the range 150 - 450°C. Nonetheless some derivatives such as butyl and pentyl ferrocenes are already more convenient to use in being liquids dissolvable in kerosene to the density of the oil to be combusted and are excellent soot reducers though still expensive.

The mechanism of soot reduction appears to depend on the catalytic oxidation of carbon to carbon dioxide by iron according to: $2Fe_2O_3 + 3C = 4Fe + 3CO_2$, a mechanism supported by observation of combustion particles consisting of a core of iron oxide surrounded by a carbon layer. Thus far, ferrocene-type compounds remain the most effective soot reducers.

However, regardless of the overall inefficiencies of combustion as a response to oil releases, it seems unlikely that circum-polar States concerned over soot emissions from the highly efficient combustion of oils in ships' engines in polar regions, could ever permit the combustion of released oil as a response procedure, though the inconsistent and paradoxical nature of belief-only regulation continues to amaze those who would prefer regulation to be knowledge-only as advocated in this website. Attempts to use towed booms to maintain combustible thickness as combustion proceeds are noted in article 74.

KNOWLEDGE REPOSITORY: FATES AND EFFECTS

Quantification of Evaporation and Dispersion

Article 39

We have seen in previous articles that the volatile components of floating oil layers evaporate into the atmosphere while the remaining non-volatile and insoluble components disperse into the sea as droplets; that all components with boiling points < 250°C evaporate within a very few hours to extents dependent on the weight percentage of their presence in the fresh oil; that the non-volatile components disperse into the sea more slowly at rates dependent on their rate of droplet formation which in turn depends on viscosity; that for liquid oils and their water-in-oil emulsions this dispersion goes to completion given enough time; and that the pour point temperature determines whether the oil is liquid or solid at ambient temperatures while its density determines whether it floats or sinks.

We have also seen in previous articles that the weight percentage boiling below any given temperature is available from the distillation profile of the oil, while its pour point and density are also readily available from the oil industry for all crude and product oils; and that these values enable predictions to be made as to the percentage evaporative loss which will occur with any specific oil, as to whether it will be solid or liquid at sea temperature, and as to whether it will float or sink. Again we have seen in previous articles that the viscosities of all oils are also available as a function of temperature; that the viscosities of their water-in-oil emulsions can be calculated as functions of their water-contents; and that, in any case, they can be sampled for direct measurement of viscosity at any incident. However, the industry has not determined the relationship between viscosity and slick dispersion rate.

As to this relationship, I noted that slick area is proportional to the quantity of oil within the slick; that dispersion occurs from the total underside area of slicks; that dispersion rate must thus be proportional to area and hence to the amount of oil present in the slick at any time; and that dispersion must therefore be a first order process which must have a determinable half-life just as has the first-order process of radioactive decay has determinable half-lives for all radio-nuclides. Thus, the emulsion viscosity at the Ekofisk blow-out was low enough to have an observed half-life of ~ 12 hours (articles 3 & 46). I recognised, however, that such evaluations of viscosity/half-life relationships for all other emulsions would consume too much ship-time, while J.A. Nichols (ex-WSL) of the Technical Branch of the International Tanker Owners' Pollution Federation (ITOPF) undertook, by reference to accumulated observations of past incidents, to allocate half-lives to four oil property groupings as tabulated below.

Property	Symbol	Group I	Group II	Group III	Group IV
Specific Gravity		< 0.8	0.8 - 0.85	0.85 - 0.95	>0.95
Pour-point °C	A	< 5 (unlisted)	> 5 listed	> 5 listed	listed
Viscosity cSt at 15°C	B	0.5- 2.0	av. 8 or solid	av.275 or solid	1500 - solid
% boiling at < 200°C	C	50-100	10-48, av. 35	14-34, av. 25	3-24, av. 10
% boiling at > 370°C D	D	0	0-40, av. 30	28-60, av. 45	33-92, av.65

The half-lives then attributed to the above Groups I, II, II and IV were as tabulated below.

Group	Viscosity (°API)	Half-Life (Hours)
I	> 45	av. 4
II	45 - 35	av. 12
III	35 - 17.5	24 - 48 range
IV	< 17.5	> 48

It should be noted that these half-lives apply to the emulsions formed by the oils; that Efofisk emulsions are up to 70% water while 70 - 80% is normal for crude oils in Groups II, III and IV above; that oil products show low to zero water-contents for Group I, and 40 - 50% for the heavier fuel oils for which half-lives are observed to be in days rather than in hours (article 42).

Article 40

With the relevant oil property values being referenced by the symbols A, B, C and D (article 39) the crude oils were grouped as tabulated below.

Group I

Product Oils	Specific Property Symbol			
	A	B	C	D
Gasoline	n/a	0.5	100	0
Naphtha	n/a	0.5	100	0
Kerosene	n/a	2.0	50	0

n/a: too low to be significant

These products evaporate within a few hours, their evaporation half-lives being in minutes.

Group II

High Pour Point Oil	Property Symbol A	B	C	D	Low Pour Point Oil	Property Symbol B	C	D
Argyle	9	11	29	39	Abu Dhabi	7	36	31
Amna	18	s	25	30	Berri	9	36	35
Arjuna	27	s	37	15	Beryl	9	35	34
Auk	9	9	33	35	Brass River	4	45	17
Bass Strait	15	s	40	20	Brega	9	38	32
Beatrice	12	32	25	35	Brent Spar	9	37	32
Bunvu	18	s	29	12	Ekofisk	4	46	25
Cormorant	12	13	32	38	Kirkuk	11	35	36
Dunlin	6	11	29	36	Kole Marine	11	34	35
Escravos	10	9	35	15	Montrose	7	36	31
Es Sider	9	11	31	37	Murban	9	36	30
Gippsand Mix	15	s	40	20	Murchison	7	36	20
Lucina	15	s	30	34	Qatar Marine	9	36	33
Nigerian Light	9	s	35	27	Saharan Blend	4	48	23
Ninian	6	13	29	40	Sirtica	7	44	27
Qua Ibbe	10	7	37	8	Stat Fjord	9	35	32
Rio Zulia	27	s	43	20	Zakum	7	34	31
San Juachim	24	s	43	20				
Santa Roasa	10	4	34	27	Gas Oil	5	-	-
Sarir	24	s	37	15				
Sena	18	s	37	15				
Thistle	9	9	35	38				
Zuctina	9	9	35	30				

These oils exhibit Group II dispersion half-lives at ambient temperatures above their pour-points, while at temperatures below their pour-points they were to be treated as Group IV oils (article 42). Those which are solid at all ambient temperatures are designated, s, in the above and subsequent tabulations.

Thus, for any incident-specific oil release we can determine whether it will be liquid or solid; determine the percentage evaporative weight loss if it is liquid as previously demonstrated for Ekofisk Oil; estimate the likely encapsulation of volatiles if it is solid as demonstrated for Beatrix Oil (article 33); estimate the increase in pollutant volume from the water-content of the emulsified non-volatile percentage of liquid oils; estimate the extent of natural dispersion of these emulsions from the tabulated half-life values as demonstrated for Ekofisk Oil; and hence estimate the quantity reaching shore in the time it takes to arrive by summing 100% and 3% of the tide/current and wind vectors respectively.

Article 41

This article continues with the ITOPF (J.A Nichols) tabulations for Half-Life Groups III and IV.

Group III

High Pour Point Oil	Property Symbol A	B	C	D	Low Pour Point Oil	Property Symbol B	C	D
Bakr	7	1500	14	60	Arabian Light	14	30	40
Belayim (marine)	15	s	22	55	Arabian Medium	25	29	45
Cabinda	21	s	21	52	Arabian Heavy	55	25	49
El Morgan	7	30	25	47	Buchan	14	31	39
Manji	9	70	21	53	Champion Export	18	15	26
Sovo	15	s	21	48	Flotta	11	34	26
Suez Mix	10	30	24	49	Forcados	12	18	34

Trinidad	14	s	23	28
Zaire	15	s	23	55

Forties	8	32	36
Iranian Heavy	25	29	44
Khafji	80	25	49
Kuwait	30	29	46
Maya	500	25	49
Nigerian Medium	40	14	40
Santa Maria	250	22	54
Tia Juana Light	2500	24	45
Medium Fuel	1500-3000		

These oils disperse with Group III half-lives at ambient temperatures above their pour points. At temperatures below their pour points they are to be treated as Group IV oils (article 42).

Group IV

Individual Oils	Property Identification Symbol			
	A	B	C	D
Bachequero Heavy	-20	5000	10	60
Bahia	38	s	24	45
Boscan	15	s	4	80
Bu Attifil	39	s	19	47
Cinta	43	s	10	54
Cyrus	-12	10,000	12	66
Duri	14	s	11	54
Gamba	23	s	11	54
Handil	35	s	23	33
Heavy Lake Mix	-12	10,000	12	64
Jatibarang	43	s	14	65
Jobo/Morichal	-1	23,000	3	76
Lagunillas	-20	7,000	9	73
Merey	-23	7,000	10	66
Minas	36	s	17	53
Panuco	2	s	3	76
Pilon	-4	s	2	92
Quiriquire	-29	1,500	3	88
Shengli	21	s	9	70
Taching	35	s	3	78
Tia Juana Pesado	-1	s	3	78
Wafra Eocene	-29	3,000	11	63
Heavy fuel		$5 - 30 \times 10^3$		

Article 42

As we have seen in article 3, my half-life concept, first suggested by our experimental releases of Ekofisk oil, was found to account for the rate of dispersion of the emulsified Ekofisk slick in the days subsequent to the well having been capped. Though this approach is not entirely rigorous, it has been found sufficiently useful at subsequent spills for J.A. Nichols to have tabulated the relevant property values for the oils as reviewed in articles 40 and 41, together with their estimated half-lives. I have subsequently used the above tabulations to compare by mass balance the amounts actually released, evaporated, dispersed and stranded with amounts which but for the salvage action would have been released, evaporated, dispersed and stranded, in a series of salvage-compensation adjudications under Article 14 of the Salvage Convention (article 3). Thus, I know that this process has explained incident-specific outcomes retrospectively and can predict them for future specific-incidents (articles 156 - 162).

As to product oils, we know that while gasoline, naphtha, kerosene and gas/diesel oil either evaporate or fail to form water-in-oil emulsions and thus were appropriately placed in Group I as having half-lives of a few hours, it is rather less adequate to associate the heavy fuel oils with the solidifiers of Groups II and III and to treat them as members of Group IV for which the half-live is estimated simply as being > 48 hours when even these heavy fuel oils are formulated for use in the liquid state, the various grades being distinguished on the basis of viscosity as follows.

Property (Units)	Grades (ISO Standard 8217 of 1996)		
	RMD	RME	RMG
Density at 15°C (kg/m^3)	985	991	991
Viscosity at 100°C (cSt)	15	25	35
Viscosity at 15°C (cSt)	2000	5000	10,000

Pour Point: max (°C)	30	30	30

As to obtaining more information on the dispersion rates of such oils, I used The Netherlands report on the *Katina Incident* of 1985 to evaluate the proportion of the release which reached shore in known times as tabulated below.

Time	Fate of Oil	Quantities (m^3)
0	Released	1624
End of Day 3	Recovered at Sea	792
Day 6	Stranded	540
Up to Stranding	Dispersed (by difference)	293

Thus, on this basis, the half-life of *Katina Incident* oil is about 5 days. Again with its density being 995 kg/m^3 and its viscosity at 100°F being 1250cSt, which converts to ~ 30,000cSt at 15°C, we see that this is similar to the top end of the viscosity range of Group IV and that this extends the half-life estimate of 48 hours for Group IV to 5 days for a very viscous fuel oil; and that Group IV might now be extended and subdivided for heavy fuel oils as follows.

Group	Sub-Group	Viscosity (cSt at 15°C)	Half-Life (days)
IV	1	2,000 - 5,000	~ 2 - 3
	2	5,000 - 10,000	~ 3 - 4
	3	10,000 - 30,000	~ 4 - 5

As to pour point, the ISO system provides a user with a temperature above which the oil will remain liquid as a guide to the heating of oils in handling and use, with actual pour points being generally lower than the specified maximum. Had the pour point of the Katina oil been 30°C, it would have been solid at the sea temperature of the incident.

Again, by the late 1970s, WSL had shown that individual HNS with boiling points < 150°C evaporate totally in 1 hour when spread to layer thicknesses of the order of 0.1mm, as do all oil components boiling in this temperature-range; that all but 15 had viscosities < 5cSt; that all but 20 had melting points in or below the ambient range; that consequently almost all liquid HNS will either evaporate, disperse with the half-lives of Groups 1 and II, or dissolve at rates comparable to the rates of dispersion of Groups I and II; that only very few will be solid at ambient temperatures; and that exceptions can be routinely identified by reference to the values of the aforementioned physicochemical parameters relevant to these individual exceptions.

At this point, it should be noted that while the articles of this website were being initially written for the ISCO Newsletter, they were being progressively summarised for the IMO through meetings 10-16 of its OPRC-Oil/HNS Technical Group as steps towards creation of the new referential knowledge repository intended to support and justify the new contingency plan and incident-specific plans to be derived from the said repository, this website now being my chosen means of publicising all three at this stage of their knowledge-only development, the intention being that future incident-specific observations will provide more precise knowledge of the viscosity/half-life relationship to the efficacy of differing dispersant formulations (articles 22 - 25 and 60 - 61) and to the efficacy of the respective design-principles of mechanical removal equipment (articles 70 and 76 - 80).

Critique of Mathematical Modelling

Article 43

At this point, we have seen that released oil spreads from the source through Phases I, II and III according to Fay; while elongating to a comet-like tail as the slick moves downwind as observed and explained by the WSL team; that this elongation is caused by the upward migration of the larger dispersed droplets from its under-surface according to Stokes and by their re-coalesce on the sea surface upwind of the upwind edge of the slick and beyond it (article 31); and that this process continues as the slick moves downwind at the wind-induced velocity of the water while the concentration of the smaller droplets beneath it decreases with depth by dilution and biodegradation to carbon dioxide and water.

Again, we have seen that dispersant-application increases the rate at which oils disperse by increasing the ease of droplet formation; that for maximum effectiveness, dispersants must be added directly to the oil; that effectiveness is reduced to the extent of dispersant-loss to the seawater; and that, in any case, dispersed droplets carry dispersant from the slick thus reducing the rate of further droplet formation (articles 29 -30 and 60 - 61).

Yet again, we should recall that the mechanism of droplet formation suggests that droplet-diameter cannot be greater than the originating layer thickness; that the very thin layers of Phase III spreading and of slick tails can be relied upon to disperse naturally at droplet diameters too small to migrate upwards; that the rate of dispersant-application is designed in accordance with effective dispersant : oil ratio for layer thicknesses of the order of

0.1mm in accordance with Fay's Phase II spreading; and that pandering to environmentalist belief caused water to be substituted for kerosene as the surfactant carrier in dispersant formulations despite the likelihood of increased dispersant-loss to the sea (articles 29 -30).

Furthermore, while the study of slick tails from small trial quantities of released oil might have provided further knowledge of natural dispersion as a function of oil/emulsion viscosities and on the efficiencies of differing dispersant formulations, interest in dispersant technology was curtailed by belief-only environmentalist opposition and attention turned to less environmentally controversial aspects of the spill response problem while doing nothing to solve the problem itself. Thus, while the articles of this website provide knowledge as to its solution and proposals towards further knowledge-acquisition to this end, I now digress here and in articles 44 - 46, to analyse the differing classes of computerisation some of which present existing knowledge to the user while others only pretend to be useful.

Thus, while the explanation of comet tails provided in article 31 and recalled in the first paragraph of this article provided insight as to the mechanism of natural and dispersant induced dispersion and was thus useful to the practical responder, others turned their attention to the computerisation of the so-called advection-diffusion model of dispersive spreading. In this model, each droplet moves as the vector sum of its sequential stepwise displacements which are computed for each small time interval δt as induced by temporal and spatial variations in tide as provided by such as the Proudman Oceanographic Laboratory, by wind-shear variation with depth down to the depth of zero-shear which itself depends on wind speed, and by surface wavelength effects as these vary with depth. Again, the movement induced by buoyancy and turbulence effects on droplets of varying size is dealt with in this model on the basis of Stokes' Law as modified by variation in Reynolds Number (article 17). Yet again, the model estimates the horizontal and vertical diffusion coefficients K_h and K_v for oil droplets by analogy with concentrations measured for the molecular diffusion of soluble chemicals and dyes.

Thus, we see that while this mathematical model reproduces the natural phenomenon of slick-tailing on computer screens, it does so by assuming the prior existence of oil droplets and by adjusting the values of its incomplete range of parameters to fit the observed tailing; that it is incapable of predicting the spreading prior to the tailing as a function of oil-specific viscosity values as already done by Fay; that it is incapable of predicting the dependence of droplet formation and size-distribution on these viscosity values; that the only oil-specific parameter in this mathematical model is the density of the droplets which thus migrate according to Stokes; and that this advection-diffusion model is telling us nothing we did not already know, and is taking us no further forward in spill response, though its mathematics may bamboozle and impress. So much for this class of mathematical computer model.

Article 44

Another example of mathematical modelling is that which computed the likelihood/non-likelihood of releases from off-shore oilfield activities reaching shore. The first such mathematical model, Slicktrack, predicted the comparative risks of oil slicks reaching various lengths of identified shorelines of the North Sea by predicting their trajectories on the basis of annual average tide, current and wind vectors. Later, this model was used to predict trajectories for oil released at specific locations at specific times *i.e.* at real incidents. These early models for open sea application ignored the cyclic self-cancelling effect of tide and included only the effects of residual currents and wind. However, within a tidal cycle, the Admiralty Tidal Stream Atlas and the tidal diamonds on Admiralty charts together with wind vectors could already be used to predict trajectories by standard navigation and piloting techniques for spill response purposes. However, neither approach included evaporative loss, water-in-oil emulsion formation, nor natural dispersion rates: nor did the models predict them. They only predicted movements as for any floating object such as a life-raft, for example.

Later, to provide more detailed coverage for its coastal terminal at Hound Point in the Forth Estuary, BP commissioned the SCICON Model for which an area of some 40 square miles was divided into 500- 600 grid squares while cross-sectional and longitudinal profiles of the estuary between its shorelines were used to calculate annual tidal data for each grid square based on the hourly tidal height difference from one edge of the area to the other via the sides of the intervening squares. Computed results were then compared with standard tidal data for the estuary and a number of additional measurements were made using current meters to check the computed values. In contrast to the Admiralty chart, there were now about 600 'tidal diamonds' in an area of 40 square miles though this intensity of modelling added nothing beyond that provided by standard navigation and piloting procedures on Admiralty charts.

However, Fay-spreading and tide/wind movement of oil releases were now displayed on computer screens by use of 200 - 500 small hexagons, the required number being computed on the basis of the volume released, these hexagons being computed to move apart to represent spreading while their assemblage was repeatedly repositioned by the computer to represent movement. Thus both spreading and movement were displayed on a chart of the estuary while a zoom control enlarged smaller areas to full frame.

Nonetheless, without such computerisation, available data on spreading, evaporative loss, water uptake, movement on wind and tide, and natural half-life dispersion could have been used to provide the amount and location of pollutant remaining at sea on an hourly basis and the amount stranding at any given time in any given place. Again, available data could have allowed for reductions in amount of floating and stranded pollutant brought about by any number of response units operating for known times at known treatment rates (article 42). Yet again, navigational calculations of movement and amount could have indicated the different consequences of differing responses at different locations within the slick and could have identified the most effective locations for defensive boom deployments. Indeed, by the late seventies, all of this could have been calculated for any given incident without the computerisation which could not yet do so (articles 161 - 162).

However, the SICON model exemplifies how mathematical modelling can at least partially present existing knowledge (movement) in a user-friendly way in contrast to the advection-diffusion model which simply seeks consistency of output with existing knowledge of the phenomenon modelled by the adjustments needed to do so. Such modelling is only of benefit if it contains variable parameters for adjustment to meet observed reality and thus to investigate the sensitivity of the model to actual changes in these parameter values. Similarly, however, mathematical modelling can be used to make spurious adjustments to parameter values to achieve consistency with the belief which initiated the model and thus achieve spurious acceptance of the said belief without contributing one *iota* to knowledge.

Such seems to be the case with the mathematical modelling of anthropogenic global warming, where adjustment of parameter values can produce temperature rises low enough to be credible and high enough to be alarming, while effort might more usefully be expended on determining the rates at which biological/geological mechanisms of carbon dioxide abstraction from and return to the atmosphere can respond to increases in the rates at which carbon dioxide is emitted by the ‘fossil’ combustion which reverses only part of the ongoing photosynthetic abstraction and which could already have been thus reversed had fossilisation not interrupted its earlier return by biodegradation (Preface and article 1).

Article 45

Further to the non-valid modelling of natural phenomena in general, we know that the so-called advection-diffusion model of oil spreading through droplet formation ignores the viscosity which is the controlling parameter of Fay spreading and of droplet formation, both of which have to happen before the said model can be applied (article 43). Thus we may conclude that this model cannot explain or predict the varying rates of spreading and natural dispersion observed to occur with oils of differing physical properties when it takes none of them into account; that to achieve this objective a model would need to account for spreading and droplet formation/size-distribution as functions of viscosity and agitation energy; that this would need observation of these phenomena at sea under differing meteorological/oceanographic conditions and under specifically controlled laboratory conditions; that this would involve measurement of agitation energy and droplet-size distribution by microscopic evaluation, photography or phase-Doppler analysis of representative samples; and that these techniques are difficult to apply because large buoyant droplets rise too fast to be representative, while the smallest may not be detected at all, and while those detected can be confused with air-bubbles. I will return to these considerations when I review dispersant efficiency evaluation in article 48.

In the meantime, we know that modelling can become a pseudo-alternative to the experimentation which reality-evaluates beliefs (hypotheses) to knowledge; that it can become a poor alternative to direct observation; and that in extreme cases it can even become anti-knowledge in its defence of belief in the corruption of science to pseudo-science. As to the application of mathematics to direct observation, the author’s derivation of a half-life for Ekofisk oil and its application to the oils of Groups I - IV as previously reviewed (articles 31 - 33) is perfectly practical and has scope for greater precision through direct observation, mathematics *per se* being simply a means of rearranging existing knowledge to a more conveniently useable form. Thus, for example, the knowledge that a rate of change is proportional to the amount present may be written $-dN/dt = KN$ and rearranged to $T_{1/2} = 0.693/K$ by mathematical analysis through a series of equations *i.e*. statements of the equality of one mathematical expression with another with no new knowledge being created by this process, the concluding statement being a restatement of the initial statement as are all the intermediate statements, this being the meaning of the recurring equality sign. Thus, while the final statement is a rearrangement of the first in a more useful form, it does not contain new knowledge per se.

However, in favouring the user-friendly computerisation of existing knowledge as per the Firth of Forth example, the UK commissioned SCICON to provide computerised models for oil movement on tide and wind for the English Channel with emphasis on inshore Oil Blocks, and on the North Sea with emphasis on the Cromarty Firth and north to Sumburgh Head, Shetland. Again, with British Marine Technology Limited wishing to make the widest possible use of its software skills and access to its Digital Tidal Atlas and Global Information System, WSL agreed to supply oil-related data to these ends with BMT providing computer screen displays of movement on percentage tide and wind vectors, though displays of oil-specific evaporative losses and half-life dispersions as functions of time from release to stranding might have been convenient than the case by case approach of articles 46 and 107 - 115. However, BMT subsequently computerised the WSL Beach Cleaning Manual (articles 92 - 98).

Of course, computerised movement by wind and tide can assist searches for any floating object as in search and rescue and in container-tracking after loss of deck-cargo. Computerisation has also been applied to discharged plume dispersion in respect of production-water, drilling-mud and cuttings in the offshore oil industry, and indeed to the discharge of any effluents containing soluble, particulate or water immiscible droplet-forming substances. However, the intending user must always ensure that the computerisation is knowledge-only or that he fully understands the significance of any failings in this regard, particularly where these have been subsumed in assumptions which stray beyond knowledge to mere belief. The user should also seek to know whether quoted toxicities relate to actual concentrations resulting from the discharge or to relative LC_{50} values which ignore actual concentrations in specific circumstances. The much more realistic approach is to expose the relevant organisms to the appropriate concentrations in the laboratory or to cage them in the actual dilution plume and to combine these more realistic approaches with radio-active tracer (C-14) determination of the critical body residue (CBR) for death and its relationship to the concentration of this component at the location of organism exposure (articles 14 - 15)

Article 46

In article 45, we saw that: $- dN/dt = KN$ leads by mathematical analysis to $T_{1/2} = 0.6931/K$ where $T_{½}$ is the half-life of the dispersion process Again, from previous articles, we saw that dispersion proceeds through droplet formation induced by the energy supplied by wave turbulence at the slick/seawater interface; that the need for dispersion energy increases with increase in viscosity from one oil to another, and again when water-in-oil emulsions are individually formed by this same turbulence; that for any energy level, the rate of dispersion depends on the number of droplets formed per unit time, and the ratio of the number of droplets small enough to remain dispersed to the number large enough to re-coalesce with the slick; and that for a given energy level this ratio decreases as viscosity increases.

With respect to droplet size distributions, it has been shown by Liebovich that the probability of an oil droplet at a depth Z at time t = 0 still being dispersed at time t, is $p(t) = ½\ \mathrm{erf}(U -Z) /2K_t t)^{1/2}$ where U is the terminal velocity at re-coalescence and K is the turbulence diffusivity which in turn is related to sea state. It was also noted earlier that the maximum diameter of droplets is equal to the thickness of the slick, though of course some or all will be smaller depending on the prevailing level of turbulent energy. Thus, for slicks of water-in-oil emulsion greater than 0.5mm in thickness, droplets small enough to avoid re-coalescence occur with 0% frequency, while for thicknesses of 0.1 mm and less the frequency of occurrence of non-coalescing droplets increases towards 100%..

Thus, for trial releases of Ekofisk oil at Phase II spreading thicknesses of around 0.1mm, it appears that droplet sizes were distributed above and below the size limit for non-coalescence at the energy levels then prevailing, while at the Ekofisk Blow-out the droplet sizes under the post-Phase III sheens were probably small enough for 100% non-coalesce. Thus, an Ekofisk emulsion of 70% water content and ~ 1000cSt viscosity, appeared to produce droplets of sizes above the non-coalescence limit in the Phase II region and ever greater frequently below this limit in the Phase III region to produce the observed half-life of 10-12 hours overall, while those oils and emulsions with higher viscosities would be expected to exhibit longer half-lives/slower dispersion-rates and *vice versa* for lower viscosities. In any case, the Ekofisk slicks whether released for trial purposes or by the blow-out were observed to diminish to around 1% of their initial amount in about 7.5 half-lives of 10-12 hours duration.

Thus, while we cannot predict dispersion rate directly from viscosity by means of a mathematical equation or from a mathematical model involving viscosity, droplet size and turbulence energy, we can expect to estimate half-lives from observing the times required for slicks of known viscosity to disperse across the whole viscosity range, by grouping all known oils into viscosity-related half-life ranges as presented in articles 39 - 42, by interpolation within and between these ranges, and by narrowing and increasing the number of such groups as observational opportunity permits in all future incidents, as I have already done for heavy fuel oils on the basis of the *Katina* incident. As to estimating half-life by observing the progress of natural dispersion, reference might be made to the following tabulation in respect of the Ekofisk blow-out before and after capping.

Hypothetical Half-Life Hours	Equilibrium Tonnage at Discharge Rate of 150 tonnes h^{-1}	Tonnage Remaining 60 hours after capping
5	1080	0.28
10	2160	34
12	2600	80
20	4320	540
60	12960	6480

The equilibrium tonnage is the amount on the sea surface when the dispersion rate equals the discharge rate *i.e.* when $0.6931T_{½} = N = 150$ (tonnes h^{-1}) *i.e.* when $N = 150T_{½}/0.6931$. Thus, by estimating the equilibrium amount to have been the daily release rate of around 2,500 tonnes, through measurement of the post-capping visible area of the slick and by estimating the amount remaining 60 hours after capping to be less than 100 tonnes, it was concluded that the half-life was 10 - 12 hours as indicated by previous experimental releases. Again we see that such a slick cannot be expected to spread beyond the area it actually reached during the blow-out, which according to Norwegian aerial surveillance was 80 x 65 km; and that the equilibrium amount of ~ 2,500 tonnes reduced in ~ 7.5 half-lives of 12 hours to ~25 tonnes.

Dispersant Effectiveness and Regulation

Article 47

Having seen that the lapse of ~7 half-lives of a first order reaction reduces the amount remaining to ~1% of the initial amount, and that lapse of another 7 reduces it to 0.01%, we know that direct observation is a more convenient and reliable means of determining half-lives as a function of viscosity than is attempting to predict dispersion rates by mathematical modelling, given the assumptions usually introduced in modelling to compensate for the absence of observational knowledge. In the following articles on response to spillage by dispersant application, however, we will see that our knowledge of natural dispersion makes it extremely unlikely that attempts to increase natural dispersion rates will be rewarded with instantly observable success.

Under conditions of 1-3 knot wind speed and sea state 1, the WSL team discharged 0.5 tonne of Ekofisk oil to the sea, measured the layer thickness, applied dispersant to it and measured the resulting sub-surface oil concentrations. In contrast to natural dispersion which had previously produced concentrations between 2 and 0.02ppm, dispersant application 3 hours after discharge was such as to have produced no more 25ppm in the top metre of seawater. Indeed, it was found to average 18ppm at the sampling depth of 30cm. Thus, in these calm conditions with low levels of natural agitation limiting immediate dilution to greater depths, the adequacy of the sampling and analytical techniques were demonstrated and thus conveyed to ASTM in 1977. With these sampling/analytical techniques, the WSL team proceeded to investigate the concentrations of dispersed oil in the water beneath dispersant-treated slicks using a fanjet apparatus which laid carpets of oil 0.3m wide on the sea surface from the moving trials launch at thicknesses up to 1mm depending on discharge pump rate and launch speed while another fanjet 100cm behind the first laid dispersants onto the oil carpet. The results obtained at 30cm depth beneath an oil carpet 1.0mm thick are tabulated below.

Time after treatment	Concentrations of Kuwait Crude Oil		
minutes.	run 1	run 2	run 3
0	34.4	24.2	0.85
1	-	15.8	-
2	47.8	-	8.7
2.5	-	12.2	-
5	-	9.4	-
7	17.8	-	3.5
10	-	5.2	-
15	-	-	1.7
18	1.9	-	-
25	-	4.2	-
40	-	1.9	-
80	-	-	1.5
100	2.2	0.8	-

On the above occasion, with a wind speed of 8-10 knots a sea state of 2-3, the level of agitation was consistent with initial concentrations being low and rapidly diminishing by dilution to greater depths. It should also be recalled that the layer thickness was 10 times that of Phase II spreading; that the measured concentrations are thus potentially 10 times higher than for natural slicks of 0.1mm thickness; and that the generally higher thickness of the preliminary 0.5 tonne trial at sea state 1, had been chosen in order to ensure the production of measurable subsurface concentrations.

It should be noted also that in 1977 McAuliffe *et al* were reporting to ASTM that C_2 - C_{10} hydrocarbons could only be detected at 2 - 60 μgl^{-1} (ppb) in the first 30 minutes after discharge because they rapidly evaporate to < 1μgl^{-1} and that while benzene and cyclohexane have very different solubility in water, their similar vapour pressures ensure that they both evaporate rather than dissolve or disperse. However, while we know that the non-volatile fraction of Ekofisk oil *i.e* 70% of the daily release rate of 2,500 tonnes was dispersing per day , we also know that such a rate could not be enhanced significantly by dispersant application over operationally localised areas within the total area of the equilibrium slick which was 80km x 35km (article 46). Thus, however effective dispersants may be, their pollutant encounter rate remains a problem as it does for mechanical removal (articles 55 and 70).

Article 48

As to comparing the efficiency of differing dispersant formulations on the basis of knowledge already available on natural dispersion, the WSL team devised the revolving flask test. This consisted in tumbling a mixture of a standard oil (topped Kuwait Crude) and the dispersant under test in a standard chemical separating funnel (the mechanically revolving flask) for a standard time, in stopping the flask to allow the larger droplets to migrate upwards; in drawing off a sample volume from the water phase containing the smaller dispersed oil droplets, and in analysing the oil-content of this water phase by extracting the oil from the water into chloroform and analysing spectrographically to determine the quantity of oil dispersed under the standard conditions of the test.

However, with no attempt having been made to create the droplet-size range of secondary dispersion in the revolving flask, we know that the larger droplets migrated to and re-coalesced with the growing/ floating oil phase at rates dependent on their individual sizes while the sample was drawn off for analysis; that consequently no attempt was made to obtain an absolute measurement of dispersant effectiveness; that the data thus produced was/is comparative as between one dispersant and another; that any desirable level of dispersant effectiveness can be accepted as satisfactory with all formulations below this level being rejected; and that the level of acceptance must be judged by means beyond the revolving flask method of initial screening as described below. In addition, a simulated beach test was devised in which the artificial sand was glass beads with the oil dispersed from them being sampled and analysed as above.

Again, it should be noted that the Revolving Flask Method premixes the oil and dispersant; and that this does not occur at sea, though it standardises the test, droplet size distributions being otherwise markedly dependent on addition technique. Yet again, the energy input by the laboratory system may not be sufficiently representative of reality. For these and possibly unidentified reasons, a sea test was devised to confirm the laboratory-based indications, to observe an acceptable level of dispersion and to further test the most promising laboratory failures.

The sea test apparatus is the double fanjet system which produced the subsurface concentrations tabulated in article 47 but with the oil pump rate adjustable to give oil carpet thickness from 1 - 4mm at the operating speed of the launch, a Seatruck. Similarly, the dispersant application rate could be varied throughout the test programme. Again, to standardise energy input a horizontal slatted 'breaker-board' (five-barred gate) was towed behind the dispersant treated carpet to immediately break it into droplets and the cut-off for acceptable dispersant performance was the degree to which 1mm diameter droplets were observable on the surface and in the water column behind the breaker-board, by observers on a second launch following behind. These observers simply recorded their observations for later assessment against pump-rates. To ensure impartial judgement, the observers were kept ignorant of the relative oil : dispersant pump rates and of which dispersant was under test at any time. In order to eliminate the effects of variation in natural agitation as distinct from that provided by the breaker-board, a standard dispersant of known capability was randomly introduced to the test sequence at times unknown to the observers, thus serving as an additional check on their judgement.

On one occasion, WSL was asked to conduct a dispersant trial in Bahrain as an adjunct to one of its overseas spill-response training courses, during which the opportunity was taken to have 20 observers recording their observations independently and anonymously on a paper format. The subsequent analysis of these observations confirmed this apparently subjective test as being objectively reliable even with observers of no previous experience. In response to those who would advocate sampling and chemical analysis over such direct observation, WSL considered the sampling/analytical approach incapable of providing reliable data on concentrations immediately beneath the sea surface given the rapid and variable rate of their dilution with depth as revealed by the minute by minute sampling and subsequent laboratory analyses tabulated in article 47 for slick thicknesses and dispersant application rates 10 times those of normal operations.

At the outset, WSL had produced a specification for dispersants as to surfactant carriers, prohibited ingredients, flashpoint, cloud point, viscosity, containers, labelling, shelf-life, and quantities to be submitted for testing. Thus, in attempting to offset belief in their toxicity regardless of their exposure concentrations, chlorinated hydrocarbons, benzene, and phenol were prohibited, while aromatic and naphthenic content was limited. Again, flashpoint had to be less than 62°C (142°F) a safety stipulation with the additional advantage of minimising carrier loss on storage in ventilated tanks, while cloud point had to be no more than -5°C (23°F). Yet again, two-layer separation could not occur above -10°C (14°F) while its viscosity at 0°C (32°F) could be no more than 50cSt unless for a concentrate when 250cSt was permitted. However, if it exhibited non-Newtonian characteristics on dilution, concentrate viscosity could not exceed 250cSt at a shear rate of $10^3 s^{-1}$. It was further stipulated that delivery be in standard steel or polyethylene drums of 45 gallon capacity, though special arrangements could be made for bulk deliveries; that all containers must be labelled with the manufacturer's name, substance identification mark, batch number and flashpoint; that the same information must accompany bulk deliveries; that shelf-life must be at least 5 years; that details as to manufacturing capacity must be submitted to meet prolonged emergency requirements, and that dispersants supplied against this specification would be evaluated for efficiency and toxicity before their use could be approved.

Article 49

After testing for efficiency by WSL, dispersants passed for potential use were 'tested for toxicity' by the Ministry of Agriculture Fisheries and Food under the provisions of the Dumping at Sea Act. Initially, LC_{50} values were measured over a 48 hour exposure of *Crangon crangon* (common shrimp) to the dispersant itself. Later, when concentrate dispersants were introduced, this organism was exposed to the dispersant/oil mixture under otherwise identical conditions with failure or success being judged on whether or not the mixture toxicity was greater than that of the oil alone, a criterion to which I objected on the grounds that it was likely to pass formulations of minimal effectiveness and to reject the most effective, given that it was the non-toxicity of dispersants which necessitated their being mixed with oil to make toxicity measurement possible at all. My objection was ignored, presumably because I wasn't a marine biologist, no scientific dismissal of my objection being possible.

Testing involved setting up five replicates containing 1000ppm oil (fresh Kuwait Crude) dispersed in seawater with 1000ppm of hydrocarbon-carried dispersant or with 100ppm of concentrates intended for operational-dilution to 10%, and five replicates containing 1000ppm of oil alone, all of these replicates being in a series of 22.5 litre Perspex cylindrical tanks each fitted with a stirring system intended to maintain the oil or the oil/dispersant in a uniformly distributed state irrespective the absence/presence of dispersant, with the stirrer paddles revolving in mesh cylinders to protect the shrimps from mechanical injury, and with the filtered seawater being continuously aerated. After 1 hour of this initial phase, 20 acclimatised shrimp were added to each tank external to the cylindrical mesh and after 2 hours the aerators were removed. The appropriate quantity of oil was then added to the water surface in each tank and to half of the tanks dispersant was added to the oil layer and after 1 minute, stirring was started and the shrimps exposed to the tank contents for 100 minutes after which stirring was stopped, the tank contents were siphoned off, and the shrimp transferred to flowing clean aerated sea water with mortalities being observed after 24 hours.

While it is impossible to duplicate sea conditions fully in the laboratory however hard we might try, it is notable how far from sea conditions this test was deliberately set. In assessing this departure from sea conditions, we might start by comparing the low and rapidly decreasing concentrations of oil and indeed of dispersants as tabulated in previous articles (e.g. article 47) even when oil layers were 1.0mm thick in contrast to 0.1mm layer thickness of Phase II spreading to which operational application was in the dispersant : oil ratio of 1 : 2 for the hydrocarbon-carried and 1:20 for the concentrates. Thus, we immediately see how far actual oil and dispersant concentrations differ from those of the above tests. Again, when the intention of applying dispersant to oil is to create the smallest possible droplet sizes to maximise the extent of dispersion without re-coalescence, it is surely bizarre to design a test which runs the risk of failing those which succeed in so doing, and of passing only those which fail to do so. Yet again, we may wonder why the aeration is stopped during shrimp exposure to these unnaturally high concentrations. Overall, the only possible explanation must be that toxicity would be immeasurably low were the shrimps to be exposed to the actual concentrations reported elsewhere in these articles, aeration being thus terminated presumably to maximise the 'toxicity'.

A beach toxicity test was also designed by MAFF, in which the test organism is *Patella vulgata* (the common limpet. In this test, limpets which had been allowed to attach to Perspex plates were sprayed with dispersant or with oil and left in moist air for 6 hours before being washed for 15 seconds in running water. The plates (5 for dispersant only and 5 for oil only) were placed vertically in recovery tanks where further rinsing takes place over a simulated tidal cycle. Limpets detaching from the plates were recorded as dead and were removed from the recovery tank immediately after the simulated tidal cycle and at 24 and 48 hours after the start of the test. After this 48 hours, any remaining limpets which were not firmly attached to their plates were gently detached and placed on the tank floor and if these had not reattached in a further 48 hours these too were presumed dead. In this test, dispersants were passed or failed on being less or more toxic than the oil.
Once again, this test may be evaluated as to its simulation of reality. Ideally, dispersants would clean oil covered limpets without killing them. Why, therefore, does this shore test not apply oil followed by dispersant to groups of Perspex-clinging limpets in parallel with the applications of oil-alone and dispersant-alone? This, trio would have revealed whether dispersant kills un-oiled limpets, whether oil kills them, and whether or not dispersants would clean rather than kill them. However, while knowing that coating shoreline organisms with oil is a closer simulation of stranded oil than exposing them to dispersed oil concentrations orders of magnitude above those of actual exposure in seawater would have been, and while knowing that careless application to clean limpets onshore is likely enough for inclusion in such a test, we also know that oil-coated limpets are likely to die anyway; but that shoreline cleaning by dispersants aids re-colonisation.

Thus, while both the sea and shoreline simulations are inadequate/misleading and could easily have been made more usefully informative, their non-realistic design suggests a desire to support anti-dispersant belief rather than to acquire knowledge of the benefits of use, this being a case of the belief-acceptance/knowledge-rejection which this website seeks to reverse.

THE KNOWLEDGE REPOSITORY: RESPONSE TECHNIQUES
Dispersant Application from Ships and Aircraft

Article 50

Equipment for dispersant application from ships such as harbour tugs was developed by WSL (F. Shuttleworth) and manufactured by Biggs Wall Fabricators Ltd shortly after the *Torrey Canyon Incident.* The spray booms, one per side and each fitted with three equally spaced fanjet nozzles, were swung out horizontally to give continuous dispersant coverage beneath each boom, while these towed a set of horizontally slatted 'breaker-boards' to provide additional agitation energy (article 48) at ship speeds of 5 - 10 knots, the dispersant pump rate being fixed at 20 gal min^{-1} in compliance with the 1 : 2 dispersant : oil ratio of the laboratory efficiency test, a slick thickness of

0.1mm, and an effective spray width of 20m *i.e.* the pump rate was scaled to a slick encounter rate of 15 - 18 tonnes of emulsion per hour. A version was designed for inshore work boats for which the scaled pump rate was 7 gal min^{-1}.

Later, the ~ 10 times more effective concentrates introduced the options of seawater-dilution to extend operational endurance of ships and workboats by a factor of 10 at the above application rates, or to increase pollutant encounter rates by increasing the speed of the equipment carrier by a factor of 10. As to the first option arrangements were made to dilute with seawater for ship and workboat operations (F Shuttleworth and J. Nightingale), while aircraft application was later considered for the higher speed option, such being largely a matter of observing whether or not the assistance of 'breaker boards' would remain essential even for undiluted application of the concentrates. To this end, trials were conducted from *Seaspring* to assess the effectiveness of undiluted concentrates under different sea states, the method being that of the WSL launch-based dispersant efficiency testing (articles 47 & 48).

With this apparatus, Kuwait crude oil was discharged at 45 litres min^{-1} while the dispersant under test was discharged at rates from 1 - 4.5 litres min^{-1} while the ship maintained a steady course and speed of 2 knots using its 360° bow-thruster to avoid main propeller agitation and, of course, the agitation 'breaker board' was absent. The procedure was to spray dispersant at a particular rate before starting the oil spray to produce the standard carpet, to spray both for 1 minute, to stop the oil before the dispersant, and to have observers in a following inflatable-dinghy report the results as they would normally do in the sea test of dispersant effectiveness. It was found that approved concentrates were effective at $1/10^{th}$ the application rate of conventional dispersants without the need for 'breaker boards'.

The next step was to investigate whether or not dispersants could be applied to oil slicks from aircraft without loss of this effectiveness. The aircraft chosen for trials purposes was a single-engine crop spraying Piper Pawnee owned and operated by Harvest Air Ltd with a range of 200 miles and a disposable load capacity of 540 kg delivered by a propeller-driven pump through spray booms attached to the trailing edges of the wings at 27 - 482 litres min^{-1} over a pressure range of 0.7 - 4.2 kg cm^{-2} depending on nozzle configuration and orifice diameter. This aircraft gave a swath width of 16 m while operating at 90 mph and an altitude of 3 - 4.5 metres. A series of water spray runs were made over an airfield (J. A. Nichols) to investigate the effects of nozzle size and configuration on droplet size and ground application rates, droplets being collected at ground level on 10 x 10 cm glass plates laid across the swath width. After each pass the diameters of spots on the plates were converted to droplet diameters using the 3 : 1 relationship between them, while the quantity of water on the plate was determined by absorption on tissues followed by extraction with toluene under reflux. Again, the possibility of evaporative loss was assessed by spraying 0.1M sodium carbonate solution in place of water, collection on the plates and rinsing with known volumes of distilled water followed by titration with hydrochloric acid to determine the molarity of the sodium carbonate in the water droplets on impact, and thus to measure evaporative water loss to the atmosphere by the observed molarity increase.

Article 51

With the techniques described in article 50, airfield trials with the Piper Pawnee were run in wind speeds of 10-12 knots using 1/8 inch orifice nozzles fitted with central cores which for crop spraying would have given an application rate of 45 gal min^{-1} or 5gal per acre. With water, however, a fine mist hung in the air for about 30 seconds while examination of the glass plates for the droplets which did fall showed them to be 70-100 μm in diameter and the actual application rate to be about 1 gal per acre, suggesting that evaporation was high in the windborne size range, whereas in relative humidity conditions of 88%, the 70-100 μm size range reached the ground with little evaporative loss as judged by titration of the Na_2CO_3 solution. To investigate the benefit of increasing droplet size above 70-100 μm, the nozzle orifices were changed to 3/16 inch and the cores removed with the result that droplet diameters were in the range 700-1000μm with application rates of 5-10gallons per acre at operating pressures of 5-20 lb in^{-2} and with an even distribution across the swath width as tabulated below.

Application Rates for Sodium Carbonate Solution
across a 16 m Swath

Run No.	gallons per acre			
1	9.0	10.4	14.9	8.3
2	9.0	10.0	10.0	8.9
3	8.1	10.8	13.5	7.2

It was noted in the above trials that uniform application across the swath width was best achieved with the aircraft flying into the wind. Though permission to spray dispersant on an airfield surface would have been difficult to obtain, this was considered unnecessary, the boiling points of dispersant concentrate formulations being high enough at 150-200°C to ensure their arrival at sea level without significant evaporative loss in the droplet size range of 700-1000μm. Accordingly, the final configuration adopted for dispersant trials at sea was to fit the Piper Pawnee with an 8m array of 44 nozzles of 3/16in orifice diameter with their cores removed and operating at 20lb inch^{-1} (1.4kg cm^{-2}) to produce a dispersant application rate of 10 gallons per acre (1.1 litres 100m^{-2}) over a 16 m swath width beneath the aircraft when flying at 90 mph and an altitude of 3m.

For dispersant trials at sea, *Seaspring* was fitted with a 4.5 m boom equipped with three fanjet nozzles to lay a 5 - 6 m wide oil carpet of thickness between 0.1 and 0.2 mm on the sea surface depending on ship speed as it headed into the wind. For each trial a control slick was laid to undergo natural dispersion for comparison with the effect of dispersant on a second slick similarly laid about a quarter of a mile distant, both slicks being along the wind direction to simulate a windrow. Immediately the second slick was laid an observation boat was positioned at the upwind end before the Piper Pawnee commenced spraying at 90 mph to apply dispersant at 10 gallons per acre from a height of 3 - 4.5 m after which the small-boat observers made repeated comparisons between the treated slick and the control. For these trials over a 4 day period, wind speeds varied from 5 - 20 knots while the dispersants tested were as tabulated below.

Product	Supplier
Corexit 9527 and 9600	Esso Chemicals
Finasol OSR5	Petrofina (UK)
Shell Concentrate	Shell International Chemical Co.
BP1100WD	BP Chemicals Ltd
Dasic Slickgone LTC	Dasic International

All of the above dispersants were found to be effective in promoting oil dispersion, though differences were observed particularly in calm seas with Corexit 9527 giving the smallest droplets, BP 1100WD the largest, and the others variously between, these differences becoming less marked as wind speed increased.

Article 52

Having modified the Piper Pawnee crop sprayer as reviewed in articles 50 and 51, a WSL investigator (H. Parker) applied the collection plate method of determining droplet size at a DC-4 (Globe Air Inc) trial organised by the Southern California Petroleum Contingency Organisation in conjunction with the American Petroleum Institute (API) and the Caribbean Contingency Organisation at Mesa, Arizona, and when this aircraft subsequently arrived in Europe for possible response to the *Amoco* Cadiz incident *Seaspring* was available for a sea trial as described in article 51. However, wind speed was too high (25 - 30 knots) to do other than release oil and emulsion from a trailing hose, allow it to spread naturally and estimate thickness at 0.6 to 0.76mm for the oil and 1.3mm for its emulsion on the basis of discharge rate, ship-speed during discharge and ribbon-width of 2 metres from aerial photography. Three ribbon slicks were thus generated by releasing 400 litres of 'topped' Kuwait crude oil, 400 litres of its 50% water-in-oil emulsion and 200litres of the oil as a control.

Indeed, for these trials over a two-day period wind speeds were so high on day 1 as to prevent *Seaspring* from laying slicks into the wind and the aircraft had difficulty in judging cross-wind drift to the extent of most of the dispersant missing its target. On day 1, the ship was stationed parallel to the slick to facilitate direct observation as the DC-4 was directed onto each slick by a spotter aircraft flying at higher altitude and photographing the operation, while on day 2 she was positioned directly upwind of the slick so as to judge the accuracy of dispersant application, after which she returned to the slick to judge its effectiveness. On day 2, Corexit 9600 applied at the standard rate of 5-10 gallons per acre was effective on the oil when repeated treatments compensated for the higher than normal thicknesses of these particular windrows, though even with repeated treatments it was noticeably less effective on the 50% emulsion. Subsequently, WSL (B. O. Dowsett) reported successful dispersion by a DC-6B at the *Ixtoc Blow-out* in the Gulf of Campeche, Mexico, while WSL (H. Parker) reported success by the Piper Pawnee at the *Betelguese Incident* in Bantry Bay, Eire.

However, with uncertainties remaining as to whether emergency spray gear and tank storage could be designed for installation and removal from otherwise ideal aircraft, attention turned to helicopters from which these items might be under-slung thus avoiding saddle tanks or fuselage/wing modifications. To this end, WSL (J.A. Nichols) investigated the droplet size spectrum produced by commercial crop spraying equipment with respect to altitude of release, the viscosity range of approved dispersants, and the ease or difficulty of operating with an under-swung tank/bucket over oil slicks at sea.

The equipment supplied by the Simplex Manufacturing Company of Portland, Oregon consisted of a 180 gallon capacity fibreglass bucket, two 12 ft nozzle-fitted spray booms and a centrifugal pump driven by a Briggs and Stratton 8HP petrol engine, the bucket being attached to the helicopter by a hook and spreader bar and the spray booms having aerofoils to prevent rotation in flight. The petrol engine was started by a cockpit switch and 12 volt battery and once started a cockpit operated solenoid valve either circulated the liquid from and to the bucket or directed it to the spray nozzles, while a pressure relief valve in the return line permitted some control over delivery rates to the nozzles. To avoid pump-damage by dry running, a float valve stopped the engine when the bucket contained < 2 gallons. The helicopters used were the single engine Hiller UH12E with a carrying capacity of 450kg and a bucket strop of 18ft and the twin engine Aerospatiale 365 with a carrying capacity of 650kg and a radio altimeter which enabled the bucket strop to be reduced to 5ft (article 53).

Article 53

The first trial with the Hiller UH12E and the 18ft bucket strop was to investigate the effect on the percentage spray delivery and droplet size spectrum of operating with the spray boom at heights of 10, 20 and 30 ft above the ground in variable wind speeds of 5-10knots , the pilot being assisted by a 30ft graduated mast at the side of his flight path and by radio contact with observers on the ground. To determine the percentage delivery of the 10 gallons per acre (11ml m^{-2}) spray rate, 20cm diameter clock glasses were placed at 2m intervals across the swath width, pre-weighed tissues were removed from sealed tubes to absorb collected droplets and resealed for subsequent reweighing, while the water (dyed with Kiton Red) was rinsed from a second row of clock glasses with distilled water, made up to 50ml in standard flasks to confirm the delivered spray weights by calibrated absorbance in a Perkin-Elmer 550 UV/visible spectrophotometer with the droplet size spectrum being determined by measuring spot diameters produced by collected spray on 24cm diameter filter papers.

The second Hiller trial with the 18ft strop was to investigate the effect of dispersant viscosity on spraying performance with the dispersants being dyed with oil-soluble Erythrosine Red. In this trial the pre-weighed tissue technique of trial 1 was used to determine the percentage actually delivered of the 10 gallon per acre spray rate, while the Kromecote cards of Ciba-Geigy Ltd replaced the earlier filter papers, the cards being photographed for spot diameter measurement.

The results of dye analysis are independent of evaporation and thus measure the discharge rate, while the tissue weight measures the rate of arrival, the difference between them indicating a loss of 15% by evaporation. which was confirmed to ± 15% by measurement of discharge rates and of before-and-after measurements of bucket contents. As to droplet size, the volume mean diameter (VDM) was found to be 950μm with a geometric standard deviation of (GSD) of 3.4, though there was a gradation in size from one edge of the swath to the other induced either by a small cross wind vector or a turbulence caused by the helicopter itself. As to variation in altitude, the droplet size distribution and the application rate remained unaffected across the 12 m swath width, while the general handling of the aircraft-bucket combination was confirmed to be satisfactory and the bucket to be easily attached and removed with the aircraft hovering. Because altitude variation did not influence results in the range investigated, it was decided to opt for 20ft in subsequent trials in light of the increasing difficulty of maintaining constancy at lower altitudes.

The dispersants selected for the two viscosity-related trials are tabulated below.

Trial	Dispersant	Supplier	Ambient Viscosity (cP)
1	BP 1100WD	BP Chemicals	20
	Finasol OSR7	Petrofina UK	70
	Dasic Slickgone LTD	Dasic International	230
2	Dispolene 345	SEPPIC (France)	110

Though the viscosity of Dasic product was within the viscosity range specified by WSL in its guidance for dispersant formulation (article 48) difficulty was encountered in meeting the target application rate of 10 gallons per minute (11ml m^{-2}) thus causing the SEPPIC product to be chosen for Trial 2 to extend the above range of viscosity > 70 but < 230cP. Following these trials Dasic introduced the less viscous LTE formulation. Nonetheless, while droplet size is expected to increase with viscosity for constant energy input this appears to be belied by Trial 1 in which water had a VDM of 950μm while the VDMs of the products in ascending viscosity were 570μm with a GSD of 3.22, 700μm with a GSD of 2.32, and 670μm with a GSD of 2.08. Thus, with surface tension and perhaps density also having an influence on droplet formation, viscosity cannot be solely controlling. In any case, application rate, droplet size, and droplet distribution across the swath width were shown to be satisfactory.

For the second helicopter trial in which dispersant was applied to oil at sea, the twin-engine Aerospatiale 365 with its radio altimeter and bucket strop of 5ft replaced the single-engine Hiller this being in compliance with regulated operation over water. This trial confirmed that slicks of fresh Kuwait and 1200cSt fuel oil as laid by *RV Seaspring*, could be dispersed by one treatment, though parts of both slicks remained untreated after two passes, indicating difficulty in dispersant placement, altitude maintenance being difficult even with the radio altimeter being monitored from the co-pilot's seat.

Article 54

On the basis of the foregoing knowledge-acquisition (articles 50 - 53), it was concluded that aircraft with a payload of 1200lb or 540kg which is that of the Piper Pawnee and between those of the Hiller UH 12E and the Aerospatiale 365, would be able to deal with 10 - 12 tonnes of oil per sortie and to achieve 2 sorties per hour at 10 miles from the loading point; that while a helicopter could have a shorter loading time than a fixed wing aircraft by use of two bucket/spray units, all aircraft would have to refuel every two or three sorties; that such would equate to average hourly performance of a ship equipped with emergency deck-loaded pillow tanks out to fifteen miles from the loading point; that while helicopters do not require an airfield, this advantage is only marginal with small fixed wing aircraft such as the Pawnee; and that while this advantage increasingly lies with the helicopter as aircraft size increased, the cost advantage increasingly lies with the fixed wing.

However, now that the neat application of concentrate dispersant reduces the load-carrying advantage of ships over aircraft, we see that this latter advantage had been maintained by extending the time on site by diluting deck-mounted pillow tanks of concentrate dispersants with on-line delivery of sea water prior to spraying (F. Shuttleworth, J. Nightingale); but that even when internal ship-tanks are available for dispersant carriage, aircraft now had the advantage of more rapid activation/on-scene arrival, and more rapid treatment on arrival than had ships; that these advantages increase with aircraft size while the variable altitude of aircraft greatly increases their slick-finding ability over that of surface-bound ships particularly when the slick has become discontinuous windrows; that aircraft are thus preferable to ships; and that the choice of aircraft numbers/sizes become a matter of comparative cost-effectiveness in terms of capital/running costs, and size/number of dispersant stockpiles at airfields nation-wide.

To avoid the usual belief-counter-belief debate, however, I defined the requirement in general terms, and contractors were invited to tender their proposals and costs. Thus, the need to locate and assess at an altitude of 1000 - 2000 ft and to spray accurately at 10 - 15 ft requires an aircraft sufficiently nimble to position and reposition with the necessary accuracy. However, the requirement is for larger payloads when spraying continuous layers prior to windrow formation. Thus, potential responders were invited to consider mixtures of small and medium-sized aircraft which in combination would be sufficient to apply a minimum of 100 tonnes of dispersant at treatment rates of 10 tonnes per hour and 5 gallons per acre within 25 hours. at a distance of 100miles from replenishment bases or 200 tonnes at 50 miles and *pro rata*, these figures being compliant with the above trial results, with the expectation of a maximum release of 5000 tonnes from damage to a single cargo tank designed to the IMO requirement, and with the expectation of the residual cargo and bunkers being removed, preferably in a safe haven.

Thus, potential contractors were invited to cost an activation time of 30 minutes in daylight hours and 2 hours in darkness for relocation to the forward base for commencement of spraying at first light. Yet again, to avoid responders opting for one large aircraft capable of delivering dispersant at 10 tonnes per hour, they were encouraged to consider smaller aircraft by inviting them to consider a rate of 5 tonnes per hour under the otherwise stated conditions on the reasoning that the quote for smaller aircraft could be doubled for the 10 tonne per hour requirement or if cost-estimates were higher than expected, it might be possible to have at least the 5 tonne option within budget.

Thus, no particular aircraft, number or type was specified and no advantage was expected from mountable/demountable equipment in aircraft deployable on other uses, it being assumed that all aircraft would have to be dedicated to the spraying task because rapidly installable gear would not solve the problem of aircraft being physically absent on another task. Again, with the requirement for operations up to 100 miles from the forward supply bases implying bases at 200 mile intervals, potential responders were invited to cost the provision of tank capacity for one day's supply of dispersant at each base *i.e.* 100 tonnes for the 10 tonne h^{-1} option and 50 tonnes h^{-1} for the 5 tonne option.

Article 55

When the tender responses (article 54) for airborne dispersant spraying were analysed, it was concluded that large aircraft were disproportionately expensive; that the correspondingly smaller affordable number, increased the risk of high percentage loss of capability through mechanical failure; that trial- experience had already shown smaller aircraft to be the more flexible with respect to transition from observational to spraying altitudes while their greater numbers enabled one to observe and guide before or after spraying while another sprayed and yet another returned to reload in this sequence; and that the greater number also allowed for the possible need to spray in more than one location at more than one simultaneous incident. However, with the load-capacity of large aircraft having obvious attraction given the known range of potential incident sizes, it was decided to go for a mixture of small and medium sized fixed wing aircraft. Indeed no helicopter-based tenders were received, their costs being non-competitive with the fixed wing option. Thus, for UK coverage, it was decided to contract for the provision of six Islander and two DC3 aircraft to operate from four main bases with sixteen supplementary bases all of which were to hold a day's supply of dispersant.

Thus with a 5000 tonne release from a single damaged tank and with the likelihood of water ingress reducing this to 2000-3000 tonnes after evaporative loss and some natural dispersion, the spray contract secured a capacity to deliver 10 tonnes per sortie (1 tonne per Islander and 2 tonnes per DC3) which equates to treatment of 200 tonnes of oil per sortie at the oil : dispersant ratio of 1 : 20 as determined by dispersant efficiency testing of neat concentrates on topped Kuwait crude oil while compliance is achieved with the target of dealing with 5000 tonnes of released oil in 25 operational hours assuming that a complete spraying sortie can be achieved in one hour from one or two airstrips 200 miles apart and that two such bases allow flexibility as to whether it is best to apply dispersant close to the location of release or close to the threatened location as the slick moves, evaporates and disperses naturally.

As to multiple-use, one clearly cannot enjoy a half hour response on callout if the aircraft is on an alternate period-contract to a second customer when required for spraying by the first. However, single-customer multipurpose use is problem-free as for example when the spraying aircraft can also be used to detect illegal operational discharges or contravention of traffic separation schemes, with or without remote sensing equipment. Thus, the aircraft contracted to the UK shipping administration for dispersant spraying were also used to monitor shipping discharges and traffic violations with the added advantages of giving pilots their required flying hours and relieving the boredom which would ensue were infrequent spill response-flying the only employment available to them.

As to the act of spraying itself, the trials on dispersant droplet size variation were designed to limit evaporative loss which would increase with decreasing droplet size; to maximise the quantity of dispersant which would fall and not remain suspended in the air which would increase with droplet size; to limit the amount which would pass through the slick which would also increase with droplet size; and to ensure the optimum droplet size to maximise the uniformity/continuity of slick coverage by the proximity and non-overlap of the spots produced by the droplets on arrival on the slick. As to optimising coverage in these ways, a droplet size of 50-100 μm would have been optimal. However, to ensure maximal arrival at the slick and minimal passage through it to the underlying water, the optimal size was found to be 800-1000 μm. Again, while this was consistent with the intention of flying into the wind or at a small angle to it as in spraying wind rows, it was noted that crosswind spraying in areas of continuous coverage could increase encounter rate by increasing the swath width beyond the span of the spray booms with associated adjustment of droplet size and discharge rate being possible.

Thus, the airfield investigations suggested the establishment of two operational modes for thick layer/ narrow windrow emulsions and for thinner layers of fresh oil, with each having its own spray nozzle and discharge rate specification and appropriate flight path with respect to wind direction, with the former requiring the larger droplet size to avoid sidewise drift of airborne droplets without danger of passage through the layer and the latter benefiting from sidewise-drift/wider-swath and the maximal coverage afforded by the smaller droplet size range. However, with dispersants being continuously under international belief-consensual attack, it was decided to leave such refinements for a possible future and introduce knowledge-only operational airborne dispersant spraying while this was still possible in the UK at least. As to dispersant enhancement of biodegradation rates, see article 99.

Dispersant-Effectiveness/Pollutant-Viscosity relationships

Article 56

We have seen in previous articles that natural dispersion removes non-volatile liquid components of oils, water-in-oil emulsions and non-volatile/insoluble/liquid HNS from water surfaces at rates dependent on their viscosities; and that dispersant-induced enhancement of natural dispersion rates decreases to zero for higher viscosities. Now, we review our knowledge of this dispersant limitation, the relevant parameters being wax/asphaltene-content, pour-point/solidification and pollutant-viscosity.

Thus, while individual oil components determine the pour-point temperatures and thus whether oils will be liquid or solid at sea temperature, as does the melting point of individual HNS, the natural dispersion rates of liquid oils/emulsions and insoluble HNS depend on their temperature-dependent viscosities, as does the degree of their dispersant-induced enhancement, unless they are non-dispersible solids. Again, the distillation profile of oils or the specific boiling-points of HNS, determine the extent to which evaporation reduces/precludes the need for dispersants or indeed for mechanical removal. Thus, by denoting the number of carbon atoms in the individual molecules as C_x, we know that petrol/gasoline consists of the C_5 - C_{10} distillation fraction, that kerosene is the C_{10} - C_{12} fraction, that light distillates are the C_{12} - C_{20}, fraction, that heavy distillates are the C_{20} - C_{40} fraction and that residual oils are the fraction above C_{40}; that all HNS with boiling points < 250°C will evaporate as will petrol, kerosene, domestic fuel oil, gas oil and naphtha, leaving no residue at ambient temperatures above 10°C; that for such there is no need for dispersant treatment; and that residual oils and lubricating oils show little or no evaporative loss and are resistant to natural dispersion and to dispersant application.

We also know, however, that the light crude oils such as Ekofisk will lose 30% by weight through evaporation; that their low viscosity water-in-oil emulsions disperse naturally with short half-lives, the Ekofisk value being 10-12 hours; and that these half-lives can be shortened significantly by dispersant treatment, should this be necessary to avoid physical coating of shorelines. As to more viscous examples, we have seen that all liquid oils have been grouped into half-life bands which enable predictions to be made as to their percentage evaporative loss and the half-life persistence of their non-volatile floating slicks; that these groupings had been tabulated by the mid-1980s (articles 39 - 42 and 46); and that further observation could by now have produced more precise groupings and more precise knowledge of the operational relationship between natural half-life and dispersant effectiveness, had responders been more informatively able to use dispersants and to report the results to IMO. As we shall see, the new contingency and incident-specific plans derived from this knowledge repository will enable this predictive precision to be thus enhanced by such reportage (articles 161-162).

As of now, we know that most crude oils have a viscosity measured at 100°F of < 50cSt, and as such are amenable to their emulsion half-lives being reduced by dispersant treatment. As to the dispersant-amenability of these water-in-oil emulsions, the limiting viscosity at sea temperature appears to be in the region of 7500cSt (corresponding to 300cSt at the reference temperature of 100°F) assuming that attempts are made to disperse emulsions down to seawater temperatures of 0°C. Correspondingly, if the lowest seawater temperature under consideration is 10°C or 20°C then the upper viscosity limit for dispersant-amenability is respectively 700cSt, or 1500cSt as measured at 100°F. Thus, dispersant application should be effective with most crude oils and their emulsions, provided the viscosity of the latter does not exceed the above limits as measured at the seawater temperature of individual incidents as interpolated on viscosity/temperature graphs, and provided this is not too much to expect of those who operate on the basis of current so-called contingency plans (articles 47 - 49, 57 -58 and 156 - 162).

Article 57

Further to article 56, we know that dispersants will fail when high pour points and high viscosities combine against them. Thus, Boscan crude oil with viscosity of 18,000cSt at the reference temperature of 100°F and pour point of 60°F is solid at sea temperatures < 60°F (15°C). Thus, whatever its viscosity might be at ambient temperatures > 15°C it will remain non-amenable to dispersant treatment, while Bacquero medium and heavy crude oils with viscosities 1478cSt and 3700cSt at 100°F and pour points -5°F and 0°F respectively, are liquid at seawater temperatures but non-amenable to dispersant treatment because of their high viscosities. Again, while Nigerian light crude has a viscosity of 4cSt and would be amenable to dispersants, its pour point of 60°F (15°C) ensures it will not be dispersible below this temperature and will be resistant to dispersion above it. Similarly, San Joaquim crude oil with an amenable viscosity of 34cSt as measured at 100°F would not naturally disperse or be dispersible because its pour point is 75°F (22°C). However, while such data have long been tabulated for easy reference, the question as to whether a crude oil will be non-dispersible/dispersible can be answered by ascertaining whether or not it is heated above ambient in transit and/or requires a further 10°F rise in temperature for discharge. Indeed, cessation of heating will effectively solidify such cargoes within an incident-damaged tank. Thus, the pour-point/viscosity question is neatly resolved by one parameter, the cargo operating temperature as is consistent with the following tabulation of non-dispersible crude oils.

Name	Loading Port	Country	Viscosity SU at 100°F	Pour point °F	Temp. Voyage °F	Temp. Discharge °F
Amna	Ras Lanuf	Libya	74	65	85	95
Bacquero medium	La Salina	Venezuela	1478	-5	1535	135
Bacquero heavy			3700	0	135	135
Bahia	Salvador	Brazil	90	100	120	130
Bakr	Ras Gharib	Eygypt	750	45	75	85
Belayans Land	Wadi Feiran		439	40	60	70
Belayans Marine			68	60	80	90
Boscan	Baho Grande	Venezuela	90000	60	165	175
Cabinda	SPMB-Landana	Angola	106	80	100	110
Cyrus	Kharg Island	Iran	1285	0	115	125
Duri	Dumai	Sumatra	600	35	80	90
El Morgan	Shakeer	Egypt	59	45	65	75
Eocene	Mina Abdulla	Kuwait	786	-30	80	90

Gamba	SPNG-Gamba	Gabon	163	60	80	90
Gippsland Mix	Western Port Bay	Australia	33	60	80	90
Hoy Lake Mix	La Salina	Venezuela	3000	10	135	135
Legunillas			1200	-5	80	90
Mercy	Puerta la Cruz		1270	-10	80	90
Nigerian Light	Bonny	Nigeria	38	60	80	90
Panuco	Tampico	Mexico	22000	35	140	150
Pilow	Carpito	Venezuela	9000	25	130	140
Quiriquie			760	-20	60	70
Ras Lanuf	Ras Lanuf	Libya	44	45	65	75
Rio Zalia	Santa Maria	Columbia	42	80	100	110
San Joaquim	Puerta La Cruz	Venezuela	34	75	95	105
Santa Rosa			30	50	70	80
Sarir	Marsa El Hariga	Libya	61	70	90	100
Seria	Lutarg	Sarawak	34	65	85	95
Tia Juana heavy	La Salina	Venezuela	1040	-35	80	90
Zeta North	Puerta la Cruz		42	70	90	100

Thus, for contingency planning purposes it is possible to know which crude oils cannot effectively be dispersed. At this point, it should be noted that viscosities may be quoted in units of Saybrook Universal seconds, Engler Specific degrees, Admiralty Redwood seconds, centiStokes, seconds Redwood No 1, *etc*, conversion scales and temperature dependency plots being readily available.

Article 58

Having noted that the upper viscosity limit for effective dispersant use on crude oil emulsions is 7500cSt at the seawater temperature of application, we can now see that this equates to effective dispersion for viscosities of 300cSt, 700cSt and 1500cSt (measured at the standard 100°F) for effective dispersion at respective seawater temperatures of 0°, 10°, and 20°C with pollutant viscosity being measurable directly at incidents. Thus, while it is difficult to predict the rate at which viscosity increases to its maximum value for any given water-in-oil emulsion, viscosity values can easily be measured and spraying can easily be stopped accordingly. In addition, we already know that oil distillates (product oils) with viscosities up to 350cSt at 100°F will either evaporate or disperse without recourse to dispersants. However, it is also known that fuel oils and lubricants of viscosity > 600cSt at ambient temperatures are generally heated to a working viscosity of 600cSt and it has been found that fuel oils and their emulsions have a dispersible limit of 5000cSt at sea water temperature probably because they lack the natural surfactants of crude oils and have higher viscosities and surface tensions which tend to permit greater layer thicknesses than do the more freely flowing/spreading crude oils, these thicker layers being disadvantageous to dispersants applied at rates commensurate with the thinner layers of crude oil for which Phase II spreading is limited by viscosity.

Thus, a limit of 5000cSt at a sea temperature of 0°C equates to a measured viscosity of 200cSt at the reference temperature of 100°F, oils of this viscosity being therefore dispersible down to sea temperatures of 0°C, while those measuring 300 and 1100cSt at the reference temperature of 100°F will be dispersible down to sea temperatures of 10°C and 20°C respectively. Indeed, even a 200cSt oil would probably be heated in transit if the ambient temperature was below 70°F and for all practical purposes it can be assumed that 500cSt and 1100cSt oils would also be heated. Thus, all heated oils whether crude or product should be treated with suspicion with regard to dispersant efficacy and all incidents involving such oils should be treated as trials/experiments for new knowledge-acquisition in these respects, while those of greater volatility and lower viscosities can be sprayed with confidence where required, or left to natural evaporation and natural dispersion (articles 156 - 162).

Again, lubricant base-stocks containing no surfactants appear to be dispersible up to viscosities of only 2000cSt at sea temperatures, these producing thicker layers than the fuel oils discussed above, even to the extent of lens formation, this limit of 2000cSt at sea temperature equating to a viscosity limit as measured at the 100°F reference temperature of only 110cSt, 250cSt and 600cSt if dispersants are to work down to sea temperatures of 0°, 10°, and 20°C respectively, with all incidents involving such oils being treated as trials/experiments for further knowledge-acquisition. Thus, these as yet tentative conclusions, are tabulated below in a manner indicative of viscosity/dispersant-efficiency relationships.

	Limiting	Sea	Viscosity measured at 100F					
Oil Type	Viscosity	temp	Centi-Stokes	Redwood	Admiralty	Engler	Engler	Saybrook
	CSt	C	cSt	No1	Redwood	seconds	degrees	seconds
Crude	7500	0	300	1200	120	2000	40	1500
		10	700	2800	280	5000	75	3100
		20	1500	6000	600	10000	200	6500
Fuel	5000	0	200	800	80	1400	28	950
		10	500	2000	200	3500	70	2300
		20	1100	4500	450	8000	160	5000
Lubricant	2000	0	110	450	45	750	15	550
		10	250	1000	100	1600	35	1200
		20	600	2400	240	4400	85	2900

Article 59

Following the contracting of permanently equipped fixed-wing dispersant-spraying aircraft in 1982, the UK Marine Pollution Control Unit (MPCU) conducted a sea trial in collaboration with Warren Spring Laboratory (WSL) and ESSO Petroleum (Exxon Corporation) to further evaluate the operational effectiveness of aerial dispersant treatment of oil slicks. This trial was based on three 20 tonne releases of Arabian Light crude oil, the first as an untreated control, the second and third for treatment with 2 tonnes of dispersant after 3 and 6 hours respective exposure on the sea surface, the intention having been to estimate dispersant effectiveness by direct observation and photographic recording, by infra red line scanning (articles 63 - 68), and by subsequent analysis of the oil-content of underlying water samples while sampling the slicks themselves for analysis as to layer thickness, evaporative loss and water-in-oil emulsion formation.

Of course, while some enthusiasts for dispersant treatment would have expected surface slicks to be removed to the water column ‘before their eyes as if by magic’, and while others opposed to such trials let alone operational dispersant use, would have expected ecological disaster in the associated body of water, yet others already knew that even such detailed monitoring of the dispersant-process would give only an estimate of its enhancement of natural dispersion. Thus, this third group already knew that Phase II spreading thicknesses were within the order of magnitude of 0.1mm; that the natural and dispersant-induced oil droplets beneath dispersing slicks were either large enough to rise to re-coalescence with the slick and thus to amount to a variable but significant proportion of the sub-surface oil collectable for analysis while that present as droplets small enough to dilute by diffusion to greater depths in the water column would be less detectable by these means; that even the fastest naturally dispersing slicks take seven half-lives to reduce to ~1% of the original amount; that dispersants are intended to shorten natural half-lives to extents decreasing with increase in pollutant viscosity; and that all half-life periods whether natural or dispersant-induced are subject to the available levels of wind-induced wave-energy.

However, having decided to proceed with this trial despite the very calm conditions then prevailing, it had to be concluded that knowledge had not been taken much further than the above, though it did suggest that such small releases might be so thin in places as to permit dispersant droplets to pass through the pollutant layer without enhancing dispersion rate. Thus, one consequence of this trial was a decision to design a higher delivery rate system more appropriate for the higher layer thicknesses of larger releases closer to source, though such never reached operational implementation, while the second was to investigate the viscosity-based limitations on dispersant effectiveness under otherwise optimised conditions. However, as to spraying close to source, it must be recognised that this leaves insufficient time for significant natural dispersion; and that it is thus better to spray slicks closer to shore having thus maximally benefited from natural dispersion during the intervening transit time.

Possibilities for Future Dispersant Formulations

Article 60

As to establishing an optimised reference against which to evaluate the comparative effectiveness of different operational means of dispersant application WSL (N. Hurford) decided to pre-mix oil and dispersant prior to release in a sea trial. To this end, the early method (articles 47 - 48) of discharging oil from *Seaspring* at known rates and known ship speeds to form a carpet of oil of known thickness, was modified in order to pre-mix dispersant with the oil in different ratios, to use oils of different viscosities, and to vary the water-contents of their emulsions. In addition, it was decided to avoid the evaporative loss from crude oils, by using fuel oil blends to achieve differing viscosity values across the spectrum of interest, WSL having already used such fuel oil blends to evaluate dispersant effectiveness in a wave-generating tank and to compare the results obtained from a flow-through and a closed fluorimeter with those obtained from grab-sampling and subsequent analysis, with the intention of towing the chosen instrument at predetermined depths beneath and behind the dispersing carpet in subsequent investigations at sea.

However, after comparative evaluation had shown a short wavelength pump-through Fluorimeter connected to an onboard chart-recorder or data-logger to be optimally suitable for the above purposes, it was found that even soluble rhodamine dye, diluting from the sea surface, produced a spatially variable output; and that calibration with analytically known oil-contents (in the form of droplets) gave results no better than to within a factor of two. Nonetheless, such an arrangement was expected to differentiate the results for premixed oil and dispersant from those of post-release addition, and to indicate the proportion of oil in the smallest droplet size range by exhibiting greater uniformity of results with increasing depths below the dispersing trial slicks .

Using the ship borne apparatus described in article 59, it was shown that when the dispersant Corexit 9527 was premixed in the ratio of 1:20 with fuel oil blends in the viscosity range 40-4000mPa, the slicks were totally transferred from carpets to the water column within 10-30 minutes to produce average oil concentrations in the range 5 - 6ppm at 0.5 metre depth and 2.5ppm at 2metre depth. Again, when the premix ratios were set at 1:20, 1:40 and 1:100 with oil blends of viscosities 54, 1,950 and 13,0690mPa, it was found that all of these blends were dispersed at 1:20, while at 1:40 only the lowest viscosity blend was dispersed with little observed effect at either of the higher viscosities, and that at 1:100 even the lowest viscosity blend remained more or less unaffected. However, for dispersion at the premix ratio of 1:20 the fluorimeter results showed a spread in concentration of 1-10ppm at 1 metre depth and 0.1-2.0ppm at 3.00 metres.

In contrast, when oil blends were discharged prior to dispersant application in the standard manner (article 48), it was estimated that about 80% of a carpet of 0.2-0.4 mm thickness was transferred to the water column for a viscosity blend of 50mPa, almost irrespective of the above application ratios to produce oil concentrations of 3-5ppm at 1 m depth and 2ppm at 2m depth. In addition, when a carpet 1km long, 5m wide and 0.1 mm thick was sprayed by two passes of one of the Islander aircraft, the IR/UV imagery obtained (articles 63-68) showed a less well defined carpet and subsurface concentrations of 0.3-0.5ppm which is an order of magnitude less than for the above results while the layer thickness was less than that of the above by up to a factor of 4, there being correspondingly less oil to disperse per unit area.

Thus, it is clear that dispersants can disperse oils, though they are not as effective when applied post-release as they are when premixed; that ratios more dilute than 1:20 are unlikely to be effective in practice since the 1:40 ratio was only effective for the low oil viscosity of 54mPa with premixing; that the premixing at the ratio of 1:20 is effective up to viscosities of at least 13,000mPa; that existing spraying techniques are operational from both ships and aircraft; that ship spraying onto slick thicknesses of 0.2-0.4mm appeared to be more effective than aircraft spraying onto a thickness of 0.1mm. As to agitation energy requirements, it should be noted that for the above ship and aircraft spraying investigations, wind speeds were 6.5 -7.5 m/s and 11 m/s respectively which may account for some of the observed differences in overall efficiency.

On the other hand, this difference could be due to dispersant droplets passing through the thinner slicks without dispersion, thus pointing again to the possibility of gaining greater efficiency by spraying thicker layers closer to source by aircraft which could be on scene quicker than ships and more capable of observing the overall task from their variable altitude, though as noted above this anticipates the natural dispersion which prevents much of the release from reaching shore in any case. Further to this question of layer thickness, WSL has also shown that stranded water-in-oil emulsions up to 4-6mm in layer thickness have been dispersed by application of dispersants at the ratio of 1 : 20, prior to subsequent agitation by incoming surf. It should be noted for future reference, that this shoreline technique might be considered more akin to premixing than to post-release application to slicks floating on water, in that dispersants may penetrate stranded pollutants in the interval between application and surf arrival (articles 94 - 95).

Recognition that dispersants cannot deal with high viscosity water-in-oil emulsions prompted WSL (N. Hurford) to investigate the possibility of breaking floating emulsions by demulsifier application. It will be recalled, however, that emulsion breakers tend to be emulsion-specific and are usually pressure-injected into online static mixers in a manner quite inapplicable to demulsifier or dispersant addition to floating water-in-oil emulsions. Again, even though demulsifiers have been shown to prevent emulsion formation, it is hardly to be supposed that they would be applied to oil slicks prior to emulsification when it is difficult enough to apply dispersants in this way. Yet again, with demulsifier : emulsion ratios being orders of magnitude less than are dispersant : oil ratios, it is difficult to see how uniform distribution of demulsifiers over the surface of slicks in the manner achieved with dispersants and by control of their droplet size. No doubt advances in demulsifier formulation would be useful in the processing of mechanically removed emulsions, but it is difficult to see how it could compensate for current deficiencies in dispersant formulations which themselves might be rectified were attempts to do so not precluded by current environmentalist belief in species-extinction/ecological disaster.

Article 61

Further to article 60, surfactants should be developed and formulations improved for extending the effectiveness of dispersants to higher emulsion viscosities and to lower wave-induced energy requirements. As to breaking mechanically removed emulsions, the need is less: they can always be broken by heat, though wider-spectrum products could be helpful. Again, development of dispersants applicable to a wider range of emulsion viscosities by improving their pollutant-mixing qualities would be helpful, uniformity of mixing, retention by the oil phase, and droplet size, being dependent on the choice of surfactant-carrier, while with demulsifiers, uniformity of mixing is normally achieved by pressurised static mixers and is thus independent of the nature of the carrier, if any.

In the early days, the surfactant carrier in dispersant formulation was hydrocarbon-based no doubt to render the formulation more oil- than water-compatible on initial contact, while permitting the surfactant to stabilise the subsequently created oil droplets against immediate re-coalesce with the oil phase and to promote their dispersion/dilution/biodegradation in the water column. Later when concentrate dispersants became available for use with on-site water as a carrier to maintain the necessary uniform distribution of droplets over the upper surface of slicks, these new formulations had to be more compatible with water than with oil on initial contact (articles 22 - 30). Later when applied without the water-carrier as in aircraft spraying, the necessary uniformity of droplet distribution on slick surfaces had to be secured through attention to the relationship nozzle design and droplet size and surface distribution on surface contact (article 51). However, the HLB (article 29) most suited to dilution with water may be detrimental to dispersion of oil and emulsion, such water compatibility being unnecessary for undiluted application from aircraft, while a hydrocarbon carrier would be beneficial in extending dispersant amenability to higher viscosity oils and their emulsions (articles 22 - 30).

Again, formulators could reconsider the breaking of removed emulsions in terms of continuous-phase inversion. Thus, we know that the presence of a demulsifier can decrease the fractional water content, ϕ_w of an emulsion (article 23) without actually breaking it, which in turn increases the fractional oil content, ϕ_o and reduces the viscosity eventually to the point of continuous phase separation as marked by an associated step-change in specific conductivity from which point the continuous oil phase might be inverted to the dispersed oil phase within the continuous water phase, though the usual outcome is the two phases of emulsion breakage. Indeed, solar energy can thus reduce the fractional water content of emulsified slicks, to an oil phase which can both disperse into the sea as oil droplets or reform the emulsion by re-uptake of water droplets as the temperature falls.

Thus, we see the interactive nature of dispersant/demulsifier formulation, the search being for surfactants which will replace the natural water-droplet/oil emulsifiers with the demulsifiers/dispersants which will stabilise the oil-droplet/water interface, *i.e.* to replace the asphalteness, wax crystals and oxidised derivatives of other oil components which stabilise the former with new surfactants which will stabilise the latter more effectively than those currently available. A second objective would be to ensure that stabilisation by bi-wetted interfacial solids, is replaced by surfactants wetted either by oil or water but not by both. In the meantime, those who advocate the application of demulsifiers to floating slicks would presumably use dispersants until emulsification defeated them, whereupon they would use demulsifiers until they could revert to dispersants and so on, though such would require the monitoring of water-content/viscosity values not so far undertaken to monitor dispersant spraying itself. This approach is not recommended operationally, though dispersion/emulsification relationships could be useful in guiding the formulation of future dispersants.

As to further work on the mechanism of dispersion and on the formulation of dispersants, it is recommended that the ship-mounted investigative equipment described in article 60 could produce a carpet of oil premixed with the dispersant formulation on test for resulting subsurface concentrations of dispersed oil to be measured at specific time intervals as arranged by mooring the ship in a tidal steam and measuring the concentrations with, for example, a flow-through fluorimeter maintained at differing known distances downstream of the moored ship. Thus, for example at a distance of 450 metres downstream of the carpet-production, a tidal stream of 0.5m/s would provide data after a time interval of 15 minutes and *pro rata*. Again, if droplet size measurements could also be made, it would be possible to distinguish between droplets large enough to be migrating upwards to re-coalescence as a slick from those small enough to remain dispersed for slicks either premixed or untreated. Of course, such efforts towards knowledge-based progress depend on environmentalists and their regulatory fellow-travellers accepting formulation-components which their beliefs currently oppose. As to the choice of hydrophilic/hydrophobic surfactants and carriers, see articles 22 - 30.

Remote-Sensing and Identification-Sampling

Article 62

It has been repeatedly noted that discontinuous oil slicks are difficult to observe at sea level or even from the bridge of a proximate ship. Though this would be relatively unimportant for response were the sea surface continuously and extensively covered with pollutant, we know that continuous slicks are eventually broken into windrows and other isolated rafts of emulsion; and that ships cannot always achieve their maximum encounter rates for dispersant-application or mechanical-removal. Indeed we have already referred to our need for aircraft in surveillance-mode to make good the observational deficiencies of those in the lower altitude spraying-mode (article 55).

However, while many an area of cloud shadow, sediment disturbance, floating seaweed, submerged sandbank or similar anomaly has been reported as oil by well-meaning aerial observers in commercial transit, and while many a so-called expert has found employment in attempting to distinguish between oil and this or that anomaly, there has never been any doubt that a remote instrumental technique for identification of oil as oil, would be helpful; and that it would be even more helpful were such instrumentation to differentiate ranges of thickness for oil layers as this would be of immediate assistance in deploying response resources to areas of maximum encounter-rate. Again, as to the policing of illegal operational discharges, it would be helpful were such instrumentation to go some way towards identifying oil and possibly oil-type without the collection of samples from the sea surface.

As to operational discharges, however, we know that these are small in comparison with casualty-related releases; and that resurfacing droplets of oil in oily water discharges through ship-board oil-water separators are likely to coalesce to Phase III areas of coloured sheen. Indeed, unless such discharges contain heavy fuel oil, it is difficult to see how sheens of less viscous oils could fail to evaporate or to form secondary dispersion droplets very quickly under normal wave action. However, since re-coalesced droplets from the discharge-points of land-based API separators also formed coloured sheens, the API Manual on Disposal of Refinery Wastes (1969, corroborated by Hornstein (1973), tabulated their colour, thickness and volume per unit area as follows:

Colour	Approximate Thickness μm	Approximate Volume/Area m^3/km^2
Silver/transparent	0.02-0.05	0.02-0.05
Grey	0.1	0.1
Rainbow	0.3	0.3
Blue	1.0	0.1
Blue/Brown	5.0	5.0
Brown	15.0	15.0
Black	20.0	20.0
Dark Brown/Black	0.1mm	100.0

Thus, while colour differentiation can indicate differing layer thicknesses, these sheens are too thin to require active dispersion or mechanical removal and thus provide no guidance towards maximising encounter rates for the layer thicknesses deemed to require dispersant treatment and/or mechanical removal at sea. Again, recognising that some operational discharges may be deliberate and involve larger quantities of more viscous oil, attempts were made to collect samples from sea and shore surfaces and to subject them to comparative analysis with tank contents of suspect ships to establish the source in terms acceptable to a law-court. However, while it has been argued that similarity in analytical results identifies a slick sample as having come from a suspect ship, it can also be argued that it only identifies a bunkering station common to many ships.

In the 1970s, there was thus scope for improving our ability remotely to detect areas of casualty-released oil, thick enough to merit dispersant treatment or mechanical removal, while remote identification and attribution of the more significant and perhaps deliberate operational discharges remained a secondary possibility. Thus, progress in remote sensing in the latter half of the 1970s by WSL (H. Parker) is reviewed in articles 63 - 68, with sampling being reviewed in article 69.

Article 63

In principle, all bodies including released oil may be detected by the radiation which they emit at various wavelengths depending on their absolute temperature and emissivity, the latter being their emission-efficiency at a given temperature. Detectors which pick up this radiation are said to act in the passive mode unless they emit radiation which they detect as a return signal, echo or back-scatter from the body to be detected, in which case they are said to be in the active mode. The radiations of interest in oil spill detection are in order of increasing wavelength, those of the ultraviolet, visible, infrared and microwave frequency bands of the electromagnetic spectrum.

At the outset, it was known that the ultraviolet band, in contrast to those of the visible and infrared, had the ability to distinguish oil from other anomalous features such as kelp beds in the passive mode; and that in the active mode, ultraviolet laser fluorescence had been considered as a possible means of differentiating oil types and for detecting subsurface floating layers. Again, the visible band had been used for oil detection and ship identification by the human eye and by photographic and television cameras, while optical colour differentiation was useful in differentiating layer thickness at the Phase III spreading stage (above Table) and while, on the basis of a light beam from a lead (Pb) laser, we already had active gated low light level (LLL)TV. Yet again, oil could be detected by infrared and ultraviolet line scanners (IR/UVLS) with the possibility of the former being able to differentiate thickness by temperature differentiation, though it would respond to any cause of temperature variation. In addition, in the microwave region we had active side-looking airborne radar (SLAR), potentially capable of indicating the area of slicks by their suppression of the capillary waves which otherwise produce ‘wave-clutter’; synthetic aperture radar for possible use from satellites; and passive microwave radiometry, already under consideration for layer thickness differentiation. Further to this review of the early 1970s we could note that microwave techniques could operate day and night and independent of atmospheric conditions while infrared techniques are limited by water vapour in the form of mist and cloud.

Thus. as to possible sensor combinations, we could see at WSL that such could include a human observer, photographic cameras, LLLTV, UVLS, visible line scanners (VLS), IRLS and SLAR, while as to human observers, there was some scope for selection of eyeglass filters to enhance contrast between oil and sea. As to SLAR we recognised that radars are optimally designed for the detection of solid targets for which purpose sea wave ‘clutter’ is instrumentally suppressed, whereas we wanted to detect clutter for maximal contrast with its oil-induced absence, and it appeared that this contrast might be enhanced by changes in wavelength and polarisation. Thus, at this early stage, we concentrated on investigating IR/UVLS and SLAR while awaiting further developments elsewhere in laser fluorescence, passive microwave radiometry and laser activated TV. As to satellites, we concluded that our primary purpose, of differentiating pollutant layer-thicknesses for optimised encounter rates in spill response, would best be achieved by the aircraft soon to be involved in dispersant spraying; and that we could leave others to advance the cause of satellites while recognising their role in weather forecasting and communications, some applications of which would automatically assist in data transfer from surveillance aircraft and in processing and analysis at operational centres without our needing to contribute directly.

As to our selected activity areas in the UV, visible and IR frequency bands, we noted that apart from the surface reflected radiance in which we were interested, the sensor also collects a background radiance which consists of a volume reflected component and a path component scattered by the atmosphere between the source and the sensor, the latter tending to dominance with increasing altitude. Again, we noted that the sources of the reflected radiance are the sky radiance which is reflected as the surface component and the so-called global radiance which is the sum of the sky and the Sun radiances received by the sensor as the aforementioned volume and path radiances; that an increase in the background radiances reduces reflected contrast which is also affected by cloud cover; and that calculation of surface reflectance for known values of refractive indices for typical crude oils suggested that surface radiance increases with decrease in wavelength. Again, we noted that the volume-reflected radiance for water has a maximum in the 450-650nm range comparable to the surface-reflected radiance component which reduces contrast below expectation on the basis of surface radiance alone; and that oils absorb in the UV/blue-green range, making optically thick layers appear darker despite the increased surface reflectance at these low wavelengths, thus offsetting expected gains in contrast as does the path radiance component of the unwanted background which also increases towards the UV/blue end of the spectrum.

However, despite the above, contrast can be increased by noting that the surface reflected radiance is linearly polarised to an extent dependent on the angle of incidence. Thus at 53° from the vertical, the Brewster angle for water, the light is completely polarised parallel to the water surface while the path radiance component is less than 20% horizontal and the volume reflected component is vertically polarised to a small extent, so that viewing at or near to the Brewster angle and receiving the radiation through a polariser set to transmit the horizontal component would increase contrast.

Article 64

Having reviewed the theory underlying remote sensing as in article 63, the following articles on this subject will review our knowledge-acquisition on the performance of remote sensing equipment in respect of its ability to discriminate slick thickness and thus increase the efficiency of response to casualty-releases from ships and oil-wells; and in respect of its less likely ability to attribute operational oil releases to individual ships and oil-wells.

Thermal (IR) radiance sensors detect apparent temperature from the physical or ‘real’ temperature and the thermal emissive of the source, the presence of an oil slick being thus able to change both of these parameters with respect to those of water by:

-the oil layer absorbing solar radiation to become warmer than the underlying/surrounding sea;
-oil close to the point of release retaining heat and thus being warmer than the sea;
-evaporation of volatile components having a cooling effect on the oil relative to the sea;
-oil reducing the evaporation of water to produce a warming relative to the evaporating sea;
-oil restricting heat transfer between atmosphere and sea to make the sea under the oil cooler in warm weather and warmer in cooler weather than it would otherwise be;
-oil becoming warmer by wind-induced viscous drag relative to the sea.

From the above possibilities, we see that oil slicks could be warmer or cooler than the sea depending on a variety of individual processes having conflicting consequences. However, on the basis of comparative emissivity (efficiency as a thermal radiator) we know that oil should appear cooler than water when both are at the same temperature, the emissivity of oil being 0.02-0.05 less than water which corresponds to an apparent temperature difference of 1-3°K

Accordingly, some tank tests were conducted under contract to WSL (H. Parker) at the University of Lancaster to investigate possible mechanisms to explain observed differences in physical temperature between oil slicks and the underlying and surrounding water, thermocouples having been located in the oil and in the water immediately below its surface at 1mm depth and in the bulk water at 3cm depth, while control tanks containing only water were thus equipped with thermocouples. In all layers from 1mm - 6mm, the oil attained a temperature higher than the water. However, when the atmospheric relative humidity RH was changed from 10% to 65%, the temperature difference ΔT_1 between oil and water decreased as did the temperature ΔT_2 between the bulk and surface water, these results suggesting that the temperature difference of interest ΔT_1 was caused by prevention of water evaporation from beneath the oil layer.

Wind tunnel experiments were carried out at wind speeds across the tank surface of 1 - 10 ms^{-1} and it was observed with air temperatures above those of the tank contents, that ΔT_1 increased with increase in wind speed and that this effect increased sharply at the transition from laminar to turbulent flow which occurred from $4ms^{-1}$ upwards, this situation simulating warm summer conditions with respect to the differential air and sea temperatures. However, even in simulated winter conditions in which the air temperatures were lower than those of the tank contents, the ΔT_1 results were qualitatively the same. This simulated winter regime was achieved by heating the tank contents above the air temperature, switching off the heaters and allowing convection stabilisation before measuring ΔT_1. These results suggest that oil slicks can be heated by viscous dissipation of wind energy; and that this is most effective at speeds above those of laminar flow.

Thus, termination of seawater evaporation and viscous dissipation of wind energy may be expected to result in oil slicks having higher physical temperature than those of the surrounding and underlying water both in winter and summer which despite the emissivity of oil being less than that of water, and thus should ensure an observable contrast when attempting to detect oil spills by thermal (IR) means. However, these results do not permit us to conclude that the effect of oil's lower emissivity can always be overridden by the above or other warming mechanisms. Again, though the Lancaster workers claimed to have confirmed their experimental results by replicating them with a mathematical model, readers will recall (article 45) that experimentation confirms mathematical models, while mathematical models do not confirm the experiments on which they are based, and do nothing at all when not based on experimentation (articles 43 - 46). The extent to which mathematical modellers misunderstand the nature of their own models clearly extends beyond those who model anthropogenic global warming.

Article 65

While WSL was investigating the potential of remote sensing to estimate area and thickness of oil slicks, others were already operating commercially available equipment in aircraft. Thus Canadian and US workers were using the Daedalus 1230 dual-channel line scanner system consisting of a UV detector sensitive to the 270-370nm spectral band and a thermal IR for the 850-1250 band; and the Daedalus 1260 multi-spectral scanner in which the near-UV to near-IR region from 380-1100 was divided into 10 channels in addition to the thermal IR detector of the 1230 model.

When these systems were used to observe test releases of Murban and La Rosa crude oils, the thermal IR detector distinguished slick regions which were warmer (brighter) than the sea from regions which were apparently cooler (darker) than the sea, suggesting that mechanisms other than the two out of six investigated by WSL/Lancaster (article 64) were involved. These effects were stable over a period of 3 hours and thus could not be attributed to different oil source temperatures, while the effect of evaporation could be discounted. Thus, the cool region was attributed to oil having a lower emissivity than water and the warm region to solar heating of the optically thicker layers. As to the visible and near-IR regions of the multi-spectral scanner, it was found that the detection thickness threshold increased with frequency as expected; that thick layers are detected primarily by volume-reflected radiance; that consequently detection would depend on oil type and extent of water-in-oil emulsion formation; and that highly absorptive oils would be less easily seen, while the more highly scattering emulsions would increase the volume-reflected radiance making them more easily seen. As to the UV imagery, it was found that the dual-channel unit gave better contrast for the thin regions of the slick than did the multi-scanner unit, mainly because of its lower noise equivalent radiance value; and that variation in detector sensitivity, noise levels, *etc*., would make results detector-specific to some extent.
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In addition, microwave sensors were available with wavelengths from 0.1 to 100cm which could operate in the passive mode to detect differences in brightness temperature between oil and water at a given wavelength, or in active mode as radars emitting and receiving differential back-scatter from sea or oil surfaces. As to passive

microwave radiometry, calculations of oil brightness over water brightness predict alternating maxima and minima as the oil slick thickness increases, though use of two frequencies removes ambiguities and determines thickness uniquely over a wide range. Thus, three floating oils were separately set up at known thicknesses in test tanks, antenna temperatures were measured, and from the alternating maximal and minimal response to thickness variation, complex dielectric constants were determined for the three oils. These oils were then the subject of sea trials in which independently measured layer thicknesses were compared with thicknesses derived from microwave antenna temperatures at 19.4 and 31.1GHz. Thereafter, in a release of 630 gallons of oil in a one metre swell and winds of 2-4ms, *in situ* thickness measurements showed the oil to be 2.4 ± 0.3mm thick within a central zone containing 90% of it surrounded by oil at a thickness of 2-4μm while repeated aircraft passes built up a two-dimensional antenna temperature contour map of the whole slick which was subsequently converted to thickness contours, though the contour intervals were too close to be confirmed by *in situ* measurements.

As to active radar, waves at sea are either gravity waves of long wavelength and large amplitude or small capillary waves, the latter being the first to be produced as wind speed increases from zero and which are ultimately superimposed on the larger gravity waves. Imaging radars detect capillary waves and only detect gravity waves by detecting the increased concentration of capillary waves on their downwind faces thus imposing a periodicity in the backscatter image which varies with viewing direction with respect to wind direction. Thus, imaging radars only see oil slicks because they suppress capillary waves which means they will see them when capillary waves are to be seen on the surrounding sea and this in turn requires wind speeds from 1-1.5 ms^{-1} to saturation at 15-20ms^{-1}.

However, for radars intended to detect solid objects, this so-called sea-clutter is instrumentally suppressed, thus reducing the ability of such radars to detect oil spills. Nonetheless, the greater resolution of synthetic aperture radars make oil spills easier to see than with lower resolution real aperture equipment, an advantage demonstrated over real oil spills off Toulon using X-band radars while oil spills off New Jersey have shown that the X-band SAR is superior to the longer wavelength L-band. Again, use of an instrument able to transmit vertically and horizontally polarised microwaves and to receive either like- or cross-polarised returns, has shown that for incidence angles appropriate to aircraft mounting, vertical-vertical polarisation is preferable in giving the strongest back-scatter while for higher altitude satellites, either like-like mode would be satisfactory.

Article 66

In light of the above, WSL arranged to measure slick thicknesses of trial slicks of Kuwait crude oil and a 40% water-content Ekofisk emulsion, for comparison with images obtained by an IR line scanner (IRLS) in the 800-1400nm spectral band and a 50kw 8.5 mm horizontally polarised Q- and H-band side-looking airborne radar (SLAR) operated from an aircraft of the Royal Signals and Radar Establishment (RSRE). Layer thickness was measured by the WSL method of absorbing the pollutant onto a 200 x 200 x 8 mm pad attached to a backing plate and handle by lightly contacting the pad with the surface layer for subsequent extraction with chloroform and spectrometric analysis, while emulsion water-contents were determined by the Dean and Stark method. The quantity of oil on the slick area of 200 x 200mm corrected for water content gave the actual thickness of the oil and water-in-oil emulsion for that particular area while a Decca 'Navigator' on the sampling boat located the position of each individual sampling point within the slick. The efficiency of pad absorption as measured in the laboratory was found to vary with thickness and on this basis correction factors were applied which gave an accuracy of ± 50%.

The above approach gave the following summarised results after a two day programme flying at different altitudes and at different time intervals after the oil and emulsion discharges:

- both the Q and H polarised SLAR and the IRLS detected oil and emulsion;
- the IRLS provided high contrast easily interpretable imagery;
- the SLAR provided uniform low contrast imagery out to the lowest thickness;
- the UVLS provided uniform low contrast with a higher threshold thickness within the uniform SLAR image, while the IRLS provided thickness contrast within the UV image;
- the IRLS showed regions brighter (warmer) and darker (cooler) than the surrounding water;
- the Decca positioning showed these regions to be respectively thicker and thinner;
- the Decca positioning showed the threshold thickness for the darker (cooler) IRLS image to be of the order of 10μm (probably 25-50μm) that of the brighter (warmer) IRLS image to be inclusive of Phase II thicknesses of the order of 0.1mm, that for UVLS to be of the order of 0.1μm (naked-eye, 0.02-0.05μm), and that of the SLAR to be of the order of 100nm;
- adoption of 1000μm (1mm) for the thickness of the warmer regions and of 100μm (0.1mm) for the cooler and multiplying by their respective areas gave agreement with the total amount known to be present to within an order of magnitude;
- the actual amount present divided by the area as measured by the SLAR gave an overall mean thickness of 15-20μm (Table in article 62).

Thus, it can be concluded that while the SLAR technique can detect pollutant slicks and determine their overall area out to Phase III edge thicknesses down to the order of magnitude of 100nm, it cannot differentiate thicknesses within it; that while the UVLS has a thickness threshold of detection of the order of 0.1µm and while the IRLS technique can identify the warmer/thicker regions of 50-100µm, say 0.1mm, for optimisation of dispersant and mechanical recovery response to casualty-releases and can dismiss from such response the thinner/cooler regions still detectable by UVLS and SLAR, none of these techniques either separately or in combination can quantify the amounts of oil present in operational discharges from ships to better than one to two orders of magnitude; and that with the cooler and warmer thresholds of the IRLS images being subject to varying thermal conditions in general, and with the UVLS image providing even less thickness data than the naked-eye, remote sensing alone is unlikely to secure convictions for operational discharges beyond legal limits unless the limit is zero, while in areas permitting discharges above zero, remote sensing by the above means is only capable of monitoring general discharge practice and traffic route compliance.

As to oil characterisation by remote sensing, laboratory-tank investigation showed that active fluorescence techniques could produce spectral differences for light and heavy fuel oils and for crude oil, though crude oils could not be usefully differentiated. However, when an unknown oil is caused to fluoresce by reception of a short pulse of ultraviolet radiation from a nitrogen source operating in the spectral band 380-680nm, and with the fluorescence being passed to a 16 channel spectrometer of channel width 20nm, the resulting spectrum can be compared with a previously prepared library of known oil spectra to effect an identification to this limited extent. Using this approach airborne instrumentation has differentiated rhodamine dye, Murban and La Rosa crude oil, and a ship, while comparison of the emitted and the returned signal intensities has differentiated slick thicknesses in a lower range than those accessible by the infrared technique. Thus, incorporation of a correlation algorithm would enable differentiation of the above limited type in real time aboard the aircraft.

By 1993 the German Ministry of Transport had incorporated a laser fluorosensor with the then standard UV/IRLS and SLAR together with a microwave radiometer in a Dornier DO228-212, this particular radiometer, having been the first of its kind to meet specified operational requirements, was a conical scanner providing a swath width of 150m at an altitude of 300m. Microwave radiometry has the potential to provide more quantified data on layer thickness than is available from IRLS.

Article 67

By the late 1970s it had been recognised that Low Light Level Television (LLLTY) had potential as a remote detector of oil slicks, its response in the 250-1200nm band depending on tube characteristics and with oil having a greater surface reflectance than water in this band. Thus, with this start and in keeping with the theory reviewed in article 63, the spectral ranges were restricted to those providing the greatest contrast. Thus, the 450-650nm band with the volume-reflected radiance for water filtered out, the UV band at 320-420nm and the IR band at 650-850 were selected using a Corning type 7-51 filter.

Selection of the UV band is based on refractive index calculations even though this benefit is somewhat reduced by the decline in visual sensitivity with decrease in wavelength. However, for clear skies the skylight to sunlight ratio is highest at the blue end of the spectrum and since skylight gives rise to the desirable surface radiance component, it could be anticipated that the 320-420nm band would give the best results under clear skies, while for overcast skies the global (sky plus Sun) radiance is reduced and the skylight to global radiance is increased, thus enhancing contrast because the surface-reflected component is enhanced over the background volume and atmospheric components. However, on the debit side, the spectrum is shifted away from the optimal blue to the less favourable red end. Nonetheless, the increased absorption of the red end by water suggests a reduction in the volume-reflected and atmospheric-scatter components, these considerations indicating possible advantages from the 650-850 band for overcast skies.

In addition, contrast can be maximised by using a polariser as mentioned in article 63, though a further factor has to be considered here. Because the skylight is reflected from the oil or water surface, its degree of polarisation is important in itself. Fortunately, the skylight polarisation depends on the angle between the Sun’s position and the direction of observation, so that when one directs the sensor away from the Sun to avoid glitter, one automatically chooses the correct viewing direction to maximise contrast at the Brewster angle. The final consideration is that the attenuation attendant on the use of filters makes it essential to benefit from the greater sensitivity of low light TV over the lower sensitivity of standard TV for maritime remote surveillance work calling for maximum contrast between floating oil and surrounding water.

Early trials of LLLTV over a natural oil seep off Baffin Island and over trial slicks in the Atlantic Ocean, provided contrast enhancement over that produced by the naked eye, thus justifying the theoretical and practical work reviewed above. However, in rough seas, foam has been shown to be indistinguishable from oil, though the simultaneous presence of both may be considered unusual, oil slicks tending to suppress the breaking of waves, while the similar inability to distinguish oil from slush and broken ice would be more of a problem in cold climes. In this connection, Canadian workers have confirmed their suggestion that switching from horizontal to vertical polarisation synchronously with image repetition would produce a flashing oil signal while that from foam, slush and pieces of ice would remain constant. However, a further problem has been noted in that any lights in the field of view cause gain-control/iris-closure to reduce sensitivity drastically.

Article 68

In light of the progress reviewed in articles 63-67, WSL (H. Parker) contributed through the NATO Committee on the Challenges of Modern Society (CCMS) to designing the International Standard Oil Wake Experiment (ISOWAKE) by which individual Member States could further evaluate remote sensing equipment for potential apprehension of illegal oil dischargers. Thus, the Member States agreed that discharges should consist of diesel oil as specified and, if desired, one or more of the heavy fuel oils or crude oils such as Bachequero 17, Minas, Nigerian medium, Sahara blend or Arabian; that such should be discharged at 30, 60, 120 and 240 litres per mile in water discharged at 3000 litres per mile; that these discharges should be effected through a 100mm pipe facing vertically down, positioned between 0.2 and 0.5 m of the ship's side, and terminating 0.5 m above the mean sea surface; that preferably the ship should be at least 100 tonnes gross; that it should be travelling at between 8 and 10 knots; and that the water depth should be sufficient to avoid wake entrainment of bottom sediment.

The Member States also agreed that aerial survey flight paths were to be towards or away from the ship along the ship's track, and perpendicular to the track 400m behind the ship; that additional flight paths were to vary the Sun/oil-sensor angle and the wind/oil-sensor angle; that the preferred times were noon, 1600-1800 hrs and midnight local time; that the preferred over-flight altitudes were 500 and 2000 ft; that additional flight lines and altitudes might be required and were thus recommended fully to exploit specific sensor performance; and that comparison flights should be conducted with no oil discharge at all. Finally, as regards reporting results, the Pilot Group agreed a facilitating format and invited the participating States to submit details of test plans and schedules beforehand.

The CCMS expected that such tests would establish the potential of existing remote sensing systems to detect illegal dischargers in the act of discharging, to show when these discharges were above legal limits, to show by how much they were in excess of these limits, and to provide hard copy evidence for use in court: all despite the inability to deliver such quantification having already been demonstrated (article 66). Again, given the difficulties of attributing operationally discharged slicks to an already departed ship, there seemed little point in remotely sensing the former unless it was unusually large enough to justify mounting a seagoing dispersant or mechanical removal response.

However, WSL also reported to the NATO CCMS that while the SLAR operated on its behalf by the RSRE had detected a discharge of 60 litres per mile from *Seaspring* at a range of 5.5 km and while it could detect much less, it could not quantify thickness variation and therefore could not quantify amount; that while within the SLAR-detected slick, the associated UVLS equipment could differentiate oil from any thermal discharges, these could not be differentiated from bright oil images of the associated IRLS equipment, and thus could no more quantify the amount of oil present than could SLAR,; that even if free from such other thermal interference such as cooling water discharges, the IRLS could not differentiate areas of differing oil layer thicknesses within the UVLS image with the precision needed to determine the quantity of oil present; that in making no such differentiation, the UVLS provides an image similar in extent to the naked eye within the area of the SLAR image; that while such a combined approach is adequate to the needs of maximising encounter rates for release response, it is inadequate to quantify oil amounts sufficiently to convict a discharger for exceeding stipulated discharge limits unless the limit be zero. As to ship identification, however, WSL reported that this is difficult at night unless suitable illumination and camera equipment are provided by the aircraft to acquire the ship's name and port of registry; that laser-activated gated LLLTV would be likely to achieve this information and to satisfy all hard copy documentation requirements; that this likelihood may be curtailed by the presence of other light sources (article 67); and that quantification of the discharge would not be possible by any available means.

WSL additionally reported with respect to both general discharge monitoring and guidance to maximal effectiveness of spill response, that the output from the IRLS, UVLS and SLAR equipment should be displayed as a TV image onboard the aircraft; that the TV should have a freeze and recall facility and that the running image should be recorded and converted to hard copy photographs. Again, because the IR/UVLS has a swath width of only a few thousand metres while the SLAR swath width is 10-20km, the images of the former must be geographically located within the image of the latter which must itself be so located; that this can best be done by annotating the images with position, time, date, altitude, flight direction *etc*.; and that this can best be done by direct linkage to the navigational and other instrumentation of the aircraft. Yet again, WSL reported that decisions on the optimal deployment of dispersant spraying and mechanical recovery could be taken onboard the aircraft or the information could be transmitted to a central and/or subordinate control centre for such knowledge-only decisions to be made there.

Article 69

We have seen from articles 66-68, that remote sensing techniques cannot quantify operational discharges from ships; that sampling and comparative chemical analysis of discharges and the tank contents of suspect ships may connect a ship to a discharge; that this sampling and analysis is qualitative not quantitative; and that neither remote sensing nor qualitative analysis can quantify discharges as being in excess of stipulated limits other than zero. As to the effects of such operational discharges, we know that these are more likely to arise from failure of coalescing/filtering units than from mal-functioning gravity-separators (articles 18-21) and thus be comparatively small, whereas deliberate discharges of waste oils are likely to be larger than either, though well short of releases from a damaged cargo-tank. Thus, while these area-thickness comparisons are potentially within the combined capacity of remote sensing units for casualty-releases as discussed in articles 66-68, deliberate waste-oil discharges detected only after detachment from the offending ship would still require sampling and chemical comparison with the oils of suspect ships before any attribution would be possible.

Again, while the complex mixtures of components which are crude oils and oil products lend themselves to individual ‘finger-printing’, these component concentrations vary with time of exposure as the volatiles evaporate and as the non-volatiles oxidise to varying extents, thus rendering them increasingly different from those of their sources (article 26). These difficulties were addressed, though only partially overcome by myself and others in *Marine Pollution by Oil: Characterisation of Pollutants, Sampling, Analysis and Interpretation*, Applied Science Publishers for the Institute of Petroleum, London 1974. Generally speaking, the best that can be done without reference to tank sampling from the suspect ship, is to characterise slick samples as those of a fresh crude oil, a weathered crude oil, a light or heavy fuel oil, or tank washings, this being sufficient for the needs of response planning should that be necessary, regardless of source-identification.

As to attribution, all oils including lubricants aboard the suspect must be sampled for analytical comparison with samples of the discharge, while in the case of tank-damage such sampling/analysis may prevent passing ships from discharging waste oils under cover of proximate tank-damage release. In respect of the fore-going, it ought to be recalled that oil discharges of litres per mile are in all respects insignificant in comparison with the 3000-5000 tonnes to be expected from impact-damage to a single cargo tank, let alone the total cargo/bunker releases which belief in species-extinction/ ecological-disaster deems preferable to the speculative risks of transfer in safe havens. As to sampling itself, it is easier to collect underlying water than floating pollutant. For relatively thick emulsion layers of say 0.2 - 0.4mm, a funnel permits collected water to be run off before transfer of the emulsion to the air-tight sample jar, while thin fresh oil layers of say 0.1mm are best collected by absorption pads which themselves are placed in the sample jars. Sampling from solid surfaces may be effected by scraping/swabbing, tar-ball hand picking, collection of oiled sand or oiled object (e.g. feathers) and transfer to sample jars. Indeed oiled seabirds may be collected in plastic bags for this purpose and for post-mortem examination, though chemical analysis has to take account of natural plumage oils. To prevent biodegradation, stored samples should be refrigerated or hydrochloric acid should be added in the ratio of 25ml (of 50% concentrate/50% distilled water) to 5 litres of sample and *pro rata*. In passing, it is perhaps worth noting that this refrigeration/acidification is to prevent degradation of the oil by marine micro-organisms, while the belief that such organisms are killed by oil is the belief in species-extinction/ecological-disaster which caused this sampling/analysis in the first place, despite its preference for total cargo/bunker release rather than transfer in safe havens.

Nonetheless, if such samples are to be analysed, it is recommended that 100ml of freshly released, relatively non-emulsified oils should be collected, while to take account of full emulsification 500ml is required. For over-side water discharges suspected of contravening oil discharge limits, 2.5 - 5.0 litre samples are recommended direct from the discharge outlet, though in zero-discharge Special Areas, smaller sample volumes may be sufficient if the larger are unobtainable. For tarry lumps and tar balls 20 - 50gm samples are adequate. As to sample containers, metal should be avoided because ‘finger-printing’ involves evaluation of nickel/vanadium ratios and trace metal contents, while plastic can also contaminate samples. Glass is best, and Kilner jar seals are acceptable with the result that those charged with sampling in the UK are supplied with 16 and 40 ounce jars, the latter packed in wooden transit boxes for recycled use.

Continuity of evidence requires that sample jars be closed with wire and a lead or wax seal or by adhesive labels stuck across the lid and jar-top and signed by the sealer. In Scotland, sampling is done in threes: one for submission to the Government Chemist or Police Laboratory, a second to be handed to the owner or master of the suspect ship for possible independent analysis and a third to be produced in court where the prosecution will be handled not by the Departmental Solicitor but by the local Procurator Fiscal. In Northern Ireland, though the Law is as for England and Wales, the Director of Public Prosecutions has asked that three sealed samples be provided as in Scotland. In all cases, the labelling/documentation requirement calls for description of sample with identification code or sample number; date, time and place of sampling; name and organisation of the sampler; method of sampling; purpose of sampling; name of suspect source and information on suspected contamination if known; and particulars of any available photographs or other supporting evidence.

Over the years, recurring attention has been given to the possibility of tagging cargo and bunker oils for ease of subsequent identification and to the sampling of floating oils from dedicated surveillance/ response aircraft, though the global administrative burden of such a scheme compares unfavourably with the alternative of relying on the delineation of Special Areas, though such delineation itself may be considered an over-reaction, given that all oils disperse and degrade naturally to carbon dioxide and water with no toxic effect on the organisms of degradation (articles 14, 15, 26 and 47 - 49).

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Mechanical Removal from Water Surfaces

Article 70

We have seen that dispersants are up to three orders of magnitude less toxic than oil which itself is non-toxic at seawater concentrations of exposure; that the layer thickness of naturally dispersing Phase II oil slicks at sea is of the order of 0.1mm; that even if such a layer thickness dispersed instantaneously, the concentration in the top metre of the water column would be no more than 100ppm; that natural dispersion rates in practice produce oil concentrations less than 5ppm in the top metre; that the dispersant-induced concentrations are initially no more than 10-20ppm in the top metre; that all such concentrations rapidly decrease through the ppb range towards zero with depth by natural diffusion, turbulence and biodegradation to carbon dioxide and water; that the oil concentration chosen to ensure observable toxicity to the test organisms in dispersant approval schemes is 1000ppm; and that the continuing absence of species-extinction/ecological-disaster from natural or dispersant-induced concentrations is thus unsurprising, while opposition to the protection afforded to individual birds and sea-surface/shoreline organisms by dispersant-use is thus beyond surprising. Nonetheless, despite there being no dispersant nor dispersed oil toxicity to cause concern, this section of the knowledge repository recognises that some oils and emulsions are non-amenable to dispersant treatment and that it is thus necessary to review our knowledge of mechanical removal techniques, if interrupted commercial activities are to be restored to their pre-incident levels as quickly and as cost-effectively as possible.

In general we have seen that dispersed oil and emulsion droplets migrate upwards in water according to Stokes's Law and coalesce to a floating separate phase in shipboard and land-based gravity separators; that in the former, the separated phases are respectively retained onboard and discharged to the sea by separate pumping systems; that in the latter, the floating phase in open-topped API gravity separators is intermittently pumped away while its layer thickness is continuously re-augmented by further droplet coalescence, thus avoiding the co-pumping of underlying water, or a skimming device is interposed to enable the layer thickness to be further reduced without co-pumping of the underlying water; and that either way, pumping can be stopped at the thus limiting layer thickness.

In contrast, however, we see that the intention in marine pollution response is to remove all of a floating layer from the open sea surface even while it continues to diminish in thickness by natural dispersion; that the thickness of this unconfined layer is only 0.1mm to start with; that the skimmer design-requirement is thus more demanding than anything intended for use in an API separator in which skimming can be stopped long before such a layer thickness is reached (articles 18 - 21). Again, we know that rotating-disc skimmers were first used in mineral processing (another WSL activity); that, for example, a mixture of crushed metal-sulphide ores may be separated from the gangue by air-bubble suspension in water to which oil is added so that the lighter sulphide particles rise to the water surface in an oil/water/air foam for disc-skimming; and that in this application the floating layer thickness can be comparable to the disc radius of 15cm, rather than the 0.1mm thickness of unconfined oil slicks.

As to the possibility of increasing the layer-thickness of pollutants encountered at sea, it was noted that such thickening arose by wind compression against shorelines or harbour walls, and it was concluded as early as the *Torrey Canyon Incident* of 1967 that similar layer thickening might occur against floating booms moored to protect specific lengths of shorelines or across the mouths of small estuaries to protect their upper reaches; and that towed booms at sea might replenish layer thicknesses depleted by skimming in a manner similar to layer-thickness replenishment by coalescing droplets in API separators, though the layer thicknesses of the former could never be expected to equal those of the latter. Thus, in all attempts to remove oil or its emulsions at sea, the encounter rate of the skimmer with the thinness of the floating layer must inevitably be lower than that attainable in an API separator, while the co-collection of free water in the former situation must be inevitable. Indeed, it could have been known at the outset that the encounter rate per metre swath per knot of advance in a layer thickness of 0.1mm would be 0.18 cubic metres (~ tonnes) per hour, this being a matter of simple arithmetic.

Thus, subsequent articles in this section, will review our knowledge of boom and skimmer designs intended to maximise performance in what ought to have been recognised from the outset as a very discouraging task. In order to make the best of it, I now review how the inevitable escape of pollutant in the water-flow beneath moored and towed booms can be minimised; how skimmer efficiency can be maximised, particularly in the pollutant viscosity range beyond that of dispersant effectiveness; and how boom and skimmer design can reduce the deleterious effect of waves. In reviewing the relevant design principles, I evaluate the extent to which actual equipment complies with these principles in reality. In considering this review, readers ought to recall that nothing escapes beneath the containing walls of an API separator; that it is unnecessary to remove all of its contained oil layer in any skimming period; and that waves are never a problem in such separators. In addition, readers ought to recognise that all of the loss mechanisms detrimental to removal from open water surfaces are aspects of natural dispersion; and that while dispersant-induced dispersion is also limited to 0.18 tonnes per hour per metre swath width per knot of advance, mechanical removal advances at one knot while dispersants advance at ~ 100 knots or more; and that while mechanical removal is thus opposed by natural dispersion, dispersant-application increases the natural rate.

Boom Designs Compared

Article 71

While the reference encounter rate of 0.18 tonnes per hour per metre swath width can be increased for dispersant treatment by increasing the travel speed of ships and aircraft, the speed of booms towed by ships to increase swath width cannot exceed that which causes water-flow under the boom to exceed ~1 knot, beyond which pollutant escapes with the water-flow, thus defeating the objective of boom-towing, or boom-mooring in a tideway, which is to increase the layer thickness of the pollutant beyond the 0.1mm of Fay's Phase II spreading, though it will increase to 0.4mm as its emulsified water-content increases to 80%. Again, while boom lengths are deployed at an angle θ to forward movement to reduce the flow-component normal to the boom by the factor, cosine θ, and while the pollutant may be thus deflected to the apex of V-boom configurations towed by a pair of ships, the skimmer at the apex is unavoidably normal to the forward movement and thus subject to the ~1 knot limitation. Again, if boom lengths are deployed against the incoming tide in an estuary from a mid-stream moored apex to a down-tide point on each shore, the benefit of cosine flow reduction will deflect incoming pollutant to collection points onshore where current flow may be slowest if water depth beneath the boom remains adequate (article 72). Thus, while this escape velocity cannot be increased much above one knot, booms ought to be designed for:

-attainment of this fundamental limit;
-maintenance of this performance by avoidance of other loss mechanisms;
-minimisation of the towing and mooring tensions which inhibit wave-following potential;
-adequate structural strength to withstand these tensions;
-lightness for convenient handling in deployment, use, and recovery;
-minimisation of bulk to facilitate storage and transportation.

As to internal tensions which can reduce the wave following characteristics of a boom and thus diminish the pollutant retention of its nominal freeboard and draft, it has been found that the force, F, exerted on the sub-surface area, A(m^2) by relative water flow, V (knots) is $F = KAV^2$ where K is a constant observed to have a value of around 15 for pollutant retention for a range of internal tension booms and 26 for the separate tension line Troilboom of Erling Blomberg. Thus, the tension in a 100m boom of 0.6m draught in a relative current of 0.5 knots would be 225kg (K=15) or 390kg (K=26), though the value of K consistent with retention of the intended presentation of freeboard and draught to wind and tide should be determined by observation for specific booms. As to wind, the effect may be taken to be a fortieth of that of water at the same speed. Thus, for 100m of boom of 0.5m freeboard in a wind speed of 15mph normal to the boom, V should be entered in the above equation as 15/40 to give F= 183kg. Clearly, the wind-effect is significant.

It is also necessary to relate such internal tensions to the holding capacity of anchors. The fisherman-type anchor is best on rocky bottoms where the holding is a matter of the size and location of the rock or rocks against which the anchor has come up fast and is thus difficult to calculate. However, the holding capacity of the Danforth type is a matter of the cohesion of the bottom in which the anchor is embedded, this in kg being 1.5 - 2.0 times the projected fluke area in cm^2 and related to anchor size (weight) and bottom cohesion as tabulated below.

Holding Capacity of Danforth-Type Anchors

Anchor Weight, kg	Holding Capacity for Bottom Types, kg		
	Mud	Sand/gravel	Clay
15	200	250	300
25	350	400	500
35	600	700	700

In mooring booms to protect estuaries against pollutant ingress, no boom element should be permitted to be at right angles to the current direction unless close to the bank or shore where current flow is minimal to zero and where such a cusp might be helpful to pollutant recovery. The recommended arrangement is to moor one end of each of two booms to a stake or block on the opposite sides of the entrance and to attach their other ends together in mid-channel to form a double chevron the common apex of which is attached to a mid-channel anchor upstream in the incoming tide or to a bridle attached to twin anchors laterally placed either side of what would have been the chosen position for one. In practice it is best to maintain both chevron arms as smooth curves by deploying intermediate anchors to each arm by a series of double-armed bridals spread at about 70° to a series of waterline boom attachments from the chevron apex to the high-tide position on both arms, the preferred angle between boom and shore being 25-35°, such intermediate anchors sharing the load with the terminal anchors, posts or blocks.

Article 72

As shown by trials conducted by the then Hydraulics Research Station (HRS), Wallingford, UK, it is advisable to measure velocities and water depths at hourly intervals during the flood tide and to determine the value of K (article 71) by measuring tensions for the boom chosen for deployment in particular estuaries before the need arises in actual incidents. In trials conducted by HRS, it was found that the terminal forces exceeded 1 tonne while three intermediate anchors experienced a total of 200kg; that in estuaries where incident deployments may be expected, such prior data collection enables the most favourable deployment locations to be identified; and that having done so, a mid-channel anchoring block and shore anchoring posts or blocks can be permanently installed. Thus, in one location HRS recommended for the mid-channel apex position, the laying of two 55lb Danforth anchors and the burying of a 6 tonne concrete block in the centre of the main channel and marked by a buoy while the shore terminals were to consist of concrete blocks with steel eyebolts or frames set into the sand above the high-water mark for loads of 3-4 tonnes.

HRS also recommended that for booms to operate optimally, the depth of water beneath the skirt should be at least 6 times the skirt draught, though this is unlikely where beach slopes are gradual enough for booms to be laid out and moorings set by men on foot at low tide. In such cases it is likely that pollutant will pass beneath the boom as it begins to float with not enough water beneath it to prevent its flow rate from exceeding 1 knot. Even booms designed to sit in the vertical position when grounded, are likely pass oil beneath them until the minimal water depth for retention is reached on the flood.

Materials such as welded polyurethane, make booms strong enough to be deployed by terminal attachment to river banks without needing intermediate anchoring points to produce a single chevron arm which permits pollutant released upstream to be deflected towards the bank attachment at the downstream end for collection and removal. This approach was adopted in Sweden by Captain Erling Blomberg who sustained the tension in a separate tension line to which a vertically battened curtain boom was attached by bridles from the tops and bottoms of the battens between which thin flotation panels were fitted within the curtain. This Troilboom could be deployed with one end of the tension line attached to a river bank and the other to a paravane controlled by lines to that bank, an arrangement which permits river traffic to pass when another such arrangement is deployed and controlled from the other bank upstream or downstream of the first.

However, WSL was more interested in using ship-towed booms to increase encounter rate by increasing swath width while retaining the possibility of removing the thus encountered pollutant from the back of the consequent U-formation of the boom without exceeding the escape velocity normal to the direction of movement at that location. WSL therefore turned its attention to the escape velocities exhibited by differing boom designs as determined by HRS (D.E Newman, N.I. MacBeth).

Escape Velocities Related to Differing Elements of Boom Design

Boom Type	Design Elements	Escape Velocity ms^{-1}
1	Vertical flexible screen	0.33
	Floats and ballast weights at intervals	
	Mooring points at waterline	
2	Figure-of-eight section flexible barrier	0.50
	Continuous air floatation and water ballast tubes	
	Mooring points at waterline	
3	Flexible continuous buoyancy chamber	0.67
	Permeable skirt chain-ballasted along bottom	
	Mooring points at waterline	
4	Rigid buoyant panels on flexible screen	0.82
	No ballast	
	Mooring points at foot of skirt	
5	Flexible continuous buoyancy chamber	1.33
	Flexible skirt chain-ballasted along bottom	
	Mooring points at foot of skirt	

Article 73

Having reviewed the nature and magnitude of the loading forces on moored and towed booms in articles 70-72, I now consider how these forces affect the performance of booms thus restrained, in respect of the influence of their differing design elements on the pollutant escape velocity by entrainment in the under-flowing water and by other identifiable loss mechanisms.

Clearly, if booms are to be successful at all, the design elements of freeboard and draft must be adequate to prevent pollutant overtopping on waves and escaping beneath at flow rates less than the fundamental escape limit, the actual escape velocity having been shown by HRS to vary depending on whether the mooring points were designed to be at the waterline or the foot of the draught (article 72). Thus, we know that mooring attachment at the water line reduces freeboard and draught by allowing the boom to tilt with the under-flowing current; that mooring attachment at the foot of the skirt reduces such tilting though the reverse tilting can produce freeboard submergence; that such attachment cannot remove such reverse tilting nor can it remove wind induced tilting; and that the combined tensions of terminal and intermediate mooring reduce the constancy of freeboard and draught by reducing the wave-following capacity of booms in the presence of waves even for booms designed to be inherently wave-following. To some extent these adverse tendencies can be reduced by reducing the mooring tensions by reducing areas of freeboard and draught exposed to wind and water, though the Blomberg separate tension line and bridle, Troilboom, design of article 72 (not included in the table) permits the inherent wave-following flexibility of the freeboard/draught-curtain to be fully realised with minimal floatation volume and ballast weight and with the top and bottom bridles maintaining a vertical and concave presentation of boom-face to pollutant, while incorporation of the 'Blomberg Circus' later permitted pollutant retention at up to ~ 3 knots (article 88).

In any case, conventional booms with attached flotation and ballast pads at intervals must have flotation volumes sufficient to counter the ballast weight and the vertical component of the mooring tensions, while the resulting lack of a smooth boom-face produces vortices which enhance the rate of pollutant escape through underflow entrainment. However, when the freeboard is a continuous buoyancy chamber filled with plastic particles for wave-following flexibility such vortex formation is eliminated. Again, the figure-eight boom, consisting of a continuous air flotation chamber and a continuous water ballast chamber, eliminates pad-induced vortices, while its bulk when not in use is very low and conducive to reel-storage. The Vikoma boom was designed on this principle and was further intended to maintain its draught and freeboard by being restrained only by sea anchors in an otherwise free-floating mode of operation, though this had an inherent design fault (subsequent paragraph)

Otherwise booms are in effect towed from the waterline and may thus have their draught component tilted backwards except when they are designed on the separate tension line and bridle principle. However, an additional advantage of this tension-line/bridle design is that unrestrained floating objects have a cyclic motion in waves; that pollutant close to the bridled barrier and the barrier itself are both free to pursue this motion; and that the relative movement between floating pollutant and barrier is thus reduced to the benefit of pollutant retention. On the other hand, the free-floating boom was designed with the intention of reducing the relative movement of pollutant and barrier virtually to zero. Thus, the boom deployed in a U-shape was intended to collect oil moving into it at 3% of the wind speed and to thicken therein because boom movement was constrained solely by a sea anchor at each end. However, WSL showed the concept to be invalid because the pollutant moves not only on the wind but on the vector sum of wind and tide, while the boom moves almost wholly on the tide by virtue of its mouth-maintained sea anchors, while any cross wind on the boom itself causes it to swing round the sea anchors to close the U by bringing its arms together as long and short contiguous lengths of a closed J-configuration. This was confirmed by WSL by placing a Decca Navigator at the ends and mid-point of the boom and plotting their movement while measuring local wind speed and direction and local tidal speed and direction with reference to the proximate tidal diamond and local tidal stream atlas.

Article 74

After the demonstrable failure of the free-floating concept, attention turned to towing booms in a U-shape with a ship at each end and with a recovery ship deploying a skimmer inside the boom at the back of the U, or in a V-shape with the apex ends separately attached to the twin-hulls of a catamaran skimmer and with a third ship in attendance to receive the pollutant recovered by the catamaran. In contrast, WSL quickly began to develop a single ship approach which deployed a recovery unit within a boom deployed alongside *Seaspring* from a jib at right angles the centre-line of the ship. Indeed with a short length of the separate tension line Troilboom deployed from the horizontal position of the jib of its forecastle crane and with a floating hose end and a deck-mounted 4 inch Spate pump, a recovery rate of ~ 9 tonnes per hour was measured for 70% water-content emulsion at the Ekofisk Blowout, an approach which was further developed by WSL as described in article 76. This approach also permitted ship speed to be optimised to prevent pollutant escape beneath the boom by onboard observation in a manner impossible with three-ship systems such as those described above, especially when forward speed could be controlled by a 360° bow-thruster as was WSL's *Seaspring*.

At this stage, it is appropriate to review other boom-related collection/recovery devices. Thus, net booms were proposed in the belief that the water beneath the pollutant would pass through the mesh rather than under it, and that the higher viscosity pollutant would be retained by the mesh rather than escaping through it with the water. Again, it was proposed that tubular nets or the practice of seine-netting could collect and recover pollutants, the former by detachment and hoisting onboard, the latter by progressively decreasing the surface coverage of the pollutant to inversely increase its layer thickness to levels supportive of directly pumped recovery (article 75). Again, bubble barriers have long been used in dock and harbour locations where conventional booms would interfere with normal ship movement, while acoustic transducers have been proposed to keep burning pollutant sufficiently clear of booms to reduce fire damage though these have not progressed beyond the trial stage (articles 35 - 38 and 74)..

A bubble barrier consists of a pipe or hose on the seabed or at some mid-water depth and which may be supported by a flotation system (as is a boom) and an air pump/compressor which forces air to emerge through a series of nozzles at intervals along the length of the pipe or tube. When the air bubbles issue they rise as they expand imparting an upward movement to the surrounding water which on arrival at the surface flows horizontally at right angles to the direction of the pipe/hose, thus preventing floating pollutants from moving across the line of surface divergence. It has been found that the effectiveness of such a barrier increases with airline depth to about 1.3 metres below the surface, while depths beyond this limit require increased air pressure without any further barrier benefit, though such pressure increase may be needed to accommodate the draught of passing ships if the pipe/tube is to be permanently in place.

As to the combustion of oil on water surfaces (articles 35 - 38), a water jet system consisting of a series of nozzles 2.5 - 3.0 metres apart at 15-30cm above the water surface and directed at it at an angle of about 10° has been proposed to hold the pollutant clear of the boom barrier which in turn supports the jet system, the jetted-water reducing the opacity of the smoke while promoting emulsification which increases the un-burnt residue. Yet again, acoustic transducers act from below and away from the boom-face at a glancing angle to the water surface, while a separate acoustic transducer at the boom apex and focussed directly upwards into the pollutant layer has been shown to volatilise the pollutant for ignition, to combust it down to 0.5mm thickness, to combust weathered layers not normally combustible, and to minimise the un-burnt residue, though it has high energy requirements. While such directed jets would presumably reduce loss of pollutant beneath booms, one might ask whether such elaborations and costs would be worthwhile given the low boom encounter rates with slick thinness and inversely large areas.

Article 75

Further to net booms, we see that the net will permit water to pass through so long as the retained pollutant does not clog or 'blind' the mesh. Again, when the pour-point of the oil renders it solid at sea temperature, pumped recovery becomes impossible, whether the mesh clogs/blinds or not. Yet again, when net clogging/blinding stops the outward passage of water, no more water will pass in and no more oil will pass in with it. Water will only pass into a towed bucket if it has holes in its bottom or its sides. However, if a tubular/conical net is long enough, considerable quantities of solid oil in lumps and granules might be collected before all the mesh becomes choked or blocked such a system having been designed by the British National Oil Company (BNOC) for possible recovery of Beatrix oil (article 33).

Thus, in the system developed by the British National Oil corporation (BNOC) for the solid oil of the Beatrice field, a tube of entry net, not expected to become blocked, tapers down to a junction ring to which the downstream collection net is attached. In this system, the collection net was held open by a frame and deployed from the sweeping vessel to give a swath width of 7 metres by a jib and mast as in the system developed by WSL from the Ekofisk experience (articles 74 and 76), and the collection net was detached and lifted onboard from the junction ring when full (2 tonnes) and replaced in an operation of about 15 minutes.

In the seine net approach to pumped oil recovery as developed by John West of Peterhead with the intention of further trial-based development by WSL, a vertical barrier of fine mesh, a net boom, was to be deployed around an area of floating oil or emulsion by paying out as the deployment vessel executed a circle as in seine netting practice, a skimmer was to be placed within the completed circle, the net was to be recovered by hauling through the Marco power block, and the reducing perimeter was to maintain a layer thickness adequate to realise the nominal capacity of the skimmer and associated pump. While the net was expected to become impermeable with no disadvantage in comparison with conventional net booms, its advantage over the latter being the lightness and flexibility which permitted the power block recovery which maintained the layer thickness needed to maximise the efficiency of pollutant removal.

Again, it was encouraging to see a professional fisherman working his traditional equipment at sea, to remember why oceanographic equipment is best handled under the direction of a fishing master, and to conclude that best use of properly selected equipment would be made by those with a fishing background. However, this concept has not yet been fully evaluated. Indeed, it was overlooked by those who devoted further trials of John West's equipment to their evaluation of its supposed potential to provide ever-longer lengths of coastal protection booming, despite such protection obviating the seine netting intention of removing pollutant prior to its proximity to shorelines.

Skimmer Designs Compared

Article 76

We have seen that skimmers are intended to remove oils and emulsions from water surfaces despite the thinness of the encountered layers even when these are increased by the use of booms; that in contrast, it is always possible to maintain the layer thicknesses in API separators at levels adequate for removal of significant quantities of pollutant per pumping period, such thicknesses being simply allowed to accumulate within the walls of such on-line separators by continuous upward migration and surface coalescence of oil or emulsion droplets from incoming water according to Stokes' Law, while the water itself continuously exits; and that in the absence of confining walls, oils and emulsions spread according to the Fay equation through the ever-thinner layers of Phases I, II and III, while dispersing naturally to droplets of ever-decreasing size and ever-increasing dilution (articles 16 - 17 and 70).

Thus, while layer thickness grows in API separators to facilitate recovery, it decreases on the sea surface to make recovery impossible unless this decrease can be avoided by collection-booming, though this is applicable only to very small fractions of the total slick area. Indeed, on this evaluation, it is little wonder that mechanical removal has a poor performance record, if recorded at all in response operations. Thus, it was against this background that the WSL R&D programme sought to relate skimmer design to the adverse factors of layer thinness, waves, and pollutant viscosity. This WSL approach recognised that recovery rate depended on thinness-dependent encounter rate, on wave-dependent break-up of layers, and on viscosity-dependent pumping. As to waves, it was predicted that the active element of any skimmer would have to remain in the wave-surface coincident with the continuous floating layer, otherwise its movement relative to the wave-surface would cause turbulence which would break the layer into irrecoverable dispersed droplets, while any skimming and transfer-pumping mechanisms would be viscosity-dependent.

Thus, over the years 1976-79, the WSL approach was to obtain, on loan or by purchase, the most promising examples of commercially available equipment, such equipment being classified as weirs, adsorption discs, ropes or belts, vortex devices and direct-suction devices. This classification was selected because the simplest way to separate a floating layer from underlying water is to permit the layer to pass over a weir while barring passage of the underlying water by the weir itself, though such devices are usually expected to operate in the absence of waves and to lose efficiency if the layer is too viscous for easy overflow. Again, this classification identified discs, ropes and belts as potentially having at least some wave tolerance in the preferential adsorption of floating layers. Yet again, even if some wave-turbulent droplet creation is unavoidable a vortex device should in principle be able to recreate two continuous phases for subsequent differential pumping. In addition, with WSL being familiar with rheology and pump technology, the oil/HNS division hoped to achieve more viscosity-independent recovery rates by vacuum-assisted pumping, given that no matter how selectively efficient a skimmer might be, pollutant must ultimately be conveyed to storage.

The consequence of this approach was the creation of a seagoing collection and removal system which naturally followed the pollutant on the wave train and which was provided with pumping arrangements capable of transferring highly viscous emulsions from the wave train to the recovery ship. It was called the *Springsweep System* after the laboratory and its parent ship, *Sea Spring*, (article 88).

Article 77

Perhaps the most basic skimmer of all is that developed by ESSO Research Centre and known as the Self-Levelling Unit for Removing Pollutant or SLURP. This is a weir skimmer with no moving parts. It is small, being 935mm in width, weighing 28kg, and capable of operating in water depths down to 25cm. The floating attitude of the unit and consequently the depth of its sub-surface weir depend on the amount of liquid contained in it during its operation. Since high pump rates are appropriate for thick pollutant layers and low pump rates for thin layers, the device is designed so that the former maintains a low liquid loading and a floating attitude which results in a deep weir position, while slow pumping and high loading maintain a shallow weir position. Thus, the unit has a variable speed pump.

The unit was evaluated at WSL using a free-flowing Kuwait crude oil at layer thicknesses in the range 1-15 mm on water at a temperature of 8°C and with pumping rates in the range of 2-25 litres min^{-1}. The results in terms of %age oil-/emulsion-content of the recovered fluids showed that the design intentions were realised within defined limits. Thus, with a layer thickness of 15mm and pump rate of 25 litres per minute (lm^{-1}) the collected fluid was 85% oil and 15% free water while at 10mm this pump rate produced 70% oil and 30% free water. However, if this pump rate was reduced to 10 lm^{-1}, the removed oil was maintained at 85%, and if the pump rate was reduced to 7 lm^{-1}, 85% oil was maintained to a layer thickness of 6mm, while at 3mm and less the %age oil becomes increasingly insensitive to pump rate reduction unless in the range < 5 lm^{-1}. Nonetheless, 5 lm^{-1} and 2.5 lm^{-1} at 3mm gives oil contents of 60% and 65% respectively while at 1mm these pump rates give 30% and 35% respectively. However, at the other end of the scale these results showed that even at a layer thickness of 15mm, pump rate had to be as low as 10 lm^{-1} to recover 100% oil.

Thus we see that the weir principle has application in removing floating oil from API separators where there is no operational need to remove all of it and no point in removing underlying water; that pumping can thus be stopped when less than 100% oil is about to be collected; that such sufficiency requires layer thicknesses unimaginable in uncontained waters where Phase II spreading presents oil layer thicknesses of ~ 0.1mm; and that sweeping boom systems could never achieve the encounter rate necessary to produce and maintain the layer thicknesses needed for a weir skimmer to deliver 100% pollutant to a transfer pump operating at a rate equivalent to the encounter rate.

As to the influence of pollutant viscosity and the presence of waves, WSL showed that the results for Kuwait crude oil could be replicated for low viscosity kerosene, light diesel, gas oil and domestic heating oil; that the weir became blocked with more viscous oils such as lubricating, heavy fuel, and weathered crude oils; and that while the SLURP could tolerate surface ripples it failed completely in the smallest waves.

Thus, WSL concluded that the SLURP was well designed for its intended application in API separators and similar locations where oil layer thickness can be controlled by partial removal and where weir level adjustment is helpful in delivering percentage oil contents higher than otherwise possible, but that it was incapable of removing all of the pollutant without co-removing underlying water; that it was incapable of useful operation in the layer thicknesses of Phase II spreading in open water, irrespective of its viscosity/wave limitations; and that consideration should thus be given to preferential oil/emulsion adsorption and rejection of underlying water.

Article 78

As noted in article 70, adsorption discs were in use in mineral processing when BP introduced this concept to marine pollution response with its nominal 100 tonne per hour Vikoma disc skimmer in the early 1970s. However, having been primarily involved in evaluating BP's free-floating boom as in article 73, and in evaluating alternate booming concepts as in articles 71-75, it was only later when the nominal 25 tonne Komara Mini-skimmer had become available that WSL chose it for evaluation of the disc principle. The skimming head of the Mini-skimmer consists of a 54.5kg circular buoyant platform, 1.17 metres in diameter, incorporating thirty-two recovery discs 28 cm in diameter mounted in two semi-circular banks around the circumference. In operation, the pollutant-bearing surfaces of the rotating discs pass through paired plastic scrapers to remove the adsorbed pollutant to a collection reservoir from whence it is pumped to storage. The unit has a 5 hp Petter diesel with spark-arrester and overrun-valve which powers a Reyrolle A70 pump to supply hydraulic fluid to twin Danfoss OMP motors for disc-drive (pneumatic-drive is also available) and a Spate 3B induced-flow pump for transfer of pollutant to storage.

Variable disc-speed in relation to layer thickness is analogous to the variable pump speed of the SLURP weir skimmer. Thus, ignoring the role of viscosity in pollutant/disc adhesion and assuming 100% disc selectivity for pollutant over water, removal rate was expected to be proportional to disc speed and pollutant layer thickness. In fact, the WSL trial results showed that for low viscosity oils of 39 and 120cSt, removal rates increase with disc speed for constant layer thickness; that for a 4000cSt medium fuel oil emulsion containing 70% water, removal rate decreased with increase in disc speed; and that when plotted against log viscosity for a layer thickness of 75mm, removal rates passed from less than 1 tonne per hour at < log1 cSt viscosity through a maximum of 4 tonnes per hour at log 2 viscosity to virtually zero at log4 viscosity, such viscosity dependence showing little or no benefit over dispersants.

With regard to layer thickness, it was found that for < 20mm, removal rates fall rapidly to insignificance; that for > 20mm, removal rates rapidly reach maxima dependent on pollutant viscosity; and that the maximum observed rate was 17 tonnes per hour for a Kuwait crude oil with a viscosity of 39cSt at a layer thickness of 78mm and a disc speed of 135 rpm. Again, it was found that if disc speed is increased to improve pollutant removal rates, the rate of free water remocal also increases; that water content increases as layer thickness decreases; that while an increase in disc speed from 65 to 116rpm increased the removal rate of an 880cSt oil by 20% , it also increased the water content by a factor of 3 at a layer thickness of 20mm; that when the layer thickness of heavy fuel oil emulsions decreased from 80mm to 25mm, the free water content of the removed fluids increased by a factor of 2 . It was therefore concluded that disc skimmers are efficient only above a minimum slick thickness, that in the case of the Komara, this minimum is 20mm; that complete removal of pollutant from seawater surfaces is therefore impractical with such devices; and that the increasing water-contents in any such attempts would become inconsistent with the very concept of skimming.

Indeed, given that the penetration of the discs below the floating layer appear to contribute to this lack of skimming success at layer thicknesses below the minimum, WSL (D. H. Thomas) compared the removal rates for a 660cSt oil at a layer thickness of 170mm and at various disc speeds with that of the Spate pump itself at the corresponding speeds, but connected directly to a 76mm diameter hose with its inlet submerged in the oil layer. This comparison gave the following results:

Speed control, rpm	Recovery Rate, tonnes per hour	
	Komara	Spate Pump
65	3.6	5.8
115	7.3	8.2
130	12.5	16.3

Thus, it would appear that for layer thicknesses greater than the hose diameter, the pump itself gives a higher recovery rate than the skimmer and pump combined, though the combination maintains its performance as the oil layer decreases to 20mm. Disc skimmers of the above type are therefore widely used for the partial removal of floating pollutants from API type separators and are currently available in a range of nominal capacities from the Kebab 1500 of capacity 1.5 tonnes per hour, through 12 and 20 tonnes per hour, while a rim on the edge at a right angle to the plane of each disc, as in the so-called T-disc has been shown by others to increase performance as have toothed discs for higher viscosity fuel oils. Again, such disc skimmers are available with nominal capacities of 30 and 50 tonne per hour, while the heavy fuel oil Komara Sea Devil has a nominal capacity of 70 tonnes per hour, any quoted nominal capacity being attainable only at layer thicknesses maintainable in API separators.

Article 79

Prior to the evaluation of disc skimmers (article 78), WSL had evaluated adsorption-rope skimmers on the grounds that the fibres of their adsorption nap would tend to remain in the pollutant layer rather than rigidly penetrate to the water beneath it. There were two available versions. That of Oil Mop Inc (OMI) consisted of a central rope core through which fine polypropylene strands had been passed to radiate out to a 23cm diameter nap along the length of the core; while that of Oil Recovery International (ORI) version consisted of polypropylene strands woven into webs which were entwined into 31 metre lengths in three different ways i.e. as a four web core to give ropes of 15 and 30 cm diameters and as a six web core to give a rope of 30cm, these tending to lie flatter on the surface than the OMI versions.

The ORI rope passed between two variable speed drive-rollers, which squeezed the adsorbed pollutant into a sump for pumped transfer to storage while the then pollutant-free rope returned to the slick and back through a floating pulley moored at a distance sufficient to optimise contact time between rope and slick, while power was supplied to the variable speed drive/squeeze rollers and to the transfer pump by an explosion-proof 6hp diesel engine.

Variable rope/pump speed in relation to layer thickness was analogous to the variable pump speed of the SLURP weir skimmer and to the variable disc/pump speed of the Komara range of disc skimmers. Thus, ignoring the role of viscosity in pollutant/fibre adhesion and on the assumption of 100% selectivity of the fibres for pollutant over water, the recovery rate was expected to be proportional to rope speed, layer thickness and the capacity per unit length of differing ropes for adsorbed pollutant. The WSL results showed that the OMI mop adsorbed diesel oil of viscosity 6.6cSt, Kuwait crude oil of 34.8cST, Kuwait emulsion of 232cST, heavy fuel oil, and Beatrice crude oil even when solid at ambient temperature; that the recovery rate for the heavy fuel could not be measured in the absence of steam heating to reduce its viscosity for de-sorption; that the rope speed should be reduced for the thinner layers to avoid water agitation and to allow time for these thinner layers to spread to the adsorbent; and that water recovery increased with decreasing pollutant layer thickness though much ran off in the vertical lift to the rollers and did not reach the collection sump.

The ORI equipment came in three sizes, the 1000 (Piranha), the 2000 (Barracuda) which had two mop bands and the 3000 (Shark) which had one, the first two being intended for use from shoreline hard- standing and the third for use from an inshore workboat. While all three employed variable speed drive/squeeze rollers, the 3000 also drew the band through a ring to assist de-sorption, and the 2000 and 3000 were equipped for steam-heated de-sorption.

The results obtained by WSL evaluation of the ORI equipment, were similar to those obtained for that of the OMI and indeed for the Komara disc skimmer. Thus, it was found that maximum removal rates could only be achieved at pollutant layer thicknesses above 20mm; that mop speed must be reduced at lower thicknesses to allow time for the pollutant layer to flow/spread to the mop band; that recovery rates were not proportional to cross-sectional area of rope or band unless saturated with pollutant; and that consequently it is more efficient to have a number of small cross-section bands rather than to have a single large cross-section band, particularly for use in unconfined layers. Evaluation of the smaller two of these devices was conducted as below, the Shark version having been unavailable.

Oil Type	Viscosity cSt	Temperature°C	Device
Diesel	7.25	12	Barracuda
		16	Piranha
Kuwait Type	10.10	12	Barracuda
Kuwait Crude	38.83	14	Piranha
Topped Kuwait	169.90	16	Piranha
Ekofisk Emulsion (40% oil)	628.80	12	Barracuda
Kuwait Emulsion (50% oil)	853.30	14	Piranha
Heavy Fuel Oil	3,200.00	20	Barracuda

Maximum removal rates for the Piranha were 1.0 m^3h^{-1} for diesel oil; 1.3 m^3h^{-1} for Kuwait, 1.25 m^3h^{-1} for Topped Kuwait, and 0.86 m^3h^{-1} for Kuwait Emulsion, while for the Barracuda they were 3.3m^3h^{-1} for the diesel oil, 4.0m^3h^{-1} for the Kuwait Type, 2.11m^3h^{-1} for the Ekofisk Emulsion, and 1.2m^3h^{-1} for the heavy fuel oil.

However, these removal rates at 20mm layer thickness, together with the water-shedding prior to arrival at the squeeze rollers and the wave-following characteristics of the floating rope, encouraged the development of a multi-band system for use at sea, despite the pollutant layer thickness of unconfined Phase II spreading being two orders of magnitude thinner than 20mm. The result was the Force 7 system of ORI which instead of a single endless mop, consisted of a fan-array of five lengths of mop material which was repeatedly cast and recovered through the squeeze rollers. When cast into the floating pollutant the lengths were separately fixed at their forward ends at intervals along a bridle and maintained in a lateral position with respect to the towing/recovery vessel by means of a paravane, while the trailing ends were attached to each other. Thus, when towing, the mop lengths were displayed in fan formation to maximize swath width and pollutant encounter/absorption rate. To achieve this deployed array, the forward end of the outer mop length was attached to a ring out-hauled along a guide wire between ship and paravane thus extending the bridle to which the other four forward ends of the mop lengths had been attached at intervals as described above, while to draw in all the mop lengths for parallel passage through the squeeze rollers, the ring was hauled inboard. Thus the array could be repeatedly deployed for pollutant absorption and de-sorption while the paravane remained in position.

The dimensions of this system were such that the saturation capacity per cast was 7m^3 of pollutant representing the nominal capacity, while WSL sea trials with Phase II oil layer thickness removed 0.6m^3 of oil with 0.6m^3 of water, while supplementary investigation in the laboratory confirmed the nominal capacity by immersing a length of mop in an oil layer of 200mm thickness which resulted in 28kg being absorbed per metre of mop length. Detailed studies of the type undertaken for the small inshore mops reported above were not possible for the larger seagoing version. However, comparison of inshore mop performance in the laboratory at the layer thickness corresponding to that of the sea trial with the ship moving through the oil layer, gave a pro rata result of 10% of the nominal capacity of 7m^3 per cast i.e. 0.7m^3 per cast which is in good agreement with the 0.6m^3 actually measured at sea, suggesting that for thicker layers of more viscous oils, results would again be pro rata with respect to the smaller versions.

Article 80

Having evaluated adsorption discs, ropes and bands as previously described, WSL evaluated the adsorption belt embodied in the Marco Catamaran Mark V, made available to it by the Department of Salvage of the US Navy. This special purpose vessel was of welded aluminium construction, 36 ft long, 12 ft beam and approximately 17 tonnes fully laden. It was powered by a 100hp Detroit diesel giving 5 knots when proceeding to the spill site and up to 3 knots astern when in pollutant removal mode. The adsorption belt (3ft wide, 30ft long and 1 inch thick) operated between the hulls while water was inducted through the belt and pollutant onto it by a 16hp pump to reduce the pollutant loss at encounter-rates of more than 1 knot. The collected pollutant was then squeezed from the belt by the upper belt-roller into a storage tank from which co-collected water was intermittently discharged to the sea over the belt to retain any residual oil-content, while the collected pollutant was intermittently transferred to a larger tank-vessel for return to shore, the nominal capacity of the transfer pump being 200gallons per minute at 60lbs per square inch. All operations were hydraulic, with controls and instrumentation being in a small deckhouse.

In the sweeping mode with the stern-doors open and the adjustable-angle belt set at about 30° to the horizontal to optimise free-water drainage, the encounter rate in a Phase II slick of 0.1mm thickness would be ~0.2 tonnes per hour at a sweeping speed of 1 knot, though assuming maximum benefit from the induction pump, this could rise to 0.6 tonnes per hour at 3 knots. Encounter-rate could, of course, be increased by placing the unit at the apex of a V-shaped boom array towed by two additional vessels, and it had earlier been shown possible to use the unit’s own power to turn a length of single-ship towed boom into a splayed J-shape, the encountered pollutant being thus deflected to the belt by the long arm of the spayed-J..

Performance evaluation by WSL showed that the belt acts similarly to adsorption ropes and bands with subsequent water-shedding being facilitated by the operational belt angle, horizontal ropes and belts generally being in the floating pollutant for longer than necessary to adsorb what they can and not long enough in the air to shed the water they could and should prior to reaching the squeeze-rollers. However, the quoted removal capacity of the Marco belt at 60 tonnes per hour for 10,000 cSt pollutant in independent skimming mode at 1 knot would require a layer thickness of 30mm or a 300m mouth-width when V-boom assisted, while at 3 knots the *pro rata* requirements would be 10mm and 100m.

In any case, I have always maintained that skimming units must follow the pollutant as it moves vertically on waves; that vessel-incorporated skimming units have inertial masses and linear dimensions too large for such wave following; that they heave bodily and end-pitch in such a way as to draw water and floating pollution under them when they rise and to displace it again when they descend; that the ensuing turbulence breaks the wave-following layer into dispersed droplets rather than maintaining this layer as needed for its removal; and that the ability of light, small and flexible skimmers to maintain layer-continuity in the presence of waves is lost by attachment to larger craft.

Thus, while the Marco skimmer design had anticipated and addressed the need for selective adhesion of pollutant rather than water, had arranged to shed water from the angled belt, and had sought to increase operating speed by innovative-use of an induction pump, its design capacity was nonetheless in excess of its likely encounter rates in unconfined slicks at sea even if supported two boom towing vessels to increase its swath width and a tank vessel to receive its recovered pollutant at its intended or even its actual rate, while its own overall dimensions were already too large to achieve reliable recovery in the presence of the sort of waves unavoidable at sea in all but the calmest conditions (article 81).

Removal-Unit/Ship Combinations

Article 81

The general conclusions on the disturbing influence of the heaving and pitching of floating skimmers, especially when rigidly attached to even small boats, can be extended to their rigid attachment to ships which neither heave nor pitch in the wave amplitudes and lengths which thus affect boats, but which nonetheless proceed as a wave-train along the sides of ships to which skimmers might be rigidly attached. The opportunity to observe the effect of such attachment arose when the US Navy Department of Salvage invited WSL to evaluate the French Cyclonet removal system which had been designed for just such attachment. This combination of recovery-unit and ship manifested the belief that attachment to a ship's side, would enable water and surface pollutant to pass though a square duct-opening half above and half below the ship's load-line into an inverted cone to create a vortex; and that this vortex would cause the lower density pollutant to accumulate centrally for pumped removal to the ship's tanks while the higher density water exited to the sea through the open-bottomed cone.

However, while centrifugal oil/water separation is a recognised technique requiring the mixture to be pumped through the cyclone at high velocity, the Cyclonet relied on sufficient velocity being available from the forward movement of the ship, despite its having to overcome the internal backpressure of the unit itself before any useful centrifugation could ensue. This seemed unlikely, while it seemed quite likely that backpressure would counter the initial entry of oil/water, that this together with the submerged-bulk of the unit would create a 'bow wave'; that, while some fluid might pass through the system, some would pass over and under it depending on the amplitude and length of the waves in which it was apparently expected to operate. Indeed, the unit would itself be likely to ensure the passage of pollutant beneath it when moving forward at ~1knot even in the complete absence of waves.

In the event, all of these phenomena were observed with the unit attached to the side of *Seaspring* as she proceeded at the speed recommended for vortex inducement with waves of 30-50cm amplitude passing along her side. Again, samples taken from the recovery pipe positioned in the central core of the presumed vortex showed oil concentrations < 1000 ppm (0.1%) in even calmer conditions while the WSL variable thickness oil carpet laid ahead of the unit was sufficient for the recovery concentration to have been 1% assuming all the oil to have been dispersed to the entry duct's average water depth of 0.5 metres. Thus, the extractable inner core contained only 1/10 of the presented oil, showing that the negative effect of waves and associated turbulence to have been as significant as was predictable.
This dispersion of floating layers by the turbulence arising from the incompatibility of the inertial-mass/linear-dimensions of skimmers, boats and ships, with the amplitude/length of waves, also arises when booms are coupled to integral skimming-craft and when differing booms are coupled one to another. Thus, having found it essential for skimmers to follow the sea/oil/air interface in waves without disturbing the pollutant layer and for booms to be light and flexible enough to follow this interface without causing the layer to overtop or pass beneath them as it would a rigid bar, it has also been found that even when the boom is satisfactory in this regard, the point of its sealed attachment to a skimming craft such as the Marco V, experiences an increased pitching amplitude and a phase lag with respect to the boom itself; and that such incompatibility produces severe stressing and causes the boom to be lifted clear of water-oil-air interface or driven beneath it *i.e.* to cause damage to the vessel-boom connection and/or loss of the pollutant intended for removal.

Thus, a hull lifting to a wave and pitching into the next, causes water displacement associated with high linear and vortex velocities which entrain pollutant droplets into the water to escape under whatever boom draught remains. Again when the end of a hull lifts, the wave is already passing under it and accentuating the lift while the volume vacated draws in water from the immediate vicinity thus entraining pollutant this time to be lost under the hull, while the subsequent dropping of the hull-end displaces this water in a manner which prevents the approach of pollutant. Thus the incompatibility of movement of skimming-craft and boom, pumps pollutant past both. Such considerations also apply to the joining of differing booms, to extents depending on the difference in their buoyancies/flexibilities, irrespective of how clever the sealed-coupling design might be.

Article 82

It has been observed that water carries pollutant beneath any barrier when its velocity, v, relative and normal to the barrier exceeds ~1 knot, that the oblique arms of a V-shaped boom array can be towed relative to the water until v cosine θ = 1knot, where θ is the ½ angle at the apex; but that the 1 knot limit still applies at the apex where the skimmer presents a barrier at 90° to the forward movement of the whole array. However, as reasoned by Commander Teasdale, it might be possible to avoid such escape by deflecting the pollutant over an adjustable weir by a suitably angled wave-damping flexible canvass sheet into an internal calm region which after re-coalesce if necessary, could be pumped to storage. On this basis he constructed his Oleanic catamaran skimmer for use at the apex of V-boom arrays and offered it to WSL for evaluation. In this catamaran, the weir is positioned between the hulls at its centre of gravity and buoyancy so that a horizontal slot between the after lower edge of the deflector and the weir lip is minimally displaced by the pitching and heaving of the catamaran in waves.

This catamaran was 5metre long with a beam of 3.5metres and a weir width of 1.53 metres and was designed to take a pollutant/surface-water layer thickness of 2.5 cm at 1 knot at which the boom-assisted encounter rate was intended to be 45 tonnes per hour. However, with an upper pollutant-layer thickness of 0.1mm, the encounter rate of the unit itself would be only 0.3 tonnes per hour. However, with WSL oil carpets of 0.3 - 0.35mm, it recovered 90% of the oil in calm conditions and with a V-boom array with a mouth of 100m it would have been expected to collect 30 tonnes per hour. It was equipped with twin transfer pumps with a total capacity of 60 tonnes per hour. Nonetheless, even the smallest waves were observed not to be sufficiently dampened by the canvass deflector to avoid driving the pollutant beneath the weir lip to escape behind the catamaran: waves again defeating intention.

Having seen that free-floating continuous rope or band skimmers had very substantial wave-following capability; but that increasing speed through the drive-rollers gave rapidly diminishing returns because the increasing shear forces reduced pollutant attachment, it was also seen that rope/band encounter-rate could be increased and shearing eliminated by mounting parallel rope bands between the hulls of a catamaran in such a way as to pass through their squeeze rollers at zero velocity relative to the forward motion of the catamaran: an arrangement which not only offered flexibility as to encounter rate but also as to linear adsorption capacity depending on the number of ropes or bands thus deployed. Such a zero relative-velocity system, operated by the Milford Haven Harbour Authority, proved effective at the *Sea Empress Incident* in 1966 (article 111).

Article 83

Returning to weirs, BP/Vikoma developed the figure-8 configuration of the original free-floating boom, initially intended to operate with the Vikoma disc skimmer, to produce the Weir Boom System by placing 10 weir slots each 1.2 metres wide and 75mm deep between the air and water tubes of a 60 metre length of figure-8 boom. The weirs were in this manner located at the water-oil-air interface and because of the general flexibility of this boom system are thus intended to follow this interface in the presence of waves. Thus, pollutant and water pass over the weir to enter a collection gallery which runs behind the figure-8 boom and connects its individual weirs. This gallery is formed by another figure-8 system consisting of a second air buoyancy tube and a lower discharge tube, the latter being fitted with 10 weir pumps in series and with the former carrying the hydraulic power lines and stabilising the main boom profile and the presentation of the 10 weirs to the floating pollutant. The positioning of the pumps in the horizontal discharge tube allows pollutant and free water to flow from the upstream pumps towards the recovery ship and its deck-mounted lift pumps.

Having developed an axial flow propeller pump and a vane pump for the discharge tube, the latter was chosen for its suction-induced flow, its higher viscosity/entrained-air tolerance, its action as a non-return valve and its blockage clearance by flow-reversal. This pump weighed 30 kg in air, was driven hydraulically by a 4kw motor, and delivered 62.5 tonnes per hour at 320rpm against a head of up to 0.7 bar, while the two deck-mounted 150mm centrifugal pumps had a combined capacity of 625 tonnes per hour (equivalent to the 10 weir pumps), could self-prime to 8.6 metres and could operate against discharge pressures up to 2 bar. In addition, the ship could hydraulically operate a dump valve at the far end to drain the system prior to its retrieval onboard. A 120m length containing the 60m weir section was to be connected to the recovery vessel at one end and to a 500 m long deflection boom at the other in an splayed J-configuration with a ship at each end and with the possibility of a 3-Ship W-configuration with the recovery ship at the central apex. In the event, a prototype J-configuration was deployed at the Ixtoc Blow-Out under two distinct wave conditions as observed and reported by WSL (B.O. Dowsett).

Thus, the system showed good wave following ability in a 6 knot wind with a 0.7 metre swell of 12 second period in which emulsion rafts/windrows of an estimated thickness of ~ 1mm were estimated to be covering ~ 50% of the sea surface and to be entering the boom array at a relative speed of 0.5-1.0 knot, while recovery rates where between 355-520 tonnes per hour of which 40% was emulsion and 60% free seawater, all of which was recovered onboard by the deck-mounted pumps operating at ~ 70% capacity. Again, in the less favourable conditions of a 15-25 knot wind with a 2 metre swell and 5 second period the recovery rates were 350-480 tonnes per hour at the same emulsion/free-water ratio of 40/60% while the viscosity throughout was estimated to be in the range 5,000-8,000cSt. For this evaluation of performance, deployment was achieved in 160 minutes and recovery in 145 minutes.

Further to the weir approach and intended for use within a towed boom, Vikoma offered the circular weir, Cascade LP3000 skimmer, with a three-float equilaterally adjustable weir depth and a nominal pump capacity of 183 tonnes per hour, though this was not evaluated by WSL.

Semi-Dedicated/Dedicated Ships and Ships of Opportunity

Article 84

Seagoing booms and skimmers and the combined boom/skimmer which is the Weir Boom, are designed for deployment from ships of opportunity, as integral parts of dedicated craft such as the catamaran-mounted belt skimmer of the Marco V, the weir of the Oleanic and the rope/belt of the Zero Relative Velocity units, and as dormant installations on ships which normally fulfil other functions such as liquid transport or dredging.

The original Sweeping Arm System was developed from that of a small dedicated vessel system which had already operated for a number of years in Rotterdam Harbour, both sweeping arms of which consisted of a rigid metal curtain between two terminal buoyancy chambers, angled to deflect pollutant to the forward-moving parent vessel from which they floated independently. The chamber nearest the vessel contained a wave compensating weir and submerged pump for pollutant transfer to the vessel. An intermediate-sized system with arms 13metres long was developed for the *Smal Agt* of the North Sea Directorate, and later, those of the dredger *Cosmos* were 20 metres in length. When not in use, the arms were stowed onboard the *Cosmos* in modified lifeboat davits which for use rotated outwards through 90° to lower the sweeping-arms to float freely with the lowering/hoisting tackles slackened-off, the arms then being positioned at 60° to the ship's centreline to provide a swath width of 55 metres.

The lack of wave following ability in the sweeping arms is compensated for by making them high and deep with the associated buoyancy being as large as necessary. Again, while the floating weir in its buoyancy chamber might not follow the internal wave oscillations sufficiently to avoid water ingress, it need only minimise them, the pumping system inlets being submerged in the said chamber, and some free water being necessary to enable the more viscous pollutants to be pumped, submersible pumps having the advantage of pushing rather than 'pulling' the pollutant up and over to the onboard storage tanks for gravity separation of its associated free water and *in situ* discharge as initially intended.

Cosmos was 113.60 metres in overall length and 20 metres in beam. Her two variable-pitch propellers each driven by a 5,200hp diesel engine gave her 13.7 knots at her dredging draft of 8.35 metres, while her manoeuvrability was enhanced by a 750 hp bow-thrust unit. Her dredge-spoil/pollutant-storage hopper had a capacity for 5,375m^3 while her side tanks provided capacity for a further 780m^3 of liquid pollutant, giving a total capacity in excess 6,000 tonnes. The designers claimed that the *Cosmos* could sweep pollutants at speeds between 2 and 3.5 knots with an expected recovery rate of 290m^3h^{-1} per mm of pollutant layer thickness at 3knots. Be that as it may, pollutant viscosity still caused problems. For example, at the *Katina Incident*, the ships *Smal Agt*, *Cosmos* and *Hein* equipped with their respective sweeping arms collected only 800m^3 over a period of 3 days which averages to only 90m^3 per ship per day, or say, 9m^3 per hour over a 10 day period (articles 42, 74, 76 and 88).

Article 85

Another approach was to create a fully dedicated multi-purpose pollution response vessel. Such was the *Fasgadair* commissioned in March 1981 by BP for duty in the Forties and Buchan oil fields the terminals at Hound Point in the Firth of Forth and at Sullom Voe in Shetland, covering training, equipment-evaluation and response at sea, in coastal waters and onshore, for which wide geographic and diverse activity, continuous use was expected. For seagoing response, the ship carried the Vikoma Seapack figure-8 boom and its Weir Boom analogue, the smaller Vikoma Coastal-Pack, a range of disc skimmers (a Seaskimmer 100, a Seaskimmer 50 and a number of Komaras). The ship also had an emulsion storage capacity of 1,578 tonnes in 9 tanks fitted with heating coils and provision for demulsifier addition. She was also fitted for spraying operations and had storage capacity for 18 tonnes of dispersant with additional capacity for 208 tonnes in some of the tanks intended for emulsion storage.

For shoreline response, the ship could be beached, its bow-doors opened and its loading/discharging ramp lowered. This 15 tonne capacity ramp could land two amphibious vehicles: an Alvis Stalwart six-wheel rough terrain carrier of 5 tonne capacity which, with its Atlas loader, could itself lift 3 tonnes of equipment and achieve 40mph on the road and 5 knots on water; and a 32 foot DUKW wheeled vehicle capable of 6 knots on water and fitted with a towing winch for inshore boom handling. In addition, the ship carried three work boats launched from deck by a 10 metre radius crane, one being an 8 metre GPR personnel/equipment carrier and inshore boom handler capable of 20 knots, another being a 10 metre towboat capable of 10 knots and the third being a purpose-built fast boom layer carrying 400 metres of heavy duty boom with a service speed of 20 knots.

As to making use of ships of opportunity, WSL evaluated the modified oil-mop system which was the Force 7 developed by ORI for use on the after deck of any offshore supply/service vessel with tank capacity for recovered pollutant. This system deployed five mop bands of differing lengths in the form of a fan in which the trailing ends are joined at a point while the leading ends are attached to rings which travel on a wire stretched outwards from the side of the ship by a paravane when the outer ring is out-hauled through a pulley on the paravane, the fan-spread being limited by the leading ends of the mop bands having been attached at intervals to a restraining bridle. Thus, in operation the un-spread bands were cast from the recovery/squeeze rollers, the fan was spread by means of the out-haul, the bands adsorbed pollutant, the out-haul was freed and the bands recovered through the rollers and the desorbed pollutant transferred to onboard storage.

Laboratory measurement by WSL showed by immersion in a 200mm layer of oil that 1 metre of band adsorbed 28kg of oil and by calculation on this basis, that the saturation capacity per cast would be 7m^3 of oil, while sea trials with relatively small amounts of oil discharged at around 1mm thickness across the width of the fan, gave results of 0.6m^3 of oil and 0.6m^3 of free water. Again, laboratory measurement by WSL on an inshore ORI mop band at the layer thickness laid down in the sea trial of the Force 7 and at the mop speed through the rollers corresponding to that at sea while the ship moved forward through the oil layer showed 10% of saturated recovery, thus predicting a Force 7 recovery rate at 10% of 7m^3, in good agreement with the 0.6m measured per cast in the sea trial. For thicker layers, recovery rates would be expected to be *pro rata* as in article 79.

Investigation of High Viscosity Recovery

Article 86

WSL continued to develop its prototype Springsweep System which had recovered 9m^3h^{-1} of emulsion at the 1976

Ekofisk Blowout, by seeking to extend its pumping capability to higher viscosities, in the knowledge that the optimal viscosity for removal by disc skimmers was 100cSt; that oil mops adsorbed such viscosities as required heat for de-sorption and pumping; that the Weir Boom and its transfer pumps had tolerated viscosities estimated at 5,000-8,000cSt; and that the transfer pumps of the Sweeping Arm had struggled at 15,000cSt (articles 42 and 84).

Thus, WSL sought to identify a pumping system which could transfer any pollutant mobile enough to flow over a weir and turned its attention to the positive displacement principle as exemplified by the Archimedean screw. However, the performance of this screw in its original form is limited by the back-pressure in the transfer hose when the screw simply turns in the fluid without pushing it forward, a problem overcome by a rotary disc with slots which intersect and seal the screw to prevent backward passage of fluid as pressure builds. However, the particulate-content of coastal and shoreline pollutants requires relatively large tolerances which limit the tolerable back pressure to about 2 bar for low viscosity fluids such as water while the more viscous oils and emulsions for which this system was now intended, require tolerances sufficiently close to tolerate back-pressures up to 10 bar and transfer hoses of maximal handling-diameter and minimal length. With these considerations to the fore, the GT-185 Archimedean screw pump of Gustav Terling Aktiebolaget achieved *inter alia* the transfer of 15,000cSt oil through 40 metres of 15.24 cm diameter hose at a back-pressure of 4 bar.

In any case, WSL already knew that the nominal transfer pump rates from skimmers could be achieved only at equivalent encounter rates none of which could readily be achieved in practice; that were they to be achieved by sweeping-booms, skimmers *per se* would be redundant because such layer thicknesses could be recovered by direct pumping through a floating hose; and that the rate determining factor in overall recovery would then be the rate of viscosity-dependent gravity flow of such layers into the said hose, were the pump itself able to transfer to storage at this rate. Accordingly, we decided to determine this viscosity-dependent flow and to identify the most viscosity-tolerant pumping principle for transfer to storage.

Thus, we measured gravity-induced flow as a function of viscosity by recording the time taken for a given quantity of oil to flow through a slot 150mm wide by 100mm deep when totally immersed in the oil. To do this, a slot of these dimensions was cut in the side of a 35 litre container, 100mm from its top. By locating the container so that the whole of the slot was immersed in oil floating on water in a sufficiently large test-tank, the time taken to fill the container to the lower lip of the slot (28.3litres) could then be used to compute the rate in m^3h^{-1} at which oil would naturally flow into a hose-end or other inlet of any dimensions when similarly immersed in floating oil of any layer thickness..

This approach was used to measure natural flow rates as a function of viscosity for comparison with pump rates at these viscosities, and to assess the rate enhancements achievable by water ‘lubrication’ in conventional pumps and by air ‘lubrication’ in vacuum pumps. For reference, it was established that natural flow rates decreased from $35m^3h^{-1}$ at 2,000cSt to zero somewhere in the viscosity range 8,000-9,000cSt. For these experiments, oil and emulsions in the viscosity range of interest were placed to a depth of 200mm on the surface of water contained in a 2.4 metre diameter tank to a depth of 0.7 metres. The transfer hose had its diameter submerged in the oil layer for transfer to a receiving hopper situated above the 2.4m diameter test tank so that recovered fluids could be returned to the test tank for repeat experiments by opening a $230cm^2$ orifice in the hopper-bottom.

The pumps used in these experiments were a 3 inch (10mm) Spate with a water pumping capacity of $30m^3h^{-1}$ and a Renvac 3/600 vacuum loader comprising a 45hp Perkins Diesel and an SR 170 Rootes Blower to be used as an air conveyer in which air was to be the conveyer/lubricant by which the oil or emulsion was to drop into the $3m^3$ collection hopper to which the blower, acting as an air conveyer, was connected by a 3metre long 100mm diameter airtight suction hose, while the hopper was also connected to the weir slot by similar hoses of various lengths and cross-sections in the course of the experiments.

Article 87

The investigative system of article 86 gave the results tabulate below for the 10mm Spate pump.

Transported Substance	Pump Rate m^3h^{-1}	Natural Flow m^3h^{-1}
Water	30	-
Ekofisk emulsion (1500cP)	11	10
Ekofisk emulsion (2000cP)	10	-
Ekofisk emulsion (2000cP) + 25% water	25	-
Ekofisk emulsion (7000cP) + 10% water	8	4.5

Thus, we see that there is a reduction in pump rate on changing from water to emulsion; that at a viscosity of 1,500cP the pump rate still equates to the natural flow rate through the weir entrance; that with 25% water as conveyer/lubricant the pump rate almost returns to that of water; and that 10% water as conveyer/lubricant maintains a pump rate for 7,000cP at almost the pump rate for 2,000cP and at the natural flow for the 1,500cP, while for the 7,000cP emulsion 10% water maintains almost the pump rate for 2000cP at about twice its own natural flow rate and at nearly the natural flow for 1500cP; and that clearly the deliberate or unavoidable addition of free water in small amounts is beneficial.

The need for an airflow in the vacuum system was easily confirmed by immersing the open end of the vacuum hose over and into the pollutant thus obtaining no pollutant flow by terminating the airflow which could be resumed by provision of a 25mm air inlet pipe through the hose wall above the immersed hose-end to replace the static vacuum with a low-pressure air flow. Subsequently a 25mm water inlet from beneath the pollutant layer was also provided to benefit from the water 'lubrication' earlier revealed by the Spate pump experiments.

The results obtained by operating at a working vacuum of 250mm Hg with and without water 'lubrication' at different hose lengths and diameters are tabulated below.

Transported Substance	Hose Length x Diameter m x mm	Pump Rate $m^3 h^{-1}$	Natural Flow $m^3 h^{-1}$
1500cP emulsion	30 x 75	12.5	10.0
+ water		15.0	
1500cP emulsion	15 x 75	17.7	10.0
+ water		19.5	
5700cP emulsion	15 x 75	8.9	7.0
+ water		19.5	
4000cP emulsion	30 x 100	14.0	15.7
+ water		27.2	

Thus, we see that the enhancement achieved in pump rate over natural flow rate diminishes with viscosity; that the enhancement achieved by air conveying is increased by water; and that pump rate increases with increase in pipe diameter and decrease in pipe length.

The results obtained by operating at a working vacuum of 375mm Hg at yet higher viscosities with one pipe length, with half of this length and with this half twinned are shown below.

Transported Substance	Hose Length x Diameter m x mm	Pump Rate $m^3 h^{-1}$	Natural Flow $m^3 h^{-1}$
7000cP emulsion	30 x 100	18.2	7.8
4000cP	15 x 100	29.0	15.7
5700cP	Twin 15 x 100	56.5	31.4

Thus, we see that even at higher viscosities, performance is enhanced over normal flow by use of wider hose, by shorter hose length, and by twining the pipe half-lengths.

Article 88

Having investigated the transfer rates achievable with the Renvac vacuum loader as reviewed in article 87, WSL proceeded to investigate the relationship between airflow and partial vacuum pressure with the results tabulated below.

Renvac Connection	Vacuum mm Hg	Airflow $l\ s^{-1}$
To air	50	354
To open hopper	88	312
To closed hopper and thence to air by a 30m x 100mm hose	250	263
To closed hopper and thence to oil by a 30m x 100mm hose	375	177
To closed hopper and thence to air by a 15m x 100mm hose	188	264
To closed hopper and thence to oil by a 15m x 100mm hose	325	201
To closed hopper and thence to air by two 15m x 100mm hoses	120	297
To closed hopper and thence to oil by two 15m x 100mm hoses	355	189

Thus, we see that that the controlling parameter is linear velocity of the transporting air; that the benefits of increasing hose diameter to decrease friction losses are consequently limited; and that hose-handling problems limit this approach in any case. In addition, it was found that air ingress was insufficient with a 25mm pipe; that a

152mm pipe was required; but that this placed half-way across the mouth of the hose-inlet significantly blocked the entry to pollutant. However, the solution to this problem was to arrange for the horizontal transfer hose to float with of its cross-sectional area partially in the air above the pollutant layer, for it to have an upward-vertical 25mm pipe to provide auxiliary air should the hose entry become intermittently submerged by wave action, and for a downward-vertical 25mm pipe to provide lubricant-water from beneath the layer of floating pollutant.

The next step was to design what was effectively a wave-responsive weir skimmer for the end of the horizontal floating hose of a deck-mounted Renvac vacuum loader, now perhaps better described as an air-conveyer. Thus the hose-end skimmer was basically a fluted metal inlet to a 15m floating vacuum hose with 25mm air and water pipes projecting vertically from its respective upper and lower surfaces and with in-built positive buoyancy sufficient to maintain the pollutant/air interface about halfway up the horizontally fluted opening. Thus, while the wave-following characteristics of this low inertial mass hose-end fitting would be somewhat reduced by its attachment to the floating vacuum hose, both are isolated from the deck-loaded high inertial mass pumping system, thus making them as free as possible from all movement-restraining inertial mass. Having, thus designed this skimming/transfer system, it remained only to combine it with the WSL prototype boom system of articles 74 and 76)..

This system had its origin in an early sea trial of the separate tension line boom of Captain Erling Blomberg in which the intention had been to tow one end by *Seaspring* and the other by a hired fishing boat. However with the latter choosing not to operate in the prevailing weather, I asked Erling to cut down his boom to a length suitable for deployment from the jib of *Seaspring's* forward crane positioned horizontally and at right angles to the ship‘s centre-line to complete our investigation of boom in the absence of fishing-boat assistance. This was the means by which this boom length was subsequently deployed in removing $9m^3h^{-1}$ of emulsion with a deck-mounted 10mm Spate pump at the Ekofisk Blow-Out of 1976 (article 76).

In the meantime, in order to encourage localised thickening of the pollutant layer, Erling had configured a small U with the innermost element of the larger U of his towed boom, by connecting the heads and feet of two of his curtain-spreader battens with short bridles. In addition, I had noticed that when a small amount of pollutant remained in this so-called oil-trap, it developed a slow circular motion, non-contiguous with the vertical curtain itself when being towed. This, in turn, suggested to me that the encountered water was not diving under the curtain at the tangential point normal to the forward motion, but was escaping from the slow vortex created at the centre of the trap by this forward motion. Again, in support of this hypothesis, we observed this vortex to be destroyed and its indicative pollutant lost in the usual way, only when towing speed was increased to ~3 knots, thus tripling encounter rate by what was subsequently named Captain Blomberg's Circus, as recalled in articles 32 and 73.

Article 89

From the separate tension-line boom trials recalled above and the Renvac air-conveyor investigations reviewed in articles 86 - 88, WSL developed the single-ship Springsweep System, by replacing the initial boom deployment from the forecastle crane-jib of *RV Seaspring* with deployment from an A-Frame and jib mountable on the side-deck of tank-ships of opportunity and by replacing the 10mm Spate pump with the Renvac air conveyer and with the floating hose-end/weir system deployed in the oil trap of the tension line boom to take advantage of the so-called Blomberg Circus as far as possible.

The Mark I A-frame (B.O. Dowsett) comprised two 10 metre lengths of 150mm square-section mild steel of 10mm wall thickness welded together at their tops, spread 2.3 metres apart at their feet and hinged to a 2.3m x 1 m rectangular base-frame constructed from 100mm x 100mm hollow section lengths of 10mm wall thickness, the corners of which were attached by chains to deck-mounted eye-bolts. A hand-operated 1000kg capacity winch was attached to one of the A-frame legs 1metre above the base to raise and lower the 15metre jib which was hinged at the mid-point of a cross member between the A-frame legs 2 metres above the base. The jib was constructed from two lengths of 200mm x 150mm hollow section steel of 8mm wall thickness with the 200mm dimension vertical, the inner being 10metres long with a universal hinge to the A-frame cross-member at the inner end and with a joint at the outer end to take its 5 metre extension. Both A-frame and Jib were equipped with all necessary stabilising stays, boom towing/controlling lines, jib topping-lift and handling-lines for the pollutant transfer hose.

Other jib/boom arrangements are possible. A floating jib freely-attached at the inner end to the ship's side with the outer end supported by a float and strut, would dispense with the A-frame, while use of a paravane would dispense with both A-frame and Jib. However, we know that 0.18 m^3h^{-1} is the encounter rate per metre swath width, per 0.1mm layer thickness, per knot of forward speed; that it is only 3 m^3h^{-1} for a single ship-mounted boom deployment of 15 metre swath width; that 80% water content of the ensuing emulsion increases this to 12 m^3h^{-1}; that windrow formation concentrates the pollutant by another factor of perhaps 5 - 10 by removing it from the inter-windrow spaces; and that windrows themselves are roughly commensurate with the 15metre single-ship sweeping width.

While this may be disappointing for removal enthusiasts especially when we recall that 12m^3 of emulsion of 80% water-content contains only 3m^3 of oil, we nonetheless know that multi-ship operations in sweeping both windrows and inter-windrows, encounter the average thickness of 0.1mm; that this recovery has to be averaged over two towing and one recovery ship; and that single-ship operations are thus likely to be the more cost-effective. Again, we know that the single-ship option facilitates observation of pollutant escape beneath the boom and the control of ship speed to avoid it; and that the Blomberg Circus effect within the pollutant trap may increase encounter rate by a further factor of three. Again, deployment from both sides of a single ship would provide another factor of two. In any case, in a sea trial of the final Springsweep System, WSL recycled through its oil trap a 12,000cSt emulsion at a rate of 60m^{3}h^{-1} which at 80% water-content would contain 15m ^{3}h^{-1}of oil.

However, we abandoned an intended trial with a pollutant viscosity of 20,000-30,000cSt at 15°C at the *Katina Incident* when we found that the layer thickness had been locally increased by funnelling through an open-apex V-boom system ahead of the Sweeping Arms, that when RV Seaspring rolled gently in such a layer, it stuck to the rising and lowering side to form an upward and downward convex surface of about 5cm in length, and that the absence of water-breakthrough in the latter case indicated a layer thickness in at least the cm-range and the danger of a blocked system and an unproductive cleaning task (articles 42, 74, 76 and 84).

Nonetheless, with one Springsweep System onboard and two in storage for deployment on ships of opportunity, *Seaspring* doubled as the UK lead responder with her pollutant tank capacity of 600m^3 and scope for lighter alternatives to the initial A-frame and jib designs as user-experience might dictate. However, the absence of incidents caused this project to be abandoned before its advantages could be fully evaluated in an incident, with even dispersant counter-believers having shown no interest in it, despite Biggs Wall Fabricators having made it available to potential customers in parallel with its WSL ship-borne dispersant-spraying systems.

Regulatory Difficulties

Article 90

Even the UK government failed to promote the use of the Springsweep System despite having funded its development and despite its comparative success. Thus, despite the ship, *Seaspring,* having been converted from an open-bottom hopper to a tank vessel for the carriage of oils and emulsions for R&D purposes in compliance with the regulations of the UK Shipping Administration, and despite the Marine Superintendent of the Shell Oil Company being willing and eager to arrange for his fully compliant coastal tankers to be a fleet of opportunity, difficulties were raised by this same UK Administration.

There are, of course, differences between oil recovery and routine tanker operations. Thus, we recall that the diesel engines of spill response equipment are not normally operated on tanker-decks, and that while collected pollutant would preferably be loaded through an open man-hole on the tank-top to avoid the additional back-pressure of the cargo-loading manifold, this is not a normal tanker practice; that vapours displaced from tanks during normal cargo-loading are vented through pipes with outlets at regulated height above deck level; and that loading pipes extend virtually to tank bottoms to avoid the electrostatic risk of explosion associated with hydrocarbon freefall. Nonetheless, we should also recall that all petroleum components with boiling points < 250°C evaporate from released slicks within a few hours, thus reducing their presence before collection takes place; and that in any case *Seaspring* had from the beginning been approved to carry fresh crude oils for discharge to the sea for R&D purposes and to take onboard recollected oils and emulsions throughout its R&D programme.

Again, as to the above, WSL had reviewed the relationship between the number of carbon atoms in the hydrocarbon molecule and its boiling and flash points as tabulated below.

Compound	Carbon Number	Boiling Point °C	Flash Point °C
Butane	4	0.5	-60
Pentane	5	36.1	-48
Hexane	6	66.0	-21.6
Heptane	7	98.4	-3.9
Octane	8	125.9	13.3
Nonane	9	150.8	31.0
Decane	10	174.1	46.1
Undecane	11	195.8	65.0
Duodecane	12	216.2	73.9
Tridecane	13	234.0	-
Tetradecane	14	252.5	100.0

Thus, we see that as soon as they are released the above components of crude oils begin to evaporate at rates dependent on their boiling points so that the boiling points and flashpoints of the residue increase progressively. Indeed, up to nonane this progression is extremely fast, with nonane itself having a specific evaporation rate of 6.6

x 10 kg m^3s^{-1} from which it can be calculated that a layer of 0.1mm thickness would be entirely evaporated in about 0.05 hours i.e. in about 3 minutes while a l mm layer would be gone in 30 minutes while for decane these times are respectively at 0.5 and 5.0 hours. Thus, recalling that with crude oils, these components are only fractionally present within the total mixture, we see that that with decane gone in minutes or even in a few hours, the flashpoint would already be above the regulatory safe limit of 62°C. Nonetheless, additional precautions are easily accommodated by requiring direct measurement of flashpoint before collection when operating close to a continuous release and by avoiding vapour-encapsulating oils such as Beatrix crude (article 33) should subsequent vapour release be deemed impossible to accommodate in other ways.

Article 91

Notwithstanding, the rapid loss of volatile components of crude oils spread thinly on the sea surface (article 90), the possibility of vapour emission from tanks being loaded with recovered pollutant caused us to submit the following proposals to the Administration regarding tankers of opportunity.

-these should be subject to prior gas-freeing unless engaged in the heavy fuel oil trade;

-deck-mounted diesel units should be at defined distances from tank vents;

-tank filling should be through the manifold unless back-pressure prevents it;

-otherwise the loading pipe should have a collar to seal it to the Butterworth or other tank top opening so that tank venting must be through the regulation vents;

-below the sealing collar, the loading pipe should extend close to the tank bottom;

-where this introduces backpressure problems, the tank should be ballasted to reduce freefall from the collar to the water and subsequently to the pollutant surface while the underlying water is progressively discharged as pollutant-loading proceeds.

We also submitted that such loading/de-ballasting could be adjusted to prevent venting and would not impose an additional task in that the free-water co-collected with the pollutant was then being discharged *in situ*. Again, a cascade system was visualised in which tanks would be successively filled via the initial loading tank while free-water separation could be achieved in successive tanks before final discharge to the sea with insignificant pollutant-content given the surrounding slick. It should be noted, however that these proposals do not constitute an officially approved procedure at this time.

Thus, despite the knowledge long since acquired on dispersant treatment and mechanical removal of released oil at sea, despite acceptance by coastal states of the responsibility for dealing with all such releases, and despite the private sector having been made strictly liable for the costs of such response, the public sector marine administrations show little enthusiasm for applying such knowledge while associating themselves enthusiastically with the environmentalist belief-consensus. Thus they blame dispersants for adding to the species-extinction/ecological disaster which has never been observed in reality, while promoting the mechanical removal which they never implement properly, and while encumbering the shipping industry and others with over-regulation and rejections of emergency arrangements of obvious compliance.

Again, despite having conferred powers of intervention upon themselves, coastal States are reluctant to intervene lest responsibility be thus transferred from ship/cargo owners to themselves, this reluctance being reinforced by environmentalist beliefs to the extent of opposing the use of save havens for cargo and bunker transfer from casualties. Yet again, this failure to implement available knowledge of the benefits and means of dispersant application, of mechanical removal, and of cargo/bunker salvage in safe havens, has the effect of passing responsibility to local government for shoreline protection and clearance, while marine administrations show little or no concern other than to place all blame on the shipping and oil industries regardless of society's essential need for maritime shipping in general and for petroleum deliveries in particular.

Shoreline Cleaning

Article 92

Having, in previous articles, reviewed our knowledge of the fates and effects of oil/HNS releases to the sea; of the strengths and weaknesses of the response techniques applicable at sea, this section of the knowledge repository now addresses shoreline clearance. Here the problem is not to remove oil or emulsion from water surfaces, but from solid surfaces which differ as to subsequent fates, effects and techniques of removal in a manner similar to releases of oil and HNS direct to land surfaces at inland sites, all of which are either continuous, or particulate with a wide range of particle size. Thus, the following articles review our knowledge of the means of dispersing pollutants from shorelines; of removing them by direct separation from underlying material; and of processing collected emulsions to waste oils for heat-generating combustion or disposal by land-farming/land-fill biodegradation, whether collected from shorelines, from inshore waters, or from the sea.

With respect to particle size, shorelines range from mud flats, through sand, shingle and rocks to cliffs and manmade structures all with differing levels of distinct flora and fauna and including those classified as salt-marches, mangroves and coral. As to flora and fauna, it should be decided at the outset to leave shorelines which are already coated to recover naturally, or to clean them to promote the natural re-colonisation which will occur anyway. With regard to individual oil-coated organisms, such as individual birds, it should be decided at the outset to adopt the triage system which would clean those in the first category, be selective as to species in the second, and to humanely putdown those in the third. Further to the second, decision should be based on known threat to species by comparing numbers oiled with the numbers born and dying annually in maintaining species numbers overall. Since no species-extinction/ecological-disaster has arisen from any incident thus far, the second triage option could be eliminated with its candidates going into the former third category.

As to mangroves and coral, the belief in dire consequences appears to have prevented investigation as to what would be the best restorative policy other than natural restoration itself. Were positive means to be considered for the removal of surface coating of mangroves, the most gentle should be attempted first, such as water-flushing, though inaccessibility may preclude anything other than the mild flushing to which they are naturally subject. In any case, whether active dispersion is attempted or not, the low initial concentrations of removed pollutant will rapidly dilute further with the not too dissimilar decay components of the standing mass of mangrove from which the fertility of such waters ultimately depends. The same is true for coral which grows only subsurface and as such is exposed only to subsurface droplets which disperse and biodegrade through concentrations rapidly diminishing to zero. It is advisable that any further consideration of mangrove and corral should start from reality-evaluation of local hypotheses as to their re-colonising sustainability.

As to salt marshes, pollutants affect only the steep-sided banks of their interspersing water courses and tidal inlets, the surface vegetation over the entire area remaining unaffected unless on exceptionally high tides. In this event, however, we know that similar to grouse-moors, the burning of pollutant and marsh vegetation in the late summer, autumn or winter, contributes to natural re-colonising and indeed to enhancement of the overall ecosystem of grouse moors. Again, we know that chronic oiling from continuous discharge from inadequate API separators, is removed by natural biodegradation and subsequent recovery when their downstream filter beds are made adequate to purpose.

As to mud flats, we know that their surfaces remain wet because of their high water table even at low tide; and that this permanent wetness limits/prevents adhesion of stranded pollutants and increases the likelihood of their re-floating on the incoming tide and departing on the next offshore wind, and thus re-presenting themselves to treatment as floating pollutants. Again, while shellfish beds and mussel-growing stakes adjacent to mudflats encourages belief-consensual opposition to dispersant use, we know that the resulting concentrations of oil and dispersants are subject to tidal movement and time-dependent dilution/biodegradation prior to arrival at such beds or stakes and after departure from them whether assisted to depart or not so assisted; and that burrowing mudflat organisms are protected from oil/emulsion by the permanently high water table in which they live.

As to sand beaches, these are exposed to higher energy waves than are mud flats, this being the principle cause of the one being sand and the other being mud, and as such enjoy much higher rates of natural cleaning by wave agitation than do mangrove swamps, salt marshes or mudflats. Again, sand beaches have no burrowing organisms, and thus lend themselves to a variety of cleaning techniques should natural cleaning rates be judged too slow in the calmer summer weather when amenity is much valued (article 93). Yet again, shingle, pebble and rock beaches are exposed to even higher energy waves, provide fewer options for artificial cleaning, and though they are penetrated by pollutants as the water table lowers with the ebbing tide, they have no burrowing animals, and with the exception of rock pools and cliffs, shorelines have no other flora and fauna. Yet again, cliffs and manmade structures cannot be penetrated and have no organisms inhibitive of cleaning. Indeed, boat slipways are limed and scrubbed to interrupt re-colonisation and growth several times a season for pedestrian safety.

Article 93

The general review in article 92 shows that shorelines self-clean as a function of water-table height and wave energy. Thus, while wind-action thickens pollutant layers against the shore, the most effective boom of all, and while these thicker layers may strand as the tide ebbs, we know that it may float off again on an offshore wind where the water table is high enough to prevent adhesion to solid particles; that it may adhere and penetrate particulate beaches where the water table rises and falls with the tide; and that it may adhere to extensive solid surfaces without penetration. Thus, whether the pollutant is non-adhering or adhering, wave action disperses it to biodegrading droplets as a function of viscosity in inshore waters and on shorelines, as it does at sea.

Again, we know that the resulting concentrations per cubic metre of seawater are limited by surface layer thickness per square metre, by the viscosity/wave-energy controlled rate of dispersion, by dilution with depth and by biodegradation; and that while the layer is thicker and the depths shallower in inshore waters than at sea, the resulting concentrations in the former are unlikely to be more than an order of magnitude greater than the latter though they may dilute more slowly; that in any case they biodegrade; that dispersion whether natural or dispersant-induced is never instantaneous; that concentrations can be measured; and that they have never yet resulted in species-extinction/ecological-disaster. Nonetheless, while the nil response option is thus always possible, it may be overruled by pressures for a faster return to amenity enjoyment, particularly in the holiday season. To this end, the available response techniques and associated equipment are now reviewed in this and subsequent articles.

On firm sand beaches the pollutant layer together with some underlying sand can be scraped off by standard earthmoving equipment such as graders and elevating scrapers, the former producing a ridge of sand-contaminated pollutant or pollutant-contaminated sand on one side of its track which can be loaded into trucks by the latter for removal when its ultimate destination is known. However, co-collection of sand can be avoided on firm sand beaches with a high water table or with the assistance of a pumped water supply, by pushing pollutant, with heavy rubber squeegee attachments to scraper-blades into contour-parallel collection trenches for pumped recovery. An extension of this technique is to apply a surfactant prior to pollutant arrival to prevent initial adhesion and ensure the success of subsequent water washing to final dispersion as a re-floated slick, such preparations being known as herders as in Shell Oil Herder initially developed for application around small floating oil slicks to modify interfacial tension so that the slick contracts to greater thicknesses of up to 4mm to facilitate removal. Though this has not found application at sea, it has been applied to shorelines prior to pollutant arrival to prevent adhesion and to facilitate re-floating (article 95).

Again, graders and scrapers can remove solid and semi-solid oils from sand, while in smaller quantities these can be removed manually with shovels by which means the sand content is more easily minimised. Yet again solid lumps (tar balls) can be removed by sieving. Of course, dispersants would be effective particularly where surf-line agitation is more effective than wave agitation at sea, were the current environmentalist belief-consensus to be overruled by the environmental knowledge available from this repository.

However, such techniques as scraping, flushing, sieving and manual removal are inoperable on shingle where the pollutant can drain to significant depths as the tide recedes, and where heavy vehicles find manoeuvring difficult, leaving only the options of natural cleaning in the rolling and tumbling action of surf or as assisted by herder or dispersant application in jurisdictions which do not misguidedly ban them. Again, we know that pollutant also has to be removed from non-particulate shoreline surfaces which range from being less easy to move than sand to being impossible to move at all such as rock formations, cliffs and man-made structures. Thus, to go beyond reliance on natural cleaning by surf action, the pollutant must be caused to disperse from these surfaces into the sea or where dispersants are erroneously banned it must somehow be run off to a collection location, the options being to reduce its viscosity by applying heat in the form of steam treatment, or to apply greater agitation energy in the form of high pressure water jets or abrasive blast-cleaning with dry or water-borne sand, though heat in the form of the burners used to remove excess tar in road repairing has been considered. At this point it should be noted that pollutants which cannot be dispersed for reasons of viscosity or belief-consensual regulation, can only be collected, transported, and downstream-processed.

Dispersant Treatment

Article 94

Generally speaking, the viscosity-determined limitations earlier indicated for seagoing dispersant-use should be a guide to shoreline use until a specific trial shows otherwise. However, our previous review of the mechanism of dispersion showed the need for dispersants to have maximal contact with the pollutant and minimal loss to the underlying sea. Consequently we can now see that dispersant application on shorelines achieves undisturbed contact prior to the tidal arrival of the wave-action which disperses it; and that shoreline treatment should to this extent be more viscosity-tolerant than seagoing treatment (articles 22 - 30 and 56 - 61).

Investigation of effectiveness by WSL showed that dispersants should be applied up to 30 minutes ahead of the incoming tide; that while this might encourage pollutant penetration of sand beaches, this is dispersed/diluted by the incoming surf-line, while dispersant penetration to the deeper pollutant in shingle beaches is beneficial in thus removing this deeper pollution when agitated by the incoming surf-line. In general, wave heights of about 25cm were found sufficient for dispersion from both types of beach, though heavier surf may be needed to agitate shingle sufficiently. In calmer conditions the necessary energy may be supplied by high pressure pumps delivering seawater at a low angle to the beach slope and directed at the beach/sea interface. The most effective dispersion is when the droplets are invisible with the dispersion plume presenting a *café au lait* appearance. Visible droplets indicate poorer dispersion while droplets > 1mm suggest approaching ineffectiveness though even larger droplets can subsequently break down in the surf, whether these are natural or dispersant-induced.

Application rates for dispersant on beached pollutant can be computed in litres per minute for any measured layer thickness on the basis of known oil : dispersant-effectiveness ratios, these being 2:1 for hydrocarbon-based dispersants or 20 : 1 for dispersant concentrates with the added advantage that adjustments are more easily made in response to observation onshore than at sea. Application rates in litres per square metre (lm^{-2}) can of course be used to compute pump rates in litres min^{-1} for any application system for which the swath width and speed of travel are known. Again, in contrast to seagoing operations on the layer thickness of 0.1mm, WSL found that layer thicknesses of up to 5mm could be successfully treated on shorelines. However, layer thicknesses in this range lend themselves to physical removal by scraping should downstream processing be acceptable or unavoidable because of viscosity, with dispersants being retained for final clearance in the former case, removal always requiring transport and downstream-processing which may be less cost-effective than viscosity-permitted dispersant treatment. If dispersant-treatable pollutant has been deposited by spring and/or weather-stressed tides, it can be pushed down to the inter-tidal zone and spread for dispersant treatment in advance of the next incoming tide.

If dispersants are to be used on rocks, cliffs and manmade structures, they should be applied within 30 minutes of the arrival of the incoming tide(s) and if natural wave agitation is insufficient water jets should be used to assist. However, in computing application rates, account should be taken of the layer thinning caused by downward flow of pollutant on non-horizontal surfaces. Nonetheless, pollutants which have weathered *in situ* may require scrubbing with stiff brooms during dispersant application no matter how thin their layering may have become. Of course the dispersant, having lower viscosity than the pollutant, drains even faster on application to non-horizontal surfaces, a disadvantage avoided by applying hydrocarbon-carried dispersant as a gel prepared by mixing the dispersant with seawater and gelling under pressure in a commercially available jet as in article 95.

Article 95

1n the early post-*Torrey Canyon* days, WSL (F. Shuttleworth) designed a ship-mountable dispersant spray-set and a smaller inshore boat version which could be adapted to spray beaches by replacing its twin spray booms with hand-lances. The inshore-boat equipment was reasonably portable and convenient to use with tube delivery to hand-lances delivering 7 gallons per minute over a swath width of 2 metres with the operators walking at a speed commensurate with the pollutant layer thickness. These early equipments were commercially supplied by Biggs Wall Ltd and were quickly followed by a variety of beach spraying equipment from other commercial suppliers.

The Beach Guard supplied by the Chapman Chemical Company was towed by, and used in conjunction with a dispersant filled road tanker on the esplanade, car park or other beach-adjacent hard-standing, while four operatives each with a hand-lance and 100metres of connecting hose walked the beach at up to this distance from the associated pump and supply units applying 2,700 litres h^{-1} of hydrocarbon-carried dispersant across a 2 metre swath width. Again, the Invictacat was introduced to widen the deployable range, this being an eight-wheeled, low tyre-pressure, self-propelled, rough-terrain vehicle, carrying its own dispersant supply and spraying 1,620 litres h^{-1} over a swath width of 2 metres from a boom on each side or through hand-lances so that operatives on foot could go beyond the operational limits of the vehicle itself to treat otherwise inaccessible locations. When the vehicle is unable to reduce its speed to deal successfully with higher pollutant layer thicknesses, it can switch to multiple passes at otherwise convenient speeds. Yet again, Cooper Pegler Knapsack Sprayers were used for localised treatment of pollutant in otherwise inaccessible locations including rocky outcrops and cliffs. As the name implies, this pressurised applicator and its dispersant supply are carried on the back of the operative who thus has considerable freedom of movement in locations accessible only on foot. This equipment could also apply gels and herders. As to dispersant enhancement of biodegradation rates, see article 99.

The most suitable gelling agents are non-ionic surfactants such as the alkyl phenyl ethers and the polyethoxylated glycols. The gelling agent is thoroughly stirred into the dispersant to a volume concentration of 20% and the mixed dispersant/gelling agent is then mixed with seawater in the combined mixing and application gun in the ratio of 3:2 to produce the gel, this second mixing stage being most conveniently achieved by feeding the two components from separate pressurised backpacks to the mixing/application gun which comprises a mixing chamber with concentric inlets and control valves which permit component-flow adjustment to the appropriate gel consistency, such a mixing/ application gun being easily produced from an oxyacetylene welding torch, though commercial equipment quickly became available.

The Oil Herders (article 93), otherwise known as Surface Film Chemicals (SFC), prevent pollutant adhesion to shoreline surfaces, to achieve clean surfaces by subsequent water-washing to collection trenches, or to contiguous seawater surfaces. Prior application frees the pollutant to run down the beach to seaward on the ebb, to be washed down to collection trenches dug for pumped removal, or to be retained between the beach and a coastal boom from whence it may be removed by skimming Again, when the slope of the beach is insufficient for the pollutant to run downwards on the interposed surface film, it may be caused to do so by the gentle action of flowing water supplied by pumps, while instead of collection in trenches it can be deflected by a V-arrangement of boards-on-edge into a sump for collection from a much greater layer thickness than is achievable in a trench or boomed area. With such techniques applied to rocky areas, pollutant may be expected to collect with increased layer thickness at low points such as rock pools thereby facilitating mechanical collection.

Indeed, small-scale trials conducted by WSL showed that rock, shingle and pebble beaches, and concrete surfaces, were left un-oiled when the tide fell after prior SFC treatment using a Cooper Pegler Knapsack Sprayer to lay down three 2 metre wide bands, the first at the water’s edge and the second halfway between the first and the third just below the high tide mark at the rate of 135 litres h^{-1} preferably about an hour prior to arrival of the oil. This delivery rate was designed to apply the SFC to the bands at a rate of 8 litres per 100 square metres, a rate which could also be delivered by the Beach Guard Trailer and Invictacat and to the sea contiguous to the shore by the inshore version of the WSL dispersant spray set, adjusted to give an application rate of 90 litres per linear mile.

In using Shell Oil Herder or BP Oil Guard, the Companies recommended protective clothing, full eye protection and gauntlet gloves; immediate removal of contaminated normal-clothing; areas of skin contact to be washed thoroughly with soap and water; and good open air ventilation, the threshold limit in air being 50ppm according to manufacturers. For storage, they recommended sealed containers to prevent evaporation, accidental release and contamination; avoidance of heat and open flame, all application equipment to be thoroughly clean, soap or detergent residues being detrimental; and sealed storage between 50° and 80°F (solidifies a 36°F) for indefinite contaminant-free life.

Mechanical Removal

Article 96

Mechanical removal has been mentioned in the previous articles on shoreline cleaning in relation to skimming and pumping from trenches, sumps, rock pools and boomed inshore waters. However, while the performance of pumps, skimmers and booms has already been reviewed in the articles on seagoing response, the shoreline techniques of mechanical scraping of liquid and solid pollutant removal of pollutant-contaminated solids, and adsorption/absorption techniques need similar review here, as do the associated techniques of 'land-farming' or *in situ* biodegradation and/or downstream processing for heat-generating combustion, whether removed from sea or shore.

Though the grader is the most discriminating scraper for removing pollutant from underlying sand, WSL enhanced this discrimination by attaching to the blade with wooden battens screw-clamps, a heavy rubber wiper cut from conveyer-belt material. Again, WSL similarly enhanced the less discriminating blades of the bulldozers and loading shovels previously used only to move and load grader collected material. Thus, with these refinements, it became possible to push pollutant not only to the side of the grader track with minimal sand, but also to use the other equipment to push the more mobile (less viscous) pollutants down the beach gradient for collection in trenches at layer depths conducive to skimmed/pumped recovery with minimisation of highly abrasive sand-contents.

However, such scraping is increasingly difficult on gravel, shingle and pebble beaches, even when tracked vehicles are substituted for wheeled, the difficulty being in controlling the depth of cut, though with the pollutant having penetrated more deeply than it does on sand, it is necessary to remove greater depths of beach material than is the case with sand. However, there being no possibility of pushing pollutant into trenches to reduce the subsequent transport and disposal problem as with sand beaches, WSL had to devise means of washing the pollutant from the beach material and returning the latter to the beach for all pollutant viscosities and all 'particle' sizes and to adopt a means of sieving tar balls from the smaller particle sizes characteristic of sand beaches.

As to the latter, the city engineer of Melbourne, Australia, had conceived the Brighton Beach Cleaner for attachment to the standard power take-off units of Massey-Fergusson tractors of industrial type MF20 or agricultural type MF135. This Cleaner was intended to remove all solids from both wet and well-drained sand beaches and WSL evaluated its performance in removing solid oil from the surface and from within sand beaches. It consisted of a conical screen and an auger screw rotating on a horizontal axis behind the tractor and two mouldboards beneath it with a forward mouth opening of 1.22 metres (4ft) and a rear exit of 0.46 metres (1.5ft) feeding into the wide end of the conical screen which is itself set to cut a few inches into the sand as the tractor moves forward. As the conical screen rotated on the power off-take, sand particles were rejected radially through the screen while the auger passed the larger oil lumps and other debris backwards and upwards to deposit in the rear-mounted bin while a levelling bar ensured a smooth surface behind the unit. The rotating cone-screens had optional mesh sizes of 12.5, 19 and 25mm and were interchangeable as best suited to sand wetness and particle size. A front-loader was in any case required to counter the rear-weight of the cleaning unit itself and this was available to move heavy/bulky objects from the path of the unit while a bucket-attachment thereto enabled transfer of the collected tar-balls to transport trucks.

Article 97

Apart from the separation of solid-oil from sand by the Brighton Beach Cleaner, there were no means of separating other more mobile oils from sand or from shingle or pebble beaches. Thus, major volumes of all such particulate materials co-collected with only very thin layered surface contamination, had to be transported to landfill at great cost and no downstream benefit wherever and whenever beach pollution was dealt with by scraping. Clearly, the separation of pollutant from beach particles would provide the possibility of removing the former alone and of returning the latter to the beach with very substantial reduction in transport costs.

To this end, WSL used its mineral processing technology to produce a variable-angle conveyer-belt elevator down which cold or heated water with or without cleaning agents would flow to be recycled through an API-type separator from the water surface of which accumulating pollutant could be removed while the cleaned particulate matter would drop to ground level from the top of the elevator. Thus, WSL reported that satisfactory performance for beach return could be achieved for sand, shingle, pebbles and stones on a single pass for low viscosity pollutants at ambient temperature; that increase in viscosity required the water to be heated; that water-recycling assisted heat conservation; that recycling though a tank acting as an API separator was in any case necessary for oil/emulsion removal; that viscosity could be reduced by pre-treatment with 1% kerosene to give satisfactory results even with heavy fuel oils; that while absolute cleanliness could not be guaranteed, this Mark 1 was capable of improvement; and that multiple units *in situ* would achieve a cleanliness level which would not have invoked response in the first place.

Again, Canadian workers, restricting themselves to small particle sizes and ignoring more massive particles, used a conveyer belt to top-load oily sand into a 30cm diameter x 2m high column into the bottom of which steam-heated water was injected at sufficient rate to create a fluidised sand bed from which an initial oil contamination of 2% was reduced by 95% at a throughput of 1 tonne of sand per hour. However, it was found that fluidisation was difficult to achieve unless the feed was very uniform while the presence of debris and particles of varied size could block the system. Yet again, workers in the USA have directed high velocity steam jets at oiled sand being conveyed over an oil reception tank on an inclined, vibrated and perforated conveyer from an input hopper at the low end to a clean sand receptor below the high end.

However, agitated washing of pollutant from particulate matter can be achieved where it lies. Thus, at the *Amoco Cadiz* incident, sand and gravel beaches were cleaned by a large number of hand hoses from a manifold supplied with seawater which thus agitated the beach material to loosen and drive the pollutant into the adjacent boomed area for collection by Egmopol skimmers operated over the boom from a barge on its outer side. This agitated washing technique was also used in intermediate storage pits dug and lined for the purpose at this incident. In these, the water jets loosened the pollutant to float clear of the solid on the initially rising water level in the pit, though this level was subsequently maintained by pumping the oily water mixture to a temporary API-type separator finally to separate the loosened pollutant from the water which loosened it. While all of this was achieved on *Amoco Cadiz* oil with ambient temperature water, the School of Ocean Sciences at the University of Wales at Bangor, suggested bio-diesel as an alternative to the kerosene used by WSL to lower pollutant viscosity, presumably believing the former to be the less toxic despite both being bio-degradable.

The alternative to separating pollutant from its associated shoreline particulates is to stabilise it within a solid/continuous accretion of the individual particles. As with the above technique of agitated washing, this stabilisation was also undertaken on a large scale at the *Amoco Cadiz* incident, the intention being to add quicklime to the sand to encapsulate the oil within the resulting cement. The original German patent calls for 2% of oleic acid and additives such as aluminium sulphate or phospho-gypsum, while French practice omitted the oleic acid. The process has been investigated by adjustment of lime content in relation to analysed oil contents in the 5-20% range and with the oily sand being layered to a depth of 20-30 cm before admixing the quicklime with appropriate mixing equipment and compacting with standard highway construction equipment with a view to incorporating it directly in active construction projects. At the *Amoco Cadiz* incident, a plant consisting of a sack opener, receiving hopper, continuous weighing system for quicklime addition, a mixer and a discharge hopper capable of processing 750 tonnes of oily sand per day was set up at Brest. Such a plant permits better quicklime dust control and general conditions of work than are possible on an active construction site. Even so, appropriate clothing and eye protection must be worn when working with quicklime.

Similar results to that of quicklime hydration are available from such proprietary hydraulic binding materials as Chemfix, Petrifix and Sialosale: all of which can be similarly mixed in located or mobile plant to produce construction powders or blocks. Such plant can be established in 2 - 4 weeks and thereafter process 500 - 700 tonnes per day, though optimal performance requires long runs and feed-material of constant homogeneity. Again, while the *Amoco Cadiz* incident coincided with substantial construction work in the port of Brest, a need to transport the product of the Brest stabilisation plant elsewhere would have reduced whatever cost-effectiveness it achieved.

Article 98

The use of adsorption to transfer pollutant from one surface to another has already been reviewed in respect of pollutant removal from water surfaces to the surfaces of endless mops, belts and rotating discs and subsequent pollutant removal from the latter in a continuous process. However, the use of adsorbents to remove liquids from solid surfaces at home, in school and in industrial premises for final disposal of both adsorbent and adsorbed liquid, long predates the design of any continuous device. Consequently, a range of adsorbent materials were already in common use for small domestic and industrial spills to land and inland water surfaces long before the very much larger ship releases to sea and shore first came to public attention.

As to mechanism, the term ‘adsorption’ to a material, relates to pollutant adhesion to its outer surfaces and ‘absorption’ to penetration of its internal channels and capillaries, the latter mechanism being more viscosity limited than the former. Again, such materials are available for use inland, on shorelines and inshore waters in small particle size to maximise external surface area and to facilitate broadcast distribution, as individual scatter-pads, or as contained in porous covers in the form of booms, this last presentation facilitating recovery of the pollutant laden material from water surfaces. It should, however, be noted that pollutants may never penetrate to the centre the material in cylindrical form, observation of this penetration failure by cutting across such cylinders after differing exposure times, having been the reason why Erling Blomberg replaced alternate flotation pads in his Troilboom with similarly thin absorption pads to produce an absorption boom for customers who wanted one.

Though adsorbents/absorbents are useable only on a small scale, their use does increase the bulk and weight of the delivery and removal task over that of the pollutant alone, and thus the large range of materials available makes choice a matter of cost in relation the weight of pollutant retained by unit weight of material. Thus, at a very early stage, WSL determined the weight of a range of common adsorbents required to retain 1 tonne of Kuwait crude oil or 1000seconds fuel oil, the results being those tabulated below.

Material Type	Composition	Form/Appearance	kg/ tonne Kuwait oil
Synthetic organic	polythene foam	Sheets	35
		Expanded powder	400
	Hydrocarbon polymer	Pads, Rolls	59
	Polyurethane foam	Chips	20
	Resin-treated α-cellulose	Powder	250
Natural organic	Felted vegetable fibre	Pads, Rolls	39
	Treated wood fibre	Pads	152
	Treated peat	Bales	189
	Fibres/inorganic granules	Bagged	142
Inorganic	Treated clays		1333-1754
			kg/tonne 1000s Fuel
Synthetic organic	Polypropylene	Looped strand bundles	33
	Plastic netting	Netting, strips	42
	Plastic mesh	Mesh strips	22

All of the above can be used inland, on shorelines and on water, the clays excepted because they sink and thus can only be applied on land or shorelines. More recently, swelling absorbents, such as those marketed as Imbiber Beads have very high absorption capacities and do not extrude pollutant under external pressure.
It should, at least, be noted that in the early days the Netherlands used a sand dredger to apply a slurry of seabed sand to floating oil slicks thus delivering the sand and its adsorbed oil immediately to the seabed which to keep navigation channels open would be dredged later and dumped further to seaward in the normal course of events. Such an obvious technique is, of course, now in breach of the London Dumping Convention, regardless of the floating-layer being only 0.1mm thick and regardless of its being biodegradable from its sand admixture.

Bioremediation

Article 99

Having recalled in the Preface and article 1 that the biological food chain continuously recycles carbon dioxide and water by photosynthesis and biodegradation; that the fossilisation of intermediate biodegradation products to natural gas, oil, and coal, is no more than an anaerobic interruption of this recycling; and that this knowledge is disputed only by environmentalist belief: it is pleasantly surprising to note the enthusiasm with which these same environmentalists embrace what they refer to as the bioremediation of shorelines. Again, despite their failure to recognise that the micro-organisms at the bottom of the food-chain/ecosystem actually proliferate in seawater in proportion to the concentration of the petroleum components present, environmentalists advocate the introduction of cultures of these organisms to biodegrade (bio-remediate) stranded oil components.

However, those who are unencumbered by environmentalist belief, recognise that the heterotrophic organisms which feed indiscriminately on petroleum components and on post-mortem biological degradation products, increase their population densities with the increased post-release concentrations of the former; that while such population-increase may preclude the need to add more heterotrophic organisms, it may be limited by its depletion of other growth factors such as inorganic nitrogen, sulphur, phosphorus and possibly iron; that while the addition of these could be beneficial it would be difficult to significantly increase their natural seawater concentrations; that such chemical additions should thus be to pollutants on beaches if at all; that regardless of any such additions, bacterial degradation being a surface phenomenon, will be more rapid at the surface to volume ratios presented by dispersed droplets in the sea than at the surfaces of un-dispersed slicks onshore; and that, consequently, we could increase the rate of natural bacterial degradation by pushing stranded pollution into the surf-line to disperse it, with or without the addition of dispersants, though the latter would further increase the surface : volume ratio of the droplets and thus increase the rate of biodegradation. Would such biodegradation be acceptable to environmentalists were it to be called bioremediation?

Without reference to surface : volume ratios, however, some environmentalist studies have suggested optimal nutrient concentrations as high as 1.5-2.5% nitrogen, and 0.2% phosphorus on the basis of the weight of oil present for shoreline biodegradation. Again, in response to the likelihood of natural inorganic growth factors being diluted away by rain, let alone seawater, enthusiasts for assisted bioremediation have suggested the addition of oleophilic compounds containing nitrogen and phosphorus as being more retentive growth factors. As to field trials of bioremediation, those conducted in relation to the *Exxon Valdez* incident were reported as showing that the rate depended on the bioremediation agent, associated nutrients, nutrient penetration into pollutant, pollutant quantity, beach type, temperature, and oxygen availability; and that despite the number and varying interactions of these identified parameters, natural rates were enhanced by factors of 2-7, with visible changes having been reported for some beaches within 15 days. Again, with one area of beach as a control and two others treated once a week with sodium nitrate and potassium dihydrogen phosphate at Bullwell Bay following the *Sea Empress* incident, it was reported by total hydrocarbon measurement that the bioremediation rate was greater than the natural rate for the heavy fuel and Forties crude oil of the incident; and that both additives were equally effective.

However effective these applications have been, it is pleasant to note their acceptance by the environmentalist lobby which otherwise denies the knowledge that oil is biodegradable with no toxic effects on the biodegrading organisms or in the food chain which they support. Indeed, references to 'associated nutrients' and 'penetration of nutrient into pollutant' clearly demonstrate environmentalist failure to recognise that the pollutant is itself a nutrient and that addition of any associated organic nutrient simply gives the organisms of biodegradation an alternative substrate to that provided by the pollutant itself. Indeed the additive may be more readily useable by the organisms and thus have the effect of reducing the rate of oil biodegradation.

Yet again, it has been reported by the Netherlands that beach sand and fine clay particles appeared to have a role in breaking emulsions in the surf line, and that the very high surface : volume ratio of the resulting oil droplets and the thinness of the associated slick promoted the desired biodegradation both natural and assisted. This process now known as clay flocculation had been investigated at the *Exxon Valdez* incident while at the *Sea Empress* incident, the polluted cobbles of the Amroth and Marros beaches were moved into the surf line where, in the absence of a control, it was believed that what would have been the natural rate of wave-agitated surf cleaning, was increased by associated sand-abrasion and clay-flocculation. Whatever 'believed' might mean, it was reported that the degree of oiling decreased with successive tides until by the fifth day there was no significant oiling of the cobble-zone. Nonetheless, while this was reported in the context of clay flocculation which itself was being considered in the context of assistance to bioremediation, we have known since the *Torrey Canyon* incident of 1967 that surf agitation with or without dispersant assistance would be a widely applicable technique for shoreline cleaning, were it not for the opposition of environmentalist belief in species-extinction/ecological-disaster.

I myself noted, at the *Amoco Cadiz* incident that polluted shores had non-polluted gaps inside offshore reefs, the surf on which had apparently dispersed the incoming slicks before they could reach these inner unpolluted lengths of shoreline. Indeed, it has long been known by those free of environmentalist belief that all oil releases would eventually biodegrade to carbon dioxide and water; and that human intervention is required only because the rate of this biodegradation is too slow for commercial requirements, when its natural rate at sea is reduced to the lower natural rate onshore. As to dispersant enhancement of biodegradation rates, see also articles 50 - 55 and 94 - 95.

Emulsion Breaking

Article 100

Previous articles have reviewed the natural dispersion/biodegradation of pollutants at sea and in the surf-line; the use of surface film chemicals to prevent shoreline retention of pollutants and to return them to the sea for removal from there or for *in situ* dispersant-induced biodegradation; the sequestration of pollutant with sand to produce building products; the enhancement of onshore biodegradation by additives; and the interruption of biodegradation by the mechanical removal of pollutants non-amenable to dispersants. This article now reviews the downstream processing required by the intention to combust collected emulsions as low-grade fuel, while noting that this collection often transposes natural *in situ* biodegradation to that of subsequent land-farming; that use as fuel in no way covers the overall cost of collection and associated downstream processing; and that consequently the term 'remove' is to be preferred to 'recycle'.

As to the nature of the emulsions collected from water or shoreline surfaces, we know that the original oil will have lost up to 30% of its weight by evaporation; that in forming the emulsion, non-volatile components will have increased their weight by up to 400% by absorbing up to 80% water; that were the emulsion to be non-Newtonian, it could become a virtual solid in undisturbed storage; and that whether it is Newtonian or non-Newtonian and whether it has been recovered from water surfaces or from shoreline trenches or sumps together with co-collected water or shoreline materials, it must be separated from such water or materials, and broken into its separate oil and water phases before the former can be 'used as a fuel'. However, we also know that while this separation facilitates pumping by reducing emulsion viscosity back to the non-volatile oil viscosity, and reduces storage and subsequent transport requirements to those of the removed oil itself, current belief-only regulations prevent *in situ* discharge of all such separated water and thus require all downstream processing to be conducted at authorised locations such as oil refineries; and that after this needless transportation the co-removed oil is land-farmed to the biodegradation which could more easily have been achieved in seawater leaving land-farming as an option for the emulsions most resistant to *in situ* dispersion/bioremediation.

As to the breaking of emulsions for use of their oil-content as fuel, we know that their stability depends on their asphaltene and wax contents, and on photo-oxidised oil components which surround and stabilise their internal water droplets against the progressive coalescence which would break them into their separate phases; that the breaking of such emulsions can be achieved by the application of heat or by static-mixer addition of demulsifiers which contain high molecular weight surface active agents which displace the stabilising asphaltenes, waxes and oxidised components; that such demulsiers can be selected by trial-and-error, or even specifically synthesised for routine use with the un-weathered emulsions encountered in the normal operations of individual oil refineries; and that the former is most applicable to the weathered emulsions arising from marine releases. Nonetheless, the increased difficulty of emulsion breaking observed with increased asphaltene content for the oils tabulated below may be taken as a guide to expectations with other oils, the difficulty expressing itself as a requirement for more demulsifier, higher temperature, or both, though individual refinery advice may be helpful (articles 22 - 26).

Oil	Asphaltene Content	Oil	Asphaltene Content
Nigerian export	0.2	Arabian medium	5.3
Forties	0.3	Medium fuel	5.7
Ninian	0.5	Heavy fuel	8.0
Arabian light	2.2	Safaniya	8.3
Kuwait	3.8	Arabian heavy	9.0

A further difficulty is that mixing conditions can cause small water droplets to grow at the expense of larger to produce increased uniformity of size without coalescing to the point of phase separation. However, it has been found that online static mixers give generally good results when this equipment is installed between the initial deck-mounted collection hopper and the ship's cargo tank or as similarly appropriate for shoreline operations, though *in situ* discharge of such separated water is prohibited by the currently consensual belief in species-extinction/ecological-disaster.

To avoid this needless transportation to approved sites such as oil-refineries for all downstream processing of emulsions and their co-collected free water, it need only be recalled that while co-collected free water and water exiting from the emulsion-breaking static mixer contains naturally dispersed oil droplets, these are gravity separated according to Stokes' Law in the receiving tank which acts as an API gravity separator in which the water depth is up to 4 x the oil depth, the water-content of the emulsion having been up to 4 x its oil-content, in which the co-collected free water also accumulates, in which naturally dispersed oil droplets migrate upwards to coalescence with the underside of the oil layer; and that from time to time the thus oil-freed water could be pumped to the sea to optimise its oil storage capacity and to have any residual oil droplets biodegrade with those arising from the natural dispersion of the contiguous slick; and that it is this *in situ* discharge which the environmentalist belief-consensus in species-extinction/ecological-disaster refuses to permit despite the now long-standing reality-refutation of this belief.

Again, in shoreline operations, initially stored volumes of emulsion/free-water mixtures could be transferred to larger intermediate storage volumes by pumps of minimal emulsification-potential though on-line static-mixers for emulsion-breaking, removal of the oil phase itself and the discharge of the water phase as from an API separator. Thus, emergency shore-side pits could serve as API-type separators provided they were lined with heavy-gauge/oil-impermeable sheeting such as PVC, polyethylene, or oil-resistant rubber to prevent ground seepage, long narrow pits being easiest to dig, line, fill and empty (articles 16 - 17). Again, it is the *in situ* discharge of accumulating free water from the API-type separator pits which the environmentalist belief-consensus in species-extinction/ ecological-disaster refuses to permit, despite its now long-standing reality-refutation.

Article 101

Transfer to the intermediate storage pits of article 100, would provide an earlier opportunity to inject demulsifiers to reduce pollutant viscosity and volume to its oil-content volume for earlier *in situ* discharge of oil-freed water thus reducing onward transport to that of oil alone. Again, while demulsification can also be achieved by addition of heat in primary or secondary storage, care is needed to avoid a dangerous build-up of sub-surface steam in high-viscosity emulsions whether steam-coils or live-steam injections are used. It is thus preferable to use an external heat exchanger to control temperatures within safe working limits. Again, separated water must be removed from the bottom of such intermediate storage tanks or pits as above. In any case, rainwater needs to be removed, particularly if surface drainage from a large area may enter the pit. Thus, such initial and intermediate storage locations can act as API gravity separators, the performance of which though less than optimal under emergency makeshift conditions onshore, can be enhanced by the use of low-sheer pumps for all two-phase transfers to avoid creation of the smallest oil droplets which are slowest to gravity-separate or do not separate at all.

Similarly, the tanks of pollutant collection vessels at sea act as API separators from which the co-collected free water and water broken from the emulsions in on-line static mixers prior to tank entry could be discharged directly to the sea in the midst of on-going natural slick dispersion just as such waters could be discharged to shore-surfaces and inshore waters from the pits of primary and secondary storage which also act as API separators as in the previous paragraph. Indeed, performance of the latter can be enhanced by commercially available skid-mounted API separators supported by filtering/ coalescing units (articles 18 21) installed immediately upstream of the final water-discharge point. Again, while such emergency arrangements may not produce water-contents below the limit required for discharge of refinery process water, shoreline processing is capable of making the recovered pollutant easier to pump by lowering its emulsion viscosity and its volume to that of the original oil minus its volatile components: there being no known need to incur the transport costs involved in all such processing being conducted at a refinery, even if such be fortuitously proximate.

Not all pollutant recovered from shorelines is liquid requiring pits to be dug for its containment. When beach material acts as an adsorbent the combination may be treated as a solid to degrees dependent on the tendency of the liquid emulsion to drain/leach from it with unacceptable secondary effects in subsequent handling. Thus, polluted beach material can be stored as piles on flat surfaces, though given the potential of the adsorbed pollutant to drain/leach, these flat surfaces should be covered with sheeting to protect the underlying ground, the sheeting being turned up and over a bund wall to collect any oily water from the pile. Again, arrangements should be made for pumping to keep the bund from overflowing, particularly in rain, and for processing to reduce oil-content to tolerable levels prior to water discharge external to the bund. Again, in transporting contaminated beach material to and from such initial/intermediate storage by lift vehicles and trucks, appropriate sheeting is needed to prevent oily water releases *en route*.

Following initial and intermediate storage with whatever emulsion breaking, oil/water separation or oil/ beach material separation has been achieved, pre-storage is required at the processor/user location, and while such emergency-capacity is limited, it is desirable that it sustain the rate at which such arrivals can be processed and used in addition to its normal through-puts. Such prior processes may include final dewatering, desalination etc. for compatibility with plant and product specifications and with existing regulation of plant operation. Clearly, biodegradation *in situ* is very much simpler to induce wherever and whenever pollutant-viscosity is amenable to effective and timely dispersion.

Known Incapacities for 'Recycling'/Disposal

Article 102

In principle, oil removed from water surfaces and shorelines could be processed with normal feed-stocks at oil refineries or combusted to produce steam for heating and power-generation. In practice, however, it must be recognised that while refineries would accept oil salvaged from casualties by cargo transfer to lightening tankers, they do not process/recycle their own wastes, preferring instead to biodegrade them on site by 'land-farming' which when practiced elsewhere is now called bioremediation by those who deny its being the ultimate fate of all organic substance (article 99). Land-farming capacity is, however, scaled to the operational needs of individual refineries and cannot thus accommodate the quantities potentially arising from the marine-casualty responses as reviewed in the foregoing articles. In any case, what is the point of collecting pollutants in these ways only to biodegrade them to carbon dioxide and water in the natural or assisted ways previously reviewed in article 99. Thus, with refinery reception being inadequate for oils other than those salvaged by cargo transfer, the only alternative apart from landfill for oily beach material not cleared by natural weathering/biodegradation processes and not transported to surf-lines for natural or dispersant-assisted biodegradation, is downstream processing for combustion for heat and power generation.

However, where combustion is an option it is better utilised prior to transport and downstream processing. Thus, while such early combustion on water surfaces has been shown not to provide a general and final solution (articles 35 -38) and while burning on shorelines causes subsurface penetration of un-combusted/melted oil, suitable burners for combustion of collected tar balls have been produced to avoid this disadvantage though without the advantage of heat utilisation. Thus, WSL designed and constructed a burner for combustion of solid oils/tar balls at a rate commensurate with their collection by such as the Brighton Beach Cleaner (article 96) to avoid having to transport them from the beach. It consisted of a rimmed and perforated plate positioned above a funnel leading to a 45 gallon drum, the plate being on three 35mm legs to promote an under-draught and the drum being the collector of un-combusted though melted oil components. With the unit being preferably of stainless steel because mild steel was prone to thermal buckling, Douglas Milton Enterprises, subsequently produced the Infernus 500, equipped with an air-blower to minimise soot formation. This commercially available unit had dimensions of 1.8 x 1.3 x 1.5m and weighed 900kg while the blower weighed 120kg. A modified version for convenient combustion of liquid oils and sludge became available later.

Were the relatively small-scale land-farming of self-produced refinery wastes to be extended to the potential scale of a major stranding pre-planning would be essential. The current refinery process involves spreading the oily waste on land followed by ploughing as on farm-land when the surface ceases to be wet and sticky. Spreading is to about 10kg m^{-2}, the initial ploughing being repeated at monthly intervals decreasing to seasonally after two years, soil pH being adjusted to 6.5 by lime application as necessary. With extension to agricultural land being ruled out by seasonal use and the potential for heavy metal accumulation, I once unsuccessfully enquired as to the possibility of using cropped forestry land. Again, while waste oils from automobile maintenance have been used for many years in the USA for dust control on dirt roads and unpaved parking lots in a balance of need and availability without long term storage, the quantities potentially available from incident response would be unlikely to find use on local roads and parking lots without long-term storage and its attendant difficulties. Yet again, contractors who collect and process lubricating oils to a product consisting of 40-50% refined lubricating oil and fuel oil are generally operating at full capacity and even with prior notification would be overwhelmed by the potential demands of incident response, particularly when the reality-refuted belief-consensus permits the release of entire cargoes through its paradoxical belief-consensual need to protect safe havens from cargo/bunker transfer operations.

In principle, oil removed by incident response could be used in oil-fired power stations, but here again feed-stock quality specifications are stringent as they would be were these oils to be mixed with coal in coal-fired power stations where problems can be foreseen from salt-corrosion and the possible presence of foreign solids. Again, while emulsions or separated oils could be disposed of in fluidised bed incinerators to raise steam for heating or power generation, while solid waste oils could be compatible with rotary kiln furnaces and liquid waste oils with municipal incinerators; and while industrial waste incinerators can deal with all classes of wastes, their capacities for additional emergency-generated wastes are limited in practice. The reality, however, is that emulsified oil has physically coated square miles of shore; that it cannot be expeditiously removed other than by dispersion; that even when it is removed mechanically, there is nowhere to take it for expeditious processing and use; and that consequently it can only be removed at the rate determined by the rate of processing and use from which there is no inherent benefit; that despite this absence of benefit, the emulsified oil has to be separated from very considerable quantities of beach material; and that the biodegradation of land farming could more easily and rapidly be conducted from shorelines by return of emulsions to the sea where all that did not strand has already dispersed and is biodegrading, if not already biodegraded.

Thus, we see that full advantage must be taken of the natural or dispersant-assisted tendency for oil to disperse and biodegrade to carbon dioxide and water at sea or in surf-lines; that otherwise, oils and emulsions either separately or in association with beach material must be removed, transported, stored and processed through emulsion/free-water separation or emulsion-solid separation, emulsion-breaking and oil/water separation, in order to make the oil even potentially acceptable to receivers who do not want or need it; have little or no free capacity to take it, and little or no additional use for it; that those who have waste oils of their own, get rid of them by natural/assisted biodegradation to carbon dioxide and water by land-farming; that those who normally burn fuels for heat and power generation will only burn removed oils to oblige; that those who operate incinerators will only burn such waste oils for payment; and that the only alternative is to pay to dispose of them to land-fill which formerly took oils at the rate of 1-2% of the total tonnage tipped to minimise the risk of leachate-contamination of ground water, though this is now encumbered/prevented by environmentalist belief-driven legislation.

Given these known incapacities, it should be recalled for example that a release of 100,000 tonnes of crude oil will evaporate leaving 75,000 tonnes of non-volatiles to form an emulsion of up to 300,000 tonnes which will naturally disperse in its half-life sequence to 150,000, 75,000, 37,500 . . . tonnes before 17,500, 8,750, 4,875. . . tonnes are left to stand depending on the half-life value, the distance to shore, and the time taken to reach it on the wind and tide vector to which it was subject. With such quantities biodegrading without any species-extinction/ecological disaster prior to stranding, why is such biodegradation not completed by returning such residual stranding amounts to the sea to avoid the trouble and cost of biodegrading them by land-farming or of processing them for combustion, and why are such releases not prevented in the first place by cargo/bunker transfer in safe havens? The answer lies in the retention of the reality-refuted belief in species-extinction/ecological-disaster.

Known Inadequacies of Contingency Plans and Compensation Arrangements

Article 103

The grounding of the *Torrey Canyon* on the Seven Stones Reef in the Scilly Isles in 1967 was an event for which there was no contingency plan and no international agreements for adequate reimbursement of commercial loss or response costs. Thus, commercial victims had to rely on whatever remedies were available under their own national law which did not extend to owners of other nationality with no assets in the country of the incident, while the Brussels Convention Relating to the Limitation of Liability of Owners of Seagoing Ships limited this liability to $80 per ship tonne, and required proof of intent or negligence by those in charge of the offending ship.

However, in 1969, the owners themselves brought into force the Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution (TOVALOP) which accepted strict liability (with only minor exceptions) for up to $160 per tonne with a limit of $16.8 million per incident for laden and un-laden tankers, this agreement being administered by the International Tanker Owners' Pollution Federation (ITOPF) while owners insured their liability with the Protection and Indemnity (P&I) Clubs for third party claims and with the International Tanker Indemnity Association (ITIA) being specifically for pollution related claims. Again, the Tanker Owners' Voluntary Agreement of Liability for Oil Pollution (TOVALOP) provided compensation for damage and clearance costs without need of court action. Yet again, in 1971, the oil industry established the Contract Regarding an Interim Settlement to Tanker Liability for Oil Pollution (CRYSTAL) funded by contributions based on each company's annual oil movements or transfers which with TOVALOP provided $36 million per incident. We should here note that while no provision was made to compensate for the standing charges of national response administrations, the available funding implied that such administrations would know or intend to learn how to respond in a cost-effective manner.

In any case, in these early days, the standing charges were small. In the UK they were subsumed in the Warren Spring Laboratory R&D programme on how to respond and in the Marine Survey Service which already held WSL ship-mountable spray gear and dispersant stocks but paid no retainer fees for the eighty or so ships of opportunity normally operating as tugs in UK ports. Again, standing costs remained low even when the dedicated MPCU of 1979 progressively held three Springsweep Systems for use on *Seaspring* and two coastal tankers of opportunity, a Force 7 oil mop for an offshore service/supply ship of opportunity, eight contracted dispersant-spray aircraft, two equipped for remote sensing, a reduced number of spray-sets for ships of opportunity, equipment for ship-to-ship transfer of oil and HNS for use by salvors, and equipment for shoreline cleaning for use by local authorities. Thus, standing costs remained low in relation to operating costs which in turn were low in relation to the reimbursable commercial loses for which the bulk of the compensation per incident must have been intended. We should note here, that this UK response provision was based on release of 3000-5000 tonnes from a single impact-damaged cargo tank and on the remaining cargo and bunkers being removed from the casualty to avoid further release from subsequent damage, though this was never publicly announced.

In 1969, governments added the Civil Liability Convention (CLC) which, as a formalised TOVALOP, came into force in 1975 with a strict liability of $18.5 million per incident; and in 1971, the International Oil Pollution Compensation Fund (IOPCF) which as a formalisation of CRYSTAL came into force in 1978 and was followed by the current 1991 Fund. The position then was that tanker owners were strictly liable for about $2.5million for small tankers up to 5000grt and to about $50 million for tankers over 140,000grt bringing the strict liability limit to about $110million for all sizes of tanker. The Fund was financed by contributions from receivers of crude or heavy fuel oil within the territory of the contracting states in proportion to the amounts transported by sea and is administered by a Secretariat, an Executive Committee and an Assembly comprising representatives from all contracting States, claims being brought directly against the IOPCF. However, despite the magnitude of the available funds IOPCF has had to adopt the policy of part payment of initial claims to preserve its ability to make < 100% payment of the outstanding balances when the final overall position becomes clear with respect to the total funds available.

Article 104

While compensation funding was being arranged for shipping incidents as outlined in article 103, the offshore operators on the UK continental shelf became parties to a voluntary Offshore Pollution Liability Agreement (OPOL) under which they accepted strict liability (with certain exceptions) for the costs of commercial damage and response to pollution arising from exploration or production activities for which the limit was $25million for costs excluding those for well control and repair. This agreement was later extended to offshore operators within the jurisdictions of Denmark, Federal Republic of Germany, France, Ireland, Netherlands and Norway, and later with Belgium and Sweden it became the 1976 Convention on Civil Liability for Oil Pollution Damage from Offshore Installations. The initial limit has been periodically reviewed and as of July 1996 was $120million with a maximum deductible $1million, though these arrangements apply only if the operator is unable to meet claims from his own resources. Indeed, the UK may not require a company to join OPOL if its own resources are judged substantial enough to cover its incident-related obligations.

However, the reference to ‘damage’ in the offshore convention of 1976 is indicative of a move from compensation claims for commercial loss and incurred response costs to compensation for damage to the environment as claimed by environmentalist belief in species-extinction/ecological disaster. This move had been progressing from the 1969 adoption and 1975 entry into force of the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution from Shipping Casualties. As a consequence, all subsequent shipping regulation has been directed to the limitation/ prevention of operational discharges and emissions from ships whether or not these are damaging to the environment in any measurable way, there being no regulation as to prevention of or response to impact-induced releases of cargo and bunkers, national administrations being required to intervene in a self-judged ‘reasonable and proportionate’ manner, there being no recognition of the implied need for administrations to know or to learn how to intervene in a cost-effective manner (article 103).

Thus, the national contingency plans of the parties to these conventions appear to say little regarding the conduct of response other than to imply or state a preference for dispersants or for mechanical recovery. The UK plan, for example appeared more concerned with procedure than with outcome. Thus, having asked all military and civil aircraft to report oil sightings to HM Coastguard and having recognised that these sightings may be of phenomena other than oil, HMCG classified them as doubtful, probable or confirmed as best it could without actually being on scene. If confirmed, HMCG sought to attribute the now supposed-oil to a supposed source, by arranging for surface samples to be taken for comparison with those taken from the supposed source as and when this could be done through the inspection procedures of the Marine Survey Service or its analogues overseas within the Paris Memorandum of Understanding. In any case, such releases were and are far too small to justify spillage response operations at sea and there is little likelihood of their coming ashore given the propensity to natural dispersion and biodegradation.

In contrast, the crew of a casualty, reports directly to HMCG staff who in addition to dealing with search and rescue, can seek information relevant to response such as the type of cargo and bunkers and physicochemical properties if known to the crew; quantities released; damage and stability assessment whether grounded or afloat; whether engines and pumps have power; wind and sea conditions in relation to the likelihood of further damage; prospects for re-floating and/or for cargo/bunker transfer either on site or in a safe haven; the owners of ship and cargo, agents, charters, underwriters, P&I Club and flag state. However, instead of applying such information to existing knowledge of the fate and effects of such releases in order to predict the post-release fate and effects of the specific cargo and bunkers onboard; to develop the incident-specific action plan accordingly; and to promulgate it to all interested parties with a role to play in executing it: the UK national administration and apparently all others, call a meeting of interested parties to discuss opinions/counter-opinions as to what to do, as if for the first time *i.e.* as if it were 1967 and the *Torrey Canyon* had grounded on the *Seven Stones*.

Again, while the Convention confers on the coastal State the Intervention Power to do whatever it decides is 'reasonable and proportionate' to prevent or reduce pollution from a marine-casualty so long as those incurring expense as a result of its decisions have the right to compensation from that State, the liability for such compensation has greatly constrained State use of the Intervention Powers. In particular, until the findings of the Donaldson Enquiry into the response to the *Sea Empress* incident, this fear of liability transfer from owner to State had prevented the entry of casualties to safe havens for the cargo/bunker transfer which would prevent/reduce pollution as the Powers had ostensibly intended. Indeed even the Donaldson findings did nothing by way of specifying how such entry might be managed nor of specifying how releases might be managed.

Known Need for and Resistance to Cargo/Bunker Transfer.

Article 105

The resistance to safe haven entry is exemplified by the following incidents. After grounding on the Hats and Barrels off south-west Wales and re-floating, the *Christos Bitas* was refused entry to a discharge port or safe haven, resulting in a BP-led ship-to-ship transfer operation in the middle of the Irish Sea, which though successful was conducted in severe weather at no small weather-risk to personnel. Again, when the *Andreos Patria* sustained damage to a wing tank off the Portuguese coast she was refused entry with the ensuing cargo transfer being conducted in even more exposed conditions far upwind in the Atlantic. Yet again, unsuccessful attempts were made to settle the capsized forward section of the *Eleni V* on a weather-exposed sandbank for cargo transfer after a collision off the Norfolk coast and before she was ultimately towed to deep water and sunk with release of the remaining cargo to join that which had progressively escaped during the three weeks spent trying to settle her on the bank rather than take her to a safe haven for a successful cargo transfer. Yet again, when the *Tarpenbek* sustained collision damage to the engine room and settled by the stern in an unstable-condition liable to capsize, she was initially anchored close to the collision site in shallow water on the Pullar Bank off Selsey Bill while a set of barge-mounted sheer legs were sent for and arrangements made for cargo transfer to the lightening vessel *Esso Purfleet*.

However, when the instability suggested securing the ship to the sheer-leg barge and beaching both on a sheltered sandbank off Ryde, Isle of Wight, the local authority declared this to be unacceptable in its capacity as an interested party, and when it was thus agreed to beach the casualty on the exposed Pullar Bank, she capsized in a south-west Force 6, greatly reducing the prospects of cargo transfer at sea and increasing those of another *Eleni V* outcome. After injunction proceedings had been resolved, however, the ship was finally brought to shelter in Sandown Bay, Isle of Wight where she was righted by par-buckling and the cargo, bunkers and lubricating oils were removed. In all of this excitement, officialdom appeared to remain unaware that all of *Tarpenbek's* tanks remained intact, the only damage having been to shell-plating in way of the engine room.

I used this eventual success to encourage the MPCU to acquire its own stockpile of cargo/bunker transfer equipment for use by salvors in safe haven locations after damage had been quantified on such considerations as:

-cargo/bunker tanks undamaged or damaged to known extent;

-release terminated or capable of being terminated prior to safe haven entry;

-degree of water bottom containment achievable by intentional release at sea, by internal tank transfers or by limited ship-to-ship transfer in respect of damaged tanks only;

-comparison of the potential commercial effects of possible releases in proximate havens.

Though the stockpile was duly acquired, and steps taken to identify possible safe havens around the UK coastline (article 106), policy as to their actual use was not further considered until the Donaldson Enquiry into the *Sea Empress* incident of 1996 (articles 107 -115).

Article 106

Despite the departmental failure to adopt a safe havens policy (article 105), I continued to argue that such was essential given the high areas of slicks per tonne released, and the inversely low encounter rates of response techniques; that adoption of this policy would eliminate the *ad hoc* pillar-to-post approach exemplified in article 105, that such cargo transfer was already a routine lightering operation in areas deemed sufficiently sheltered; that similar cargo transfer would be possible from casualties provided they had not lost power for their own pumps and the lightering tanker had been provided with the appropriate inter-ship fenders; and that even if the casualty had lost power, cargo/bunker transfer to any small tanker would be a routine matter for a salvor having access to portable transfer pumps, power supplies, fenders and other auxiliary equipment, such being by then available from our own stockpile.

The transfer pumps chosen for this stockpile were the Framo TK5 and TK6 designed to operate through standard deck openings in submerged mode to push rather than pull at nominal rates of 190 and $500m^3h^{-1}$. Even so, appropriate heaters were included to ensure that tank contents cooled by loss of power could be reheated to facilitate pumping. Inflatable fenders were chosen in preference to the permanent Yokohama-type for ease of storage, transportation and deployment, each being 1167Kg in weight and stored in a cargo net on a pallet for helicopter-delivery, and each being 16m long and 3.75m in diameter when inflated. Again, lay-flat floating hose was chosen and stowed in 15 boxes each containing approximately 666 ft and quick-acting couplings and spares of stainless steel were chosen together with a special banding tool to connect spare/replacement couplings to hose-ends.

To avoid ingress of air and creation of explosive mixtures, tank atmospheres are normally rendered inert with engine exhaust. Consequently, to make good the loss of engine power in casualties, two emergency inert gas generators, capable of supplying $1600m^3h^{-1}$ and $1000m^3h^{-1}$, were stockpiled in recognition of the need to ensure the cargo transfer rate did not exceed the inert gas generation rate thus maintaining a positive tank pressure sufficient to avoid air ingress to the emptying tank. Again, oxygen analysers were included to monitor tank atmospheres, each equipped with a 20m flexible suction hose and hand-operated bellows to pump samples through the intrinsically safe analysers. Conversely, for the elimination of vapours in enclosed spaces other than tanks onboard casualties, compressed air driven portable ventilation fans, flexible ducting and injector nozzles were also provided, as were breathing and resuscitation equipment, protective clothing, fire-fighting equipment, emergency lighting and portable radio communication equipment, all such being intrinsically safe.

However, despite this emergency equipment stockpile having been acquired and operationally packaged for helicopter-delivery, adoption of a safe haven policy remained illusive. Thus, while the Marine Survey Service identified potential safe havens around the entire UK coastline in respect of access, water depth, internal area, shelter from specified wind directions, anchor holding-ground security *etc*; and while the parameters of damage stability assessment and of controlled release prior to entry had been identified to avoid inadvertent sinking and/or inadvertent release within the haven or its approaches as outlined in article 105, environmentalist beliefs and fear of liability transfer from the ship/cargo owner to the State prevented the Intervention Powers from securing safe haven use in any coastal State, while in the UK the results of the coastal survey fell into abeyance until the *Sea Empress Incident* enabled me again to draw attention to the need for these Powers to be used to this end.

Known Incapacities of Response Exemplified by the *Sea Empress* Incident

Article 107

The response to this incident is reviewed against the knowledge summarised in the previous 106 articles and against the extent to which this knowledge has been used, ignored or forgotten since its acquisition. No incidents large enough to have exercised the UK response capability of 1986, had arisen until 1996, the only potential candidate having been the *Braer* incident of 1993 which released a total cargo of 86,000 tonnes of Gullfacks crude oil. However, its physicochemical properties were such as to permit all of it to disperse naturally without significant emulsion formation and thus without any need for dispersant/removal response in the high wind and wave conditions prevailing at the time. Thus, when the *Sea Empress* incident arose in February 1996, nobody in the MPCU had had any direct contact with the WSL R&D programme or with the use of the resulting equipment stockpiles and aircraft contract.

The first report (July 1996) of the *Sea Empress Environmental Evaluation Committee* (SEEEC) gave an account of the early events. Thus, on the evening of 15 February 1996 the ship grounded in the entrance to Milford Haven with an initial cargo loss estimated at 6,000 tonnes; re-floated, anchored and grounded again on the night of the 16th with further release of oil; re-floated on the high tide of the 17th, grounded again with a further release of oil on the 17th; grounded again on the 18th with a subsequent release at low tide and on all subsequent low tides, the largest release probably occurring between midday and midnight on the 19th which was later estimated at 30,000 tonnes, while some 360 tonnes of heavy fuel oil were released over the period 15-21 February.

Thus, had the WSL knowledge-repository not been previously dissipated, the physicochemical properties of Forties crude oil could have been used to predict the likely weight %age of evaporative loss; the persistence of the ensuing emulsion from its half-life as a floating slick; the quantities likely to strand; and the locations of stranding after known times of travel under the influence of known wind and tide. Thus, reference to the tabulated properties of Oil Groups I - IV (articles 39 - 42) would have shown that Forties crude oil was a member of Group III; that it would remain liquid at any seawater temperature, its pour point being -3°C; that it would lose 32 wt % by evaporation; that the water-content of its emulsion would be 70-80%; that the non-volatile release quantities would thus increase by a factor of four; and that the expected half-life would be in the 24-48 hour range.

However, given that Forties crude is a blend of oils from a number of UK North Sea fields and that consequently its properties could vary from time to time, further information on any specific cargo can be sought when the range of possible variability is considered significant enough to justify the search. In this case we find that the published data for Forties oil taken from the World Guide Analyses of the Institute of Petroleum is in good agreement with the earlier data from Oil Groups I-IV (articles 39 - 42) and from the Marine Pollution Control Unit Report of December 1996 which is presumably for the loaded cargo, the main difference being in the evaporative loss to be expected. Data from these three sources are compared below as far as the respective data allow.

Property (units)	Inst. Pet.	Group II	MPCU
Density (kg/litre)			0.82
Gravity (°API)	36.6		
Viscosity (cSt) @ 10°C	9.6	8	
@ 15°C			3.88
@ 21°C	6.8		
Asphaltenes (wt%)	0.2		0.2
Pour Point (°C)	-3		-3
Yield (%) @ 175°C			36.65
@ 200°C		32	
@ 232°C	34		43

It could have been concluded, therefore, that the crude oil carried by *Sea Empress* was of Oil Group III (articles 39 - 42) which subject to possible re-evaluation of evaporative loss would have a dispersion half-life estimated by interpolation within the stated range. Thus, with the viscosity for Forties oil at 8cSt being close to that of Ekofisk oil at 4cSt, and with the latter being a Group II oil of half-life 12 hours as confirmed by WSL at the Ekofisk blow-out in 1976, this 1996 incident could have enabled the actual half-life of this Forties oil to be more precisely estimated by observation. Nonetheless, this opportunity remained unrecognised by everyone officially involved.

Article 108

By comparing the distillation yields at differing temperatures below 250°C, as in the Oil Groups I-IV (articles 39 - 42), with the Ekofisk distillation yield of 33% at 250°C and with its 35% loss of volatiles after 8 hours exposure at sea in summer conditions and its 25% in winter conditions as observed by WSL in trial-releases and at the blow-out, we see that evaporative loss from Forties crude in winter conditions could have been expected to be about 32%. However, the consequences of a 40% loss could also have been considered (Table in article 107), the MPCU data being assumed to relate to the actual Forties blend onboard the *Sea Empress*. Again, in common with all liquid crude oils the emulsion volumes could have been expected to be four times that of their oil-contents, though a factor of three was assumed for this incident.

As to the volatiles, coastal communities close to casualties have detected their odour, and consequently they should be reassured that there is no danger at the atmospheric concentrations involved, the danger of explosion being confined to the casualty itself and the danger of fire being confined to its immediate vicinity. Onboard fire has incommoded coastal communities with smoke and smuts in the past, concerning which they should also be reassured and guided as they were at the *Sea Empress* incident, onboard personnel having been twice evacuated though no fire or explosion occurred.

As to viscosity and half-life of the non-volatile emulsion, comparison of the API value of 36.6 with the range of values of Group III oils (17.5 - 36) and of the viscosity of 8cSt at 15°C listed for Forties in the Group III Table, with those listed in the Table of article 107, shows that the cargo of the *Sea Empress* was at the lower, less persistent end of the viscosity range of Group III oils. On the other hand, its asphaltene value, though low for oils in general (article 100), is high, at 0.2-0.3, for North Sea oils, that of Ekofisk being 0.03 wt%. Thus, the half-life of the Forties blend at the *Sea Empress* incident could have been placed in the middle of the 24-48 hour range *i.e.* in the 30-42 hour range, though with this guidance, direct observation could have given a more precise value within this range(article 107). As to the heavy fuel oil onboard, plots of viscosity against temperature for the three grades and reference to their respective half-life ranges (article 42) could have suggested the middle half-life range of 4-6 days in the absence of observed solidification, enquiry, or direct measurement of the actual viscosity. Again, with heavy fuel oil emulsions being about 50% water, the emulsion quantity could have been expected to be double the quantity released as is usually the case for heavy fuel oils.

As to salvage of ship, cargo and bunkers, the circumstances closely approached the ideal in respect of both opportunity and need. Thus, the discharge berth to which the ship had been heading was only a few miles further up the haven, while the need to remove it from its location of exposure to winter gales from the southwest and from proximity to the rocky seabed on which it had already grounded more than once could not have been more obvious. Again, whatever difficulties were cited to explain why the opportunity to satisfy this need was not taken in a timely manner, all ‘obstacles’ appear to have been overcome speedily enough when the decision was finally taken to move the casualty to Herbrandston Quay where 58,000 tonnes were discharged, though not until an additional 67,000 - 69,000 tonnes had been lost through successive groundings and successive hull and tank damage, none of which prevented the ultimate move to the Haven terminal for discharge, nor indeed to Belfast for later dry-docking.

Article 109

Having allocated incident-specific values to the fate-controlling parameters of oils released at sea in articles 107 and 108, I now consider the results which could have been expected from the application of dispersants and the deployment of mechanical removal equipment. Forties crude, with its viscosity in the Group II range and with its allocation to Group III being in respect of its density and asphaltene content, could have been seen to be amenable to dispersant treatment and to be in need of such, given the proximity of its release to adjacent shores. However, environmentalist belief-driven reluctance to apply such treatment is shown by the following information provided by MPCU contractors NETCEN to an Institute of Petroleum seminar.

Date (February)	Time (hours)	Oil Release (tonnes)	Dispersant used(tonnes)
15	20.00-22.00	2,000	2
16			2
17	20.00-23.00	5,000	4 + (2 demulsifier)
18	21.00-24.00	5,000	31 (+ 6 demulsifier)
19	10.00-13.00	8,000	42
19	22.00-01.00	20,000	
20	10.00-13.00	15,000	123
21	00.00-02.00	10,000	180
21	11.00-14.00	7,000	
22			65
Totals		72,000	445 (+ 8 demulsifier)

This table gives more information on oil releases than did the first official report (article 107). However, there are significant differences. Thus, while the Master estimated the initial release at 2,000 tonnes as in the above Table, the first official report gave it as 6,000. Again, while the first report refers releases to the times of high and low water, this second report refers them to time intervals into which fall the less frequently quoted tidal times of the first report, while an MPCU report of December 1996 makes internally compensating changes in releases identified by precise times to result in the same total of 72,000 tonnes released, though with 446 rather 445 tonnes of dispersant used and with no tally of demulsifier use, and with a footnote indicating the Master's estimate of the initial release to have been 5,000 tonnes, later raised by the SEEEC to 6,000 tonnes by December 1996. None of the above differences are of significance other than to suggest that more care should be expended on response planning and execution than in discussing how response reports are to be written after reality has revealed the lack of response knowledge exemplified by the incident itself.

Thus, we may note that with an official estimate of ~ 5000 tonnes having been released on the evening of the 15th, only a tentative trial spraying of 2 tonnes of dispersant was authorised and repeated on the 16th. Again, despite there being no need for a trial given the known viscosity of the oil, it was the 18th before we see 29 tonnes being recorded before the 110 tonnes of the 19th, and while we see a drop to 57 tonnes on the 20th, it reached its height at 179 tonnes only on the 21st before dropping back to 67 tonnes and to cessation thereafter, despite 72,000 tonnes of oil having been released in this period, an accounting which reveals either an absence of response knowledge or a submission to the belief-consensual regulation which limits dispersion application to arbitrary water depths. This concern over dispersant-use sits oddly with the lack of concern over the releases which called for it.

Article 110

No details are available on the viscosity of the *Sea Empress* pollutant as it changed with emulsion formation after each release or on the timings of the actual spraying operations with respect to these releases. It is therefore difficult to identify the ages of the emulsions and thus the efficiency of spraying them. However, if we allow the efficiency to decrease from an initial dispersant : oil of 1 : 20 through 1 : 10 to 1 :5 as emulsification and weathering proceeded, and attempt to determine the age of that which was sprayed, we see that the first 2 tonnes of dispersant could not have been applied to the initial release until first light next day; that the second 2 tonnes could not have been applied to the next 5000 tonnes before first light on the 18th; that the 31 (or 29) tonnes on the 18th could not have been applied to releases on the 18th but to those of the 15th and 17th because of the intervening hours of darkness; that this delay by darkness recurred with the release on the 17th and with the first releases on the 19th, 20th and 21st; that on the latter three dates, dispersant was applied after weathering times of 12 to 24 hours; and that the last 65 (or 67) tonnes of dispersant on the 22nd could not have been applied to emulsions less than 24 hours old. On the other hand, the timing of the release on the 18th, and the second releases on the 19th, 20th and 21st suggest dispersant could have been added to relatively fresh oil, though very substantial accumulations of aged emulsion were on the sea surface at all times from the 18th onwards.

Thus, on this basis, we might estimate the amounts of the various releases remaining after dispersant treatments as recorded above, for the above efficiency ratios, as shown below.

Date and Time	Tonnes released	Dispersant tonnage	Dispersed tonnage			Remaining tonnage
			1:20	1:10	1:5	
15/21.39	2000					
16		2		20		1980
17/23.24	5000	2		20		4980
18/11.58	2000	29	580			1420
19/00.19	5000					5000
19/12.43	8000	110	2200			5800
20/01.03	20000					20,000
20/13.26	15000	57		570		14,430
21/01.45	10000					10000
21/14.08	5000	179		1790		3210
22		67			335	335
Totals	72000	446		5515		66,585

Thus, I have applied the efficiency ratio of 1:10 to dispersant applied to night releases, the ratio of 1:20 to day release, these ratios being applicable 50:50 to dispersants applied to night and day releases on same date, and the ratio of 1:5 to the even more delayed dispersant application on 22 February. On this basis my estimate is that 5,515 tonnes of oil were dispersed by the 446 tonnes of applied dispersant, leaving 66,585 tonnes of oil to disperse naturally, to be removed from water surfaces or to strand (article 102).

At this stage, with the slick thickness of 0.1mm being the basis of dispersant : oil ratio of 1: 20, we see that 100 tonnes (m^3) would have been present for each km^2 of sea surface; that 446 tonnes of dispersant would have been applied to 5,515 m^3 of oil covering an area totalling 55.15 km^2, while 72,000 m^3 covered an aggregate area of 720 km^2; that dispersants were only applied to 7.6% of the total oil released; that in dispersing an estimated 5,515 tonnes (m^3), the dispersant tonnage was only 62% effective, thus exhibiting an effectiveness ratio of 1 : 12.4; and that even at a ratio of 1:20, it could not have dispersed more than 8,920 tonnes of oil. Nonetheless, those who fail to take account of natural dispersion have erroneously concluded from their estimates of stranded tonnage that dispersant effectiveness ratio at this incident was 1 : 60 which is quite impossible (articles 60- 61).

Article 111

The oil removed from water surfaces at the *Sea Empress* incident is reported to have been 2,000 tonnes after-emulsion breaking and water-decanting at the Texaco Refinery. With some adverse weather interruption, this recovery had been achieved from 15 February to 7 March by two Pollcat inshore skimmers operating within the Haven before joining the Egmopol inshore skimmers operating further east on the south coast of Pembrokeshire off Tenby in association with six sea-going removal vessels of which two were from France and two from The Netherlands and with some 20 smaller craft not all of which were equipped for such removal, six local fishing boats, for example, being employed in towing boom-corralled pollutant from shallow water out to the sea-going removal vessels.

As to allocating unit contributions to the above total, it was reported that one Pollcat skimmer, *Seamop*, a zero relative velocity rope-mop skimmer with a swath width of 1.5 metres, was filled to its 45m^3 capacity by 02.25 hours on 16 February, while the other, *Seasweep*, fitted with a 5 metre sweeping boom and associated Lori weir-skimmer was thus filled in about the same time; and that a 25 knot Seatruck was used to locate and direct them to the most continuous pollutant layers, by which means, 1,275 m^3 of oil was removed in the following 10 days, the transit down-time of the Harbour Authority skimmers being reduced by their discharge to a support barge which discharged to the Texaco refinery.

As to shoreline operations beyond the Haven, it was reported that some of the pollutant removed off Tenby had been washed from the beaches by local authority personnel for removal by the small harbour skimmers sailed from the Haven to these more exposed shorelines; and that combined with the Pollcat/ Egmopol operation they collected another 230 tonnes of oil which one of the Pollcats transported as unbroken emulsion and co-collected free water to the seagoing recovery vessel *Forth Explorer* thus contributing to the 600 tonnes of oil attributed to this inshore/seagoing recovery operation after emulsion-breaking and free water separation at the Texaco refinery. Incidentally, the Egmopol catamarans collected emulsion and free water, by means of a series of parallel troughs mounted across an endless/inclined belt between two rollers, the troughs collecting in rising through the floating layer on rounding the submerged bottom roller and discharging to reception on inverting over the top roller. Thus, with the earlier Haven removal of 1,275 tonnes of oil, the total water-surface removal by inshore skimmers amounted to 1,605 tonnes of the overall total of 2,000 tonnes, thus leaving only 395 tonnes (20%) to have been removed by the six seagoing ships.

Thus, with dispersants accounting for 5,515 tonnes of oil as emulsion (article 110), with mechanical removal from water surfaces accounting for 2,000 tonnes of oil, and with 3000 -5,000 tonnes reported as having been recovered from beaches, we see that more oil was induced to disperse than was removed from shore and water surfaces combined, while less was removed from water surfaces than reached shore; and that with only 7,515 tonnes of oil having been accounted for prior to stranding, and only 3,000 - 5,000m^3 after stranding, we must now consider the balance of the 72,000 tonnes released.

Article 112

In this and subsequent articles, I review the fate of the total releases of Forties crude and heavy fuel oil at the *Sea Empress* incident, by computing the percentage volatile loss, the amounts of crude and fuel oil emulsions subsequently created, the half-life-dependent rates of natural dispersion to be expected for these emulsions, the amounts of identified releases likely to strand after wind- and tide- dependent times at sea, and the amounts naturally dispersed after stranding, in order to quantify the individual time-dependent fates of releases amounting to 72,000 tonnes in total.

If the loss of volatiles was 40% as claimed by the MPCU Report rather than 32% as earlier measured for the similar Ekofisk oil, then of the 72,000 tonnes released in total, only 43,200 tonnes of non-volatiles would remain (rather than 48,960 tonnes) from which we have to deduct the amounts removed at sea (2,000 tonnes) and dispersed by dispersants (5,515 tonnes) to leave either 35,685 or 41,445 tonnes to form emulsions of about 107,335 or 124,055 tonnes to disperse naturally or to come ashore in times insufficient for complete dispersion. The simplest way to compute the amount remaining after different periods of natural dispersion for any release is to reduce it by half for each successive half-life. Thus, for 40% evaporative loss and an initial emulsion of 107,055 tonnes we see that the successive amounts for half-lives of 30, 36 and 42 hours are shown below (articles 39-42).

Half-life 30 hours			Half-life 36 hours			Half-life 42 hours		
Hours	Days	Tonnes	Hours	Days	Tonnes	Hours	Days	Tonnes
0	0	107,055	0	0	107,055	0	0	107,055
30	1.25	53,527	36	1.5	53,527	42	1.75	53,527
60	2.50	26,763	72	3.0	26,763	84	3.50	26,763
90	3.75	13,381	108	4.5	13,381	126	5.25	13,381
120	5.00	6,690	144	6.0	6,690	168	7.00	6,690
150	6.25	3,345	180	7.5	3,345			
180	7.50	1,672						

Thus, were 107,055 tonnes of emulsion to be at sea for 6 days (144 hours) with a half-life of 36 hours, the amount potentially stranding would be reduced by natural dispersion to 6,690 tonnes, such a half-life being in the middle of the Group III range of 24 - 48 hours as appropriate for the physicochemical properties of Forties oil. Again, were it to remain at sea for 7.5 days (180 hours), only 3,345 tonnes would remain to strand. The above table also indicates the time-dependent sensitivity of this approach to variation in half-life from one oil to another within this moderately high half-life range.

However, while some emulsion came ashore with an average age of 1.5 days during the 3-day period of onshore winds of 15-18 February, that which subsequently came shore in the onshore winds of the 6-day period from 22-27 February was 6 days old on average, because the intervening 3-day period of offshore winds from 19-21 February kept it dispersing at sea prior to the resumption of onshore winds of 22-27 February thus further aging it by 3 days before coming ashore on average on 24 February within this 6-day stranding period which terminated with the onset of offshore winds for the period 28-29 February after which no significant amount came ashore. However, computation of the total amount which did strand in the period 15-27 February, requires the half-life concept to be applied to the released quantities which actually attained the average ages of 1.5 and 6 days prior to stranding.

As to the heavy fuel oil, concerning which we have neither reports of solidification nor of viscosity, I allocated the median viscosity range of 5.000 -10,000 cSt at 15°C and the median half-life of 4 - 6 days to this Group IV oil (article 42). On this basis, the 360 tonnes reported as having been released would have formed a 50% oil-water emulsion of which 360 tonnes would have stranded after 4 - 6 days on the above totalised approach. However, with no reported breakdown of the quantities and timings of these comparatively small releases, we need say no more than that if half had been released in the first onshore wind episode almost all of this would have gone ashore while the half released in the second episode would have been reduced to a quarter, so that three quarters of the 360 tonnes might have stranded overall as a 50% emulsion containing 270 tonnes of fuel oil.

Article 113

In article 112, I reviewed my half-life method of determining the amounts of floating pollutant (oil or HNS) likely to come ashore as a function of elapsed time at sea (articles 39-42). I now present the first stage of my consideration of such times in relation to the individual oil releases from the *Sea Empress* and the winds and tides to which they were subject prior to stranding. Both the SEEEC and MPCU Reports provide data on wind velocities from 15 February to the end of the month, these being confirmed by Paragon Associates, of which I was one of a team of three who obtained data from the St Govan ODAS marine weather buoy, reference 62303, located 4.7nm to the south of St Govan's Head (51.5°N, 4.9°W) about 12nm south east of the Milford Haven entrance and about 25nm south west of Pendine Sands, between and including which, the Pembrokeshire coast was affected by the releases in addition to the Haven shores themselves. In addition, I obtained data on tidal streams from the Admiralty Pilot for the West Coast of England and Wales; the Admiralty Tidal Stream Atlas for Irish Sea and Bristol Channel; and the tidal diamonds on the Admiralty Charts of the affected area.

Meanwhile, reference to the available release data showed that from 15 - 18 February and from 22 - 27 February inclusive, individually quantified releases partially came onshore under onshore winds, while in the offshore winds of 19 - 21 February they largely remained un-stranded prior to stranding on the onshore winds of 22 - 27 February inclusive. Again, reference to the current and wind together shows that on the ebb tides of 15 - 18 February the floating pollutant would have moved out of the Haven and northwest along the coast from St Anne's Head towards the Skokholm and Skomer Islands with a tendency to strand on the adjacent mainland coast under the influence of onshore winds from the west northwest during this period; that pollutant released towards the end of the ebb and still non-stranded, would be caught on the ensuing flood and either re-enter the Haven or pass across its mouth under the west northwest wind towards St Govan's Head with some of it likely to strand in Freshwater West before reaching the intermediate Linney Head from whence some of it would move parallel to the coast before clearing it beyond St Govan Head, this latter movement being advanced by the ensuing flood up the Bristol Channel by which time any pollutant in the vicinity of the Haven entrance would enter to strand on inner shorelines as dictated by the wind-direction and its lee-shore; and that all such stranding emulsion between 16 to 18 February inclusive would have been at sea for 1.5 days on average.

In contrast, we see that the offshore winds from the north northeast would have moved emulsion further offshore in the period 19 - 21 February to be subjected successively thereafter to winds from the northwest, southwest, west, south southeast, west, south, and east southeast causing it to approach shore again further to the east and to strand at Manorbier, Tenby, Amroth, Marros and Pendine Sands; that such releases would have been at sea for 3 days prior to the recurrence of onshore winds in the period 22-27 February during which these releases would strand after on average after another 3 days. Thus, we see, with reference to tidal ebb and flow and to the sequence of onshore and offshore winds, that oil released up to and including 18 February and which threatened the Haven itself, its western and eastern headlands, the outer beaches from Freshwater West to Gluck's Hole and towards St Govan's Head, would have been at sea for an average of 1.5 days before stranding; and that releases which stranded further to the east towards Tenby around Carmarthen Bay to Pendine Sands would have been at sea for an average of 6 days prior to stranding (article 112).

Article 114

Having related the dates of oil release at the *Sea Empress* incident to wind and tide patterns to estimate the times spent at sea before standing on different lengths of shoreline in article 113, I now review the quantities thus released before and after the onset of the offshore north northeast wind on 19 February. Thus, if we refer to the releases which took place under offshore winds up to and including 18 February as those of category 1 and those from 19 - 21 February as category 2, we see that the respective total releases are 12,000 and 60,000 tonnes or 9,000 and 63,000 according to the differing official figures tabulated earlier, *i.e.* a volume ratio of 1:5 or 1:7 in favour of the stranding influence of onshore wind in this incident, the former ratio being taken for my subsequent analysis to avoid over emphasising this influence on the fate of its sequential releases.

Thus, in estimating the amounts likely to strand from these two quantified categories of release after their differing times at sea, we also have to allow for the differing amounts treated by differing amounts of dispersant and for the differing amounts mechanically removed. However, having already computed the amount of oil removed by dispersants from category 1 releases in the period 15-18 February as 620 tonnes, and from category 2 releases in the period 19 - 21 February as 4,895 tonnes, we see that the amounts of emulsion remaining in these two categories were respectively 8,380 and 58,105 tonnes. However, in the absence of any breakdown of the respective amounts removed from water surfaces, I have simply distributed the total 2,000 tonnes 50:50 between my two release categories to give the remaining amounts as respectively 7,380 and 57,105 tonnes which with reduction by 32% for evaporative loss become 5,012 and 38,832 tonnes of oil respectively. Thus, with these adjustments, we find that the amounts of emulsion subject to natural dispersion in these categories are 15,036 and 116,496 tonnes. Thus, the results of applying my half-life treatment for half-lives of 30, 36 and 42 hours to my two release categories after 32% evaporative loss are tabulated below.

Category 1(15-18 February Inclusive)

Half-life: 30 hours			Half-life: 36 hours			Half-life 42 hours		
Hours	Days	Tonnes	Hours	Days	Tonnes	Hours	Days	Tonnes
0	0	15,036	0	0	15,036	0	0	15,036
30	1.25	7,518	36	1.50	7,518	42	1.75	7,518
60	2.50	3,759	72	3.00	3,759	84	3.50	3,759
90	3.75	1,879	108	4.50	1,879	126	5.25	1,879

Category 2 (19 February onwards)

0	0	116,496	0	0	116,496	0	0	115,248

30	1.25	58,248	36	1.50	58,248	42	1.75	57,624
60	2.50	29,124	72	3.00	29,124	84	3.50	28,812
90	3.75	14,562	108	4.50	14,562	126	5.25	14,562
120	5.00	7,286	144	6.00	7,203	168	7.00	7,203
150	6.25	3,643	180	7.50	3,601			
180	7.50	1,821						

Lack of available detail on the fuel oil releases which were officially estimated at 360 tonnes prevents their similar treatment, though my allocated half-life of 4 - 6 days (article 42) and 50:50 split between the above categories suggests that around 270 tonnes of oil would have come ashore as 540 tonnes of a 50% oil emulsion.

The above table shows that for evaporative loss of 32% and a half-life of 36 hours the amount of emulsion likely to strand after being at sea for an average of 1.5 days within the three days of category 1 releases is 7,518 tonnes while that of category 2 after being at sea for an average of 1.5 days of offshore winds and over the subsequent 6 days of onshore winds is 7,203 tonnes which added together gives a stranded total of 14,721 tonnes of emulsion, while for 40% evaporative loss, the quantities of categories 1 and 2 subjected to natural dispersion as emulsions are 13,260 and 102,795 tonnes respectively which results in 6,630 and 6,425 respectively for a stranded total of 13,055 tonnes of emulsion. Thus, for 32% or 40% evaporative loss, we have 4,935 tonnes or 4,352 tonnes of stranded cargo oil, to each of which we can add about 270 tonnes of fuel oil or 540 tonnes of emulsion.

Article 115

Having previously estimated the amount of stranded oil at the *Sea Empress* incident from evaporative loss and viscosity controlled half-life of the emulsified non-volatiles, I now compare my estimates with what can be gleaned from official reports as to how much actually stranded.

The SEEEC Report states that between 10,000 and 15,000 tonnes of emulsion stranded over more than 200 miles of coastline, the information provided for individual locations being sparse. However, this Report does state that pollutants began to come ashore on the evening of the initial grounding and on the following day in large quantities at West Angle and Angle Bays and at Freshwater West, while several beaches within the Haven were polluted over the following days; that from 21 - 26 February, small patches stranded from St Anne's Head to Skommer Island and along the south Pembrokeshire coast where they came ashore at Stackpole and Manorbier in amounts up to 700 tonnes of emulsion on 24 February, at Pendine Sands in amounts up to 1,000 tonnes on 24 - 26 February and at Lydstep on 26 February; and that the most significant day was 27 February when some 70% of the total came ashore from Tenby to Marros, suggesting a total of 5,800 tonnes of emulsion for Carmarthen Bay shores as a whole. Again, the MPCU Report adds somewhat to the above details in agreeing the total emulsions to have been from 10,000 to 15,000 tonnes. As to the fuel oil,, however, the SEEEC Report suggests the estimated 360 tonnes to have comprised releases in the period 15 - 21 February of which the most significant was on the evening of the 21st with smaller releases at the discharge jetty with others occurring on the tow to Belfast. Again, this Report refers to the appearance of fuel oil in an arc offshore between Amroth and Saundersfoot within Carmarthen Bay, and even to some tens of tonnes of oil pellets on the southeast coast of Ireland, though it reports no attempt to attribute these to the *Sea Empress*, while the MPCU Report simply repeats the total release as being 360 tonnes.

Now with reference to the Table in article 112 we see that with 40% evaporative loss and a 36 hour half-life, the amount of emulsion coming ashore in the first 3 days of onshore wind would have been 53,527 tonnes had sufficient oil been released in that period and the amount coming ashore in the six day period of onshore winds which followed the intervening 3 day period of offshore winds would have been 6,690 tonnes to give total stranding of 60,217 tonnes of emulsion with an oil content of 20,072 tonnes which clearly did not happen, because the releases were sequential and subject to differing wind/ tide vectors. However, when we recognise that only 1/5th of the total release occurred over the first 3 days to strand on average on day 1.5 and that 4/5ths of the total release remained at sea for the next 3 days to strand over the subsequent 6 day period of onshore winds, we see from the Table in article 114 that 32% evaporative loss and a half-life of 36 hours permits a first stranding of 7,518 and a second of 7,203 tonnes which totals to 14,721 tonnes containing 4,907 tonnes of oil, that for 40% evaporative loss the corresponding total stranding would be 13,338 tonnes of emulsion containing 4,395 tonnes of oil; that 270 tonnes of fuel oil may be added to both to give respective overall totals of 5,177 and 4,665 tonnes of oil; and that this seems to be in adequate agreement with the 3,000 - 5,000 tonnes of oil estimated to have stranded by direct observation, thus further vindicating the half-life approach which I developed from trial releases and from the *Ekofisk Blow-out* and extended from the report of the *Katina Incident* (articles 39 - 42 and 46).

Again, the agreement of the amount stranded according to the forgoing analysis with the amount stranded as reported by MPCU/SEEEC (having taken account of the removal of 2,000 tonnes from water surfaces and the induced dispersion of 5,515 tonnes) leaves little to be accounted for by post-stranding natural dispersion/biodegradation, but shows that the balance of the 72,000 tonnes released which evaporated and dispersed/biodegraded naturally at sea amounted to 61,485 - 59,485 tonnes depending on whether 3000 or 5000 tonnes were recovered from shorelines. However, had there been no intervention, all of the 72,000 tonnes would have been naturally dispersed to 1% (720 tonnes) in ~ 7 half-lives (10.5 days) and to 0.01% (7.2 tonnes) in another ~ 7 half-lives, i.e. to 7.2 tonnes in 3 weeks, had it remained at sea for these lengths of time without stranding as did the Ekofisk release which after a 32% evaporative loss dispersed/biodegraded entirely at sea with a half-life of 12 hours as confirmed by direct observation (articles 39 - 42, 46 and 102).

Prior to 1996, I was already using this mass balance-approach to estimate the degree to which cargo/bunker transfer had reduced potential stranding in a succession of arbitration awards to salvors, during the course of which I applied it to the *Sea Empress* incident largely for my own interest. I could equally well apply it to the *Deepwater Horizon* incident should anyone be interested in further exemplifying this approach to determining the rates of natural dispersion which enhance natural rates of biodegradation, while, as to dispersant use at the *Deepwater Horizon* incident, those who have read articles 29 -30, 50 - 69 and 99 already know that prior mixing of dispersant into escaping oil might have enhanced its natural dispersion while no such enhancement could have resulted from injecting dispersants into the subsurface plumes of already dispersed droplets reported to have existed at this incident: such action would simply have added dispersant to seawater while, for effectiveness, it must be applied to continuous oil layers of appropriate thickness for subsequent dispersion by wave agitation. As to future developments, however, it should be noted that premixing would be advantageous if it could be arranged (articles 60 - 61).

KNOWLEDGE SUPPRESSED BY BELIEF.

Knowledge Suppressed by Belief: *Sea Empress* and Other Incidents

Article 116

In articles 107 - 115 on the *Sea Empress Incident*, we saw that the use of dispersants was suppressed, thwarted or ignored by retention of the reality-refuted belief in species-extinction/ecological-disaster to the extent of dispersing only a little more oil than came ashore; that nonetheless it was nearly three times the quantity removed mechanically from water surfaces; that these quantities together were dwarfed by those of natural evaporation and dispersion/biodegradation which amounted in total to about 60,000 tonnes (article 115); that these comparisons are common to all incident-responses thus far, except where dispersants are prohibited; and that it is surely time for policy-makers to acknowledge the over-riding role of natural evaporation, dispersion and biodegradation, to accept available knowledge, and to reject the paradoxical consequences of its counter-beliefs.

To encourage this knowledge-acceptance/belief-rejection by policy-makers, this section uses the *Sea Empress* incident as an example of how the belief in species-extinction/ecological-disaster opposes the knowledge which from 1979 onwards could have permitted the use of dispersants, the *in situ* discharge of downstream process water, and cargo/bunker transfer in safe-havens, and which could have restored localities to their pre-incident conditions cost-effectively by minimising releases, could have relied on their natural evaporation and dispersion/biodegradation by enhancing the latter by dispersant use, could have assisted the complementary mechanical removal of dispersible releases by permitting their downstream process waters to be discharged to seawaters already biodegrading the naturally dispersing slick itself, and recognised that only non-dispersible emulsions need be thus removed and processed.

As to dispersant-use, the aerial spraying capacity available to the MPCU had risen by 1996 from 6 Islanders and 2 DC3s to 7 DC3s *i.e*. from 10 to 14 tonnes per sortie (articles 50-55) while two of these aircraft and another on call from the Environment Agency were equipped for the control and evaluation of response operations by remote-sensing (articles 62 - 69), all of which were deployed to the *Sea Empress* incident together with a C130 of 12 tonnes capacity per sortie for part-time deployment. Nonetheless, belief-only regulation in respect of water-depth, limited the dispersant treatment rate to an average of only 49 tonnes or 3.0 sorties per day, and to <13 sorties on the most active day. Had the C130 made one sortie that day, the DC3s would have made ~ 12 sorties, while given the proximity of the replenishment airfield, the initially intended 10 sorties (article 55) by the DC3s on each of 9 spraying days would have delivered 1260 tonnes of dispersant instead of the actual delivery of the 445, even without recourse to the C130 which on an average of one sortie per day would have applied another 108 tonnes. In contrast, on the most active day, only 179 tonnes of dispersant were applied (article 110).

As to mechanical removal from water surfaces, even allowing for its wave and encounter-rate limitations (articles 70 - 89), the recovery of only 2,000 tonnes of oil at the emulsion viscosity of this incident was disappointing, given the number of systems available and the quantity of oil released. No doubt, late arrival of the seagoing recovery vessels, prevalence of onshore winds and shore-proximity put them at a disadvantage with respect to the inshore units, but the presence of six must have arisen from the belief in species-extinction/ecological-disaster which limited dispersant-use while preventing the cargo/bunker transfer to the adjacent refinery which caused a further release of ~68,000 tonnes which would have increased the likelihood of such extinction/disaster had it been other than reality-refuted belief. Again, we know that the encounter-speed of removal units is only 0.5-1% that of aerial dispersant-spraying units; that the proximity of the operational base favoured the latter, while the belief in species-extinction/ecological-disaster which prevented *in situ* decanting of water associated with emulsion removal was unfavourable to the former; and that had more been removed from water surfaces more would have needed transport to, and processing at the Texaco refinery in Milford Haven.

As to shoreline mechanical removal (articles 96 - 98 and 101 - 102), we know that the stranding of only 3,000-5,000 tonnes of oil caused 900 men to be employed at the height of the shore-clearance operation; and that despite the intention of completion for the Easter holidays of 5 - 8 April 1996, the MPCU report of December 1996 was speaking of completion by Easter 1997. Clearly, a quicker and more cost-effective restoration to pre-incident conditions could have been possible had the retained cargo and bunkers been discharged at the refinery before the further 67,000 - 69,000 were released, and had dispersants been fully used as ought to be required of every contingency plan worthy of the name.

Instead, the response was prolonged and the cost increased by the belief-driven ban on dispersant-use on shorelines and in shallow coastal water, and on the decanting of free and demulsified water thereto. Thus, 20,000 tonnes of emulsion and associated free water removed from water surfaces and from trenches and pits on the beaches had to be taken by sea or road to the Texaco Refinery at Milford Haven to process 13,000 tonnes of water to a belief-acceptable oil-content before being finally decanted. In addition, of the total collection of 10,800 tonnes of polluted beach material, 7,300 tonnes went to the Texaco refinery for land-farming, 3,500 tonnes went some distance to landfill, and some 120 tonnes of oiled-sand was cold-mixed at the refinery to produce a 5/20 HRA road surfacing material. Thus, most of the removal dealt with by biodegradation on land and in landfill, could have been dealt with in seawater, but for the reality-refuted belief in species-extinction/ecological-disaster.

The proximity of the Texaco refinery was fortunate even if its storage, processing and land-farming capacities were limited to the extent of determining an upper rate for collection and transport from sea and shore, refineries normally having capacity only for their own onsite wastes and not for those arising elsewhere. Clearly, contingency plans worthy of the name ought not to result in the removal of material quantities beyond the capacity to cope with them expeditiously and cost-effectively, particularly when the pollutant is capable of comparatively rapid dispersion/biodegradation in seawater with or without dispersant-assistance, some 60,000 tonnes having naturally evaporated/dispersed/biodegraded in this incident, as the stranded quantity would have, had it been returned to the sea (articles 107 - 115 and 117 - 120) rather than removed to the refinery. Clearly, knowledge was thwarted by belief in all of the above response-stages, as it has been in all incidents thus far.

Article 117

Before reviewing the belief-driven waste-management regulations which now additionally thwart our knowledge of emergency response as exemplified in article 116, I now evaluate how much worse the *Sea Empress Incident* could have been, had the believers in species-extinction/ecological-disaster paradoxically succeeded in releasing all of its cargo and bunkers.

Let us suppose that the un-released 58,000 tonnes of oil had not been discharged to the refinery as all but the first impact release of 2000-5000 tonnes could have been; that it had been released to the sea as the 72,000 tonnes had been; and that it had been released in various amounts and subjected to onshore/ offshore winds as the 72,000 tonnes had been. Thus, had it been released over three days and stranded under onshore winds with an average age of 1.5 days, the stranding would have amounted to 19,720 or 17,400 tonnes of oil for evaporative losses of 32 or 40% respectively (scenario 1). Again, if this last 58,000 tonnes had been released in the same proportion and to experience the wind/tide conditions of the actual incident, the amounts released would have been 11,600 tonnes to strand in 1.5 days to the extent of 5,800 tonnes and 46,400 tonnes to strand after the subsequent six days to the extent of 2,900 tonnes which together would have amounted to 8,700 tonnes of oil which after evaporative loss of 32% or 40% would have been 5,916 or 5,220 tonnes of oil (scenario 2). On the other hand, if all of the 130,000 tonnes had been released from 15 - 21 February, this would have resulted in 26,000 tonnes coming ashore at the average age of 1.5 days to the extent of 13,000 and of 10,400 tonnes coming ashore in the 6 days to the extent of 6,500 tonnes, to give a combined total of 19,500 tonnes which after an evaporative loss of 32% or 40% would have been 13,260 or 11,700 tonnes (scenario 3).

Thus, had greater casualty-damage caused release of the additional 58,000 tonnes in three consecutive days of onshore winds as of the period 15 - 18 February (scenario 1), had this additional amount been released in the proportions of the actual incident between the period of offshore winds of 19 - 21 February and the period of onshore winds of 22 - 27 (scenario 2), and had the casualty been damaged to the extent of losing all of its cargo in the period 15 - 21 February (scenario 3), we see that the beach pollution would have been greater by the factors shown in the following tabulation which also considers the 2,400 tonnes of fuel oil of which 360 tonnes were released in the incident.

	Oil Release, tonnes	Oil Stranded, tonnes	Foot Note	Factor
Incident reported	72,000	3,000 - 5,000	a	1
	360	216		1
Incident analysed	72,000	3,000 - 5,000	b	1
	360	270		1.25
Scenario 1	58,000	17,400 - 19,720	c	4

		2040	2040		9.4
Scenario	2	58,000	5,220 - 5,916	c	1.2
		2040	1424		6.6
Scenario	3	130,000	11,700 - 13,260	c	2.6
		2,400	1440		6.7

a: stranding estimated for the actual incident by the MPCU, the factor thus being unity.
b: stranding estimated by the half-life method used for the incident and for scenarios 1,2,3.
c: the factor by which to multiply the MPCU estimate of 5,000 tonnes stranded in the incident to obtain the stranding to be expected for each scenario.

Further to the above, we recall that the above tonnages should be multiplied by three to obtain the emulsion tonnages for the crude oil at the reported water-content of 63%, and by two for the fuel oil.

Thus, we see that failure to discharge the casualty at the refinery caused a release of at least 67,000 tonnes of oil in addition to the 2,000-5,000 lost on initial impact; that quite credible scenarios indicate the scale of additional shoreline stranding which could have arisen had commonsense not finally permitted the casualty to be discharged as it could have been sooner; and that early objection to what was later successful must have been due to knowledge being thwarted by belief. While the results of implementing this belief were caused by its fear of inadvertent releases during cargo/bunker transfer, one can only be amazed that the report of the Donaldson enquiry made no overt reference to the wholly avoidable consequences of this reality-refuted belief.

Article 118

Having, emphasised the advantages of cargo/bunker transfer by reviewing the disadvantages of only belatedly doing so at the *Sea Empress* incident, and having reviewed hypothetical scenarios on absolute failure to do so, I now emphasise the advantages of expeditious transfer of cargo/bunkers by reviewing the geographical extent of the shoreline pollution which could have arisen, had belief-only aversion to such transfer given rise to the stranding scenarios of article 117, had dispersant-use and recovery from seawater surfaces been no more acceptable/successful than in the actual incident, and had the time and costs of processing, ‘recycling’ and disposing of shoreline-collected materials been thus extended over more lost Easter and summer seasons and over even longer fishing bans, while greater amounts of emulsion and free-water took even longer to process, decant, land-farm, landfill, or whatever.

As to geographical extent, releases under the onshore winds and tidal streams of scenario 1, would have been localised as in the actual incident to produce up to 4 times as much cargo and up to 9.4 times as much bunker pollution of the Haven itself, and of the external coast running northwest from St Anne’s Head to, and including, Skokholm and Skomer Islands and of the external coast eastwards to St Govan’s Head, while the intervention of offshore winds, subsequent onshore winds and the tidal streams of scenario 2 would have extended coastal pollution to the east beyond Pendine Sands to the Gower Peninsula, the Three Rivers Estuary, the Bury Inlet and all points between, thus maximising belief-driven excitement by placing numerous SSSIs, two Nature Reserves, one Marine Nature Reserve and a substantial part of the Pembrokeshire Coast National Park at risk of pollutant stranding. As to scenario 3, the area affected would have been that of scenario 2 with the quantities stranding being greater by a factor of 2.6 for cargo and 6.7 for bunkers.

As to the additional quantities of the fuel oil in these scenarios, the MPCU report of December 1996 confirms that the amount in the actual incident was disproportionately troublesome in comparison with the much larger amounts of the crude oil releases; that the co-presence of their emulsions complicated clearance, handling, processing and final disposal operations by their higher viscosity and differing interaction with beach materials; that despite this higher viscosity, fuel oil emulsions sometimes penetrated lower than those of the crude oil (or were sequentially stranded) and sometimes collected in depressions to form hard crusts of ‘asphalt pavement’ which when disturbed could cause further spreading of more liquid sub-layers. Clearly, the intensity and extent of these reported phenomena would have increased in proportion to the quantities stranding in each of the above scenarios.

Even with releases smaller than from the *Sea Empress*, shoreline clearance can still be surprisingly troublesome when thwarted by reality-refuted belief. After an eleven-day cargo transfer of 160,000 tonnes from the *Exxon Valdez*, grounded on Bligh Reef in 1989, had limited the damage-related release to 40,000 tonnes, and after this had been diminished by evaporation, natural dispersion, and removal of 2,350 tonnes from the emulsion collected from water surfaces, the emulsified quantity which stranded still caused nearly 6,000km of shoreline to be surveyed of which some 2,400 km involved over 11,000 workers at its height, in removing lightly scattered patches and tarry residues with shovels, buckets and other hand tools outside Prince William Sound, while within the Sound some 400km were washed with cold or hot water to release pollutant from beach material for removal by 50-crew custom-built barges equipped with some 10,000ft of boom, skimmers, pollutant storage tanks, power generators, heaters, fuel, and in some cases adapted concrete-pumps. In addition, nutrients/fertilisers were added to the indigenous micro-organisms to achieve bioremediation rates from 3 - 5 times normal as assessed by monitoring the increasing concentration of the relatively non-degradable marker hopane, on 120km of coastline at a cost of $10 million from 1989-1991.

Thus, we see the benefits of cargo/bunker transfer, given that the thickness-limited pollutant encounter-rate resulted in only 2,350 tonnes being removed, depite mechanical removal from water surfaces being the only approved option. Again, we see that shoreline clearance is a major task given the limited encounter-rate capacities of both dispersant-treatment and mechanical-removal of release-residuals from water surfaces prior to stranding, especially when only the latter is permitted; that the quickest possible provision of cargo/bunker transfer equipment ought therefore to be the main objective of response planning; that bioremediation would be accelerated by dispersant-use both at sea and onshore; but that these wholly beneficial activities require available knowledge to be accepted and reality-refuted belief to be rejected.

Article 119

Having shown that cargo/bunker transfer is the sole means of avoiding releases beyond those of initial tank-damage, that even these lesser releases can be beyond contingency provisions for timely dispersion and/or physical removal of residuals to prevent stranding; and that reality-refuted beliefs thwart all three: I now show the disadvantageous extent to which the downstream processing of wastes removed from sea and shore have themselves been increasingly thwarted by the ever widening requirements of reality-refuted beliefs for needless transport, treatment and disposal of wastes in general.

Thus, prior to the *Sea Empress* incident, a regulatory framework had been developing in the UK through the Environmental Protection Act of 1990, the Waste Management Licensing Regulations, and National Waste Strategy of January 1996, without forethought as to its impact on emergency-generated marine wastes, as revealed by Environment Agency staff at an Institute of Petroleum *Sea Empress* Seminar in September 1996. Thus, the 1990 Act embodied more stringent belief-driven standards for landfill by requiring groundwater protection by containment to replace earlier reliance on dilution/ dispersal/biodegradation, while the National Waste Strategy incorporated a hierarchy of waste-specific disposal options believed to be the most environmentally friendly on a case-by-case basis, thus eliminating landfill as a disposal option for hydrocarbon wastes, its anaerobic decrease in rates of degradation being believed to damage the environment by increased leaching to groundwater and methane escape to atmosphere, though landfill was not known to be thus damaging.

While this belief in damage ostensibly permits exemptions for emergency-generated oily wastes in undefined ‘emergency circumstances’, potential receivers are nonetheless unwilling to seek such exemptions for fear of creating subsequent regulatory problems for themselves. Given the undefined and arbitrary nature of the regulations, the removal of pollutant from a beach is more readily seen as an emergency operation than is the temporary/intermediate storage of the wastes thus removed. Yet again, were such storage deemed to be outside the emergency-provision, a licence would be required which might not be forthcoming and which, in any case, would be treated as a request for planning permission which itself is a lengthy procedure requiring consultation with other bodies, unless the waste is to be recycled or put to direct use, in which case it can be provisionally exempted as provided within the Act and the EC Directives from which it derives. Taken together, these regulations are obstructive in leaving too much to interpretations of environmentalist belief by those with no responsibility for returning the said environment to its pre-incident condition quickly and cost-effectively.

Further to the absence of knowledge, reports by the Marine Accident Investigation Branch (MAIB) into causes of accidents are intended to avoid repetitions by determining whether the accident under review occurred because of non-compliance with existing regulations or because of compliance with a defective regulation which in light of the investigation needs corrective amendment. Thus, in considering the grounding of the *Sea Empress*, the Marine Accident Investigation Board (MAIB) report followed standard practice as to cause(s). However, with regard to incident-response, the assumption must be that accidents will occur, contingency planning being redundant were this not so. On the other hand, with the contingency plan having failed to consider provisions for emergency cargo cargo/bunker transfer and with there being no referential regulation, the MAIB report merely describes the efforts made to hold the ship in the Haven entrance ostensibly for cargo/bunker transfer at the grounding location, and thus failed to consider actual discharge to the destination-refinery, this not having been identified as an option.

Thus, in this latter phase of the report, the authors were bereft of any prescriptive regime or even general guidance within the national contingency plan as to the role of officials or salvors respecting ship-to-ship or ship-to-shore transfer of cargo/bunkers from casualties. Thus, they had to fall back on references to the general concept of good seamanship against which they could conveniently discuss the handling of the ship *in situ* in the absence of any regulatory framework against which compliance/non-compliance could be assessed, or which itself could be assessed as needing amendment towards improving future incident response. Indeed, the extent to which the operations under discussion appeared to unfold rather than to be directed was a pointer in themselves to the absence/inadequacy of documented guidance for those involved, though the most glaring deficiency was the absence of any written justification for attempting ship-to-ship transfer in the mouth of the Haven or indeed at the destination-refinery only a few miles further in. As to citation of any supposed difficulty with the latter option, the writers of the report knew that the ship had ultimately been towed to the said refinery for discharge, and thence to Belfast for dry-docking.

Article 120

Because of belief-consensual reluctance to bring casualties into safe havens for sheltered cargo/bunker transfer, salvors are forced to provide their services in exposed seas at no little danger to themselves as individuals, while ships' crews are deprived of the traditional right of entry to a safe haven when in distress, a deprivation which but for the belief-consensus in species-extinction/ecological-disaster could long since have been rectified by the Marine Safety Committee of the IMO.

Nonetheless, despite both real and belief-imposed difficulties, member companies of the International Salvage Union provided their services to 169 ships in 1996, many of which involved the transfer of oil, chemicals (HNS) and bunkers amounting to nearly 2 million tonnes in total, the corresponding figures for 1994 and 1995 being 2.1 million and 1.87 million tonnes respectively. For 1996, the potential pollutants removed were 1.75 million tonnes of oil, 62,000 tonnes of chemicals and 58,000 tonnes of bunkers in a total of 20 ship-to-ship transfers, while in 1995 there had been 21 such transfers of which the largest were 290,000 tonnes from the *Galp Funchal* and 343,000 tonnes from the *Kraka*. By February 1996, therefore, it was impossible to doubt that the cargo remaining after the initial impact-release is potentially salvable; and that such quantities on release to the sea would far exceed anything preventable from stranding by dispersant-use or mechanical removal at sea and/or inshore waters.

At this point, it should be recalled that the WSL R&D programme recommended a contracted aerial dispersant-spraying capacity to treat no more than the residuals from 5,000 tonnes of oil per operational day whether emulsified or not, this target being the release-limit from a damaged IMO-designed tank (articles 47-61); that the nominal removal capacity, again based on realistic encounter rates, had been set by the same R&D programme at 1,200 tonnes of windrowed 80% emulsion per working day, this to be provided by a Springsweep system deployed from *RV Seaspring* and from each of two coastal tankers of opportunity, together with one Force 7 Oil Mop deployed from an offshore supply/service vessel of opportunity, and with the expectation of achieving 2,400 tonnes, were six Springsweep systems to be double-deployable on their three ships (articles 70-91). Again this R&D programme recommended the stockpiling of a range of specialist beach cleaning equipment capable of dealing with residual-standing from such single-tank releases in a matter of weeks for use by coastal local authorities (articles 92-102), and of emergency Oil/HNS cargo/bunker transfer equipment with the capacity to create safe void-space at the rate of $1000m^3h^{-1}$ for use by salvors in transferring un-released cargo/ bunkers to sound vessels or direct to refineries even when casualties were without power, and thus to encourage adoption of a safe havens policy for such transfers, refineries supplied by sea being themselves located for weather protection in just such havens (articles 105 and 106).

Thus, with the International Convention on Intervention on the High Seas having been incorporated in national law and with the *Sea Empress* incident having provided a glaringly obvious opportunity to intervene within the 3-mile limit, it was not surprising that failure to do so caused an Enquiry to be held under Lord Donaldson into the conduct of salvage operations in the UK. However, while being surprised to find that the Enquiry was inviting responses as to what intervention powers a Secretary of State might need to correct current deficiencies, I responded that the powers were adequate if knowledgeably used; but that even when officialdom did move the *Sea Empress* to its destination-refinery, it remained uncertain whether the powers had been invoked or not. In any case, I referred the relevant sections of my 1983 book to the secretariat provided to the Enquiry by the Policy Division of the UK Shipping Administration, and while hearing no more about it then, I was somewhat gratified to learn later that a new post of Secretary of State's Representative (SOSREP) had been created, and that the newly appointed incumbent was intended to do whatever he judged necessary and to be dismissed if this was later judged by others to be wrong. However, I remained ungratified in noting that judgement is mere belief-consensus; and that knowledge *per se* was still being ignored..

Later in 1997, it was reported in the aftermath of the *Exxon Valdez Incident*, that the US National Plan for Oil Spill Response had empowered the senior on-scene USCG representative to resolve all differences of opinion as to how to proceed in marine incident response, and that the USEPA now had a similar role at inland incidents. However, even with these stated intentions, it remained unclear whether the conduct of incident response would ever be based on the knowledge being reviewed in these articles or whether opinion/counter-opinion, *i.e.* one belief-consensus or another, would continue to override this knowledge, as appears again to have been the case with the *Deepwater Horizon* incident.

Thus we see that reality-refuted belief in species-extinction/ecological-disaster thwarts the cargo/bunker transfer which is known to be the surest means of preventing releases from posing any risk of either; and that nonetheless this knowledge has not been recognised in any regulation thus far, despite total releases of cargo/bunkers never having produced any extinction/disaster thus far. Again, we see that this reality-refuted belief produces regulations which prevent dispersants from increasing the natural dispersion/biodegradation which is known to reduce the stranding of releases and which is known to increase this natural dispersion/biodegradation when stranded releases are thus dispersed back to the sea. Yet again, we see that this belief produces regulation preventing the online decanting of water separated from releases removed from sea and shore, that it thus requires all processing/decanting to be through regulated installations onshore despite its being more quickly and cost-effectively achieved at sea or on shorelines; that in thus leaving increased amounts to strand, it increases the amount mixed with particulate beach-material; that it bars from disposal to landfill that which could have been much reduced in the first place, had separation of pollutant from water been permitted at sea and had dispersants been permitted to separate pollutant from beach material onshore and to return the former to the sea for dispersion/dilution/biodegradation while leaving the latter *in situ* (articles 92- 95).

In the next section (articles 121 - 124), I differentiate knowledge from its counter beliefs and invite policy-makers and regulators to reject the former and to accept the latter.

Knowledge/Belief Differentiation: Ecology and Anthropogenic Global Warming

Article 121

For policy-makers to accept knowledge and to reject belief and thus to harmonise technology with the environment, the knowledge/belief dichotomy must be definitively differentiated (Foreword, Preface and articles 1-15). Thus, with this differentiation having been applied in the Preamble to the Knowledge-Repository, in the Repository itself and in my analysis of the *Sea Empress* incident, and with this knowledge/belief differentiation now being available to publics and politicians alike through this website, policy-makers have no rational alternative other than to accept that the non-volatile components of oils form water-in-oil emulsions of higher viscosity than the fresh oil (articles 16-30); that individual HNS do not form such emulsions; that oils, emulsified oils and HNS float, sink, evaporate, dissolve or disperse on operational discharge or accidental release (articles 31-46); that their initial concentrations and subsequent dilutions and biodegradations preclude toxic effects whether natural or dispersant-induced (47-59); that greater effectiveness can be sought through use of this knowledge in future dispersant formulations (articles 60-61); that differing slick thickness ranges have been related to differing remote sensing images (62-69); that suitably selected equipment can remove pollutants of higher viscosities than can be effectively treated with dispersants (70-91); that the viscosity-dependent effectiveness of dispersant treatment and mechanical removal have been reality-validated for at sea and shoreline use; that the elements of downstream processing of emulsions removed from water surfaces and shorelines have been reality-validated (92-102); and that all response policies arising from beliefs counter to this knowledge are non cost-effective (103-106) as exemplified by the actual response to the *Sea Empress* incident (107-120) and by all incidents from the *Torrey Canyon* to the present inclusive.

Having differentiated knowledge from its counter-beliefs and having thus differentiated their respective consequences, articles 121-124 now recall the nature of this differentiation (Foreword & Preface), while articles 125 - 127 show how knowledge-acceptance/belief-rejection will enable the former to restore localities to their pre-incident conditions quickly and cost-effectively, while articles 128 - 129 show how the suppression of reality-validated knowledge by reality-refuted belief can be terminated by the knowledge-acceptance/belief-rejection which, in addition, would suspend all other beliefs pending their reality-validation or reality-refutation as specific hypotheses.

To enable policy-makers to adopt this long overdue knowledge-acceptance/belief-rejection, my most recent book[3] has shown that the reality-validated knowledge which is craftsmanship, science and technology and the knowledge-content of our traditional behaviour codes differs from the beliefs which socio-political policies have always implemented without any reality-validation or reality-refutation; that the accumulated failure of such policies in reality has caused violence, revolution and war since time immemorial; that our species has nonetheless failed to recognise this peaceful/non-peaceful contrast as being of itself a differentiation of knowledge from belief; and that while this failure did not prevent our previous knowledge-based progress, it now thwarts it, by eliding/conflating belief with knowledge in general, and belief-consensus with science in particular (articles 14 - 15 and 43 - 49).

Thus, my third book has shown that these ubiquitous elisions and conflations could be eliminated for the first time ever, by general acceptance that our imaginative beliefs become knowledge only when evaluated for compliance/non-compliance with reality; that this reality-evaluation requires direct observation or designed experimentation as to specific cause-effect relationships; that belief remains belief when this reality-evaluation is impossible in principle or *pro tem* practice; that existing knowledge can be differentiated from existing belief by recognising the presence or absence of prior reality-evaluation; that opinion/counter-opinion is belief/counter-belief supported by partially selected facts/counter-facts, neither set of which amounts to debate-terminating knowledge because their cause-effect relationships are rhetorical in not having been individually established; that debate is thus interminable in the absence of conclusive knowledge; that the only outcome of debate is a transient belief-consensus wholly inadequate for implementation in reality; and that reality-evaluation not only differentiates the knowledge/belief dichotomy but also those of truth/falsehood, wisdom/folly, right/ wrong, good/bad, science/pseudoscience and commonsense/nonsense. Indeed, it resolves epistemology itself in enabling knowledge-contents to be differentiated from the belief-contents of behaviour-codes, philosophies, politics, economics and all other mixtures of knowledge and belief as yet undifferentiated (Foreword, Preface and article 1).

Thus, having differentiated knowledge from belief in general, we know in particular that the belief in species-extinction/ecological-disaster is thus differentiated from the knowledge that the number of individuals dying from physical coating by oil are too low and too transient for such extinction/disaster; that the concentrations of oil/HNS exposure to organisms in the water column are too low and too transient for such extinction/disaster; that no such extinction/disaster has arisen at any incident thus far whether dispersant treated or not; that the belief in dispersant-use causing species-extinction/ecological-disaster is thus differentiated from the knowledge that such use reduces the numbers coated without significant increase in seawater concentrations, and from the knowledge that the concentration-depth profiles for dilution and biodegradation within the water column as a whole are indistinguishable whether natural or dispersant-induced, the localised areas of low-encounter-rate application being ever smaller the greater the slick area (articles 50 - 55 and 92 - 98); and that mechanical removal is similarly localised (articles 70 - 89 and 96 - 98).

Again, we know that the belief in anthropogenic global warming can thus be differentiated from the knowledge that the global biomasses of land and sea are continuously recycling through the atmosphere as carbon dioxide by photosynthesis and bio/oxidative degradation; that the tectonic plate movement which forms carbonate rock in mountain building and which decomposes it in volcanism also recycles carbon dioxide through the atmosphere; that were there no volcanic return, this sequestration as carbonate by the Urey reaction would have terminated the photosynthesis on which all life depends by removing all carbon dioxide from the atmosphere before hominid evolution could have begun; and that these global biological and geological carbon dioxide cycles are unlikely to be disturbed significantly by our combustion of organic material, the carbon dioxide equivalent of which would already be recycling through the atmosphere and biomasses had it not been 'fossilised' to natural gas, petroleum or coal by localised oxygen depletions in the first place (Foreword, Preface and articles 43 - 46).

Article 122

With article 121 having recalled that knowledge has now been definitively differentiated from belief in general and in particular, this article now provides a few more relevant particulars. Thus, we know that belief in the permanent toxicity of released oils/HNS can now be differentiated from our knowledge that all organic material which constitutes the biomass of all land and marine ecosystems is recycled by photosynthesis and biodegradation from and to carbon dioxide; that the biological carbon dioxide cycle of land-based ecosystems continuously introduces intermediate biodegradation products to the marine ecosystem by river run-off and atmospheric rainout; that the greater proportion is continuously produced by the marine ecosystem itself; that this moves back up the food chain, sinks to sustain food chains at greater depth or returns to surface waters by the up-welling which makes continental-shelf waters more productive than ocean waters; and that, consequently, no such product is toxic per se.

More particularly, we know that primary marine production arises by photosynthesis from carbon dioxide in the light-penetrating euphotic zone where phytoplankton species undertake the role of land plants; that chemosynthetic bacteria synthesise organic molecules from carbon dioxide by energy derived from oxidation of such as the ammonium ion, molecular hydrogen or hydrogen sulphide instead of from solar photons; that there would be no marine photosynthesis if carbon dioxide did not dissolve in seawater; that the acidification of seawater is thus a non-problem; that heterotrophic bacteria use preformed organic molecules as food-sources in the secondary production of the marine ecosystem which extends from the euphotic zone to the seabed thousands of metres below it, and ranges from bacteria to blue whales; and that unutilised food sources sequestered from the cycle of synthesis/ biodegradation by anaerobic conditions are 'fossilised' to natural gas, petroleum and coal.

Thus, given the dependence of heterotrophic bacteria on pre-existing organic material, we should not be surprised by our knowledge that such are capable of utilising petroleum components and organic HNS, the precursors of which would have been part of the food-source during their pre-fossilisation passage to the seabed; that the populations of such heterotrophic species at the bottom of the marine food-chain/ ecological-system are proportionate to the standing concentrations of oil runoff from land, of casualty-related releases, and of natural petroleum seepage; and that these are the organism types which bio-remediate contaminated sites on land and shore. Again, while natural seeps and other releases expose organisms to a wider range of hydrocarbon classes and homologues within each class than are present in their food-source precursors, and while low molecular weight hydrocarbons and aromatics of petroleum origin could have concentration-dependent narcotic and toxic effects, we know that both evaporate rapidly without any such effects. Yet again, we know that while higher molecular weight poly-nuclear aromatic compounds (PNAH) are not evaporated, those which are absorbed by filter-feeders are rapidly excreted unchanged or as recognisable metabolites with removal of taint on exposure to clean water prior to sale. In addition, we know that free-swimming fish do not acquire taint unless surface-contaminated by being drawn in nets through floating slicks; and that all organic compounds, pre- or post-fossilisation, degrade to carbon dioxide and water when exposed to natural oxygen concentrations whether or not directly utilised as food-sources in ecological systems (article 26).

Again, further to exposure-concentrations, we know that evaporation, dispersion or solution from floating oils/HNS spread to ~ 0.1mm layer thickness cannot have any significant effect on the volumes of underlying seawater or overlying atmosphere; that were such rates to be instantaneous, the concentration in the bottom metre of the atmosphere or the top metre of the water column could not be more than 100ppm; that rates of dispersion/solution being less than instantaneous, the top metre concentrations in seawater are always well short of

100ppm and continue to dilute and biodegrade though the ppb range to zero in the seawater and atmosphere columns. Yet again, we know that the surface-proximate concentrations arising from floating layers of oils/HNS or from more compact non-spreading sunken volumes of individual HNS are never more than their proximate saturated vapour or their saturated solution concentrations; and that such concentrations subsequently dilute and degrade within the seawater or atmospheric column, though such dilution of the latter is constrained for releases in confined spaces onboard ship and thus requires specific attention in the salvor-related aspects of response. More generally, we can differentiate the above knowledge from counter-beliefs which have no reality-validation and are thus refuted by the above knowledge

As to time-dependent human exposure to concentrations above floating slicks in ship-borne response operations, we know that individual HNS and oil components with boiling points ≤150°C or ≤ 250°C evaporate totally from layer thickness of 0.1 mm in <1 or <5 hours respectively despite non-volatile oil components forming water-in-oil emulsions in the meantime; that 0.1mm and 1.0mm layers of the single compound nonane would entirely evaporate in 3 or 30 minutes; that while vapours from oil slicks containing nonane as a natural component would burn when ignited, explosions are possible only in confined spaces onboard casualties; that the latter can be avoided by direct measurement of space constrained concentrations with respect to the relevant upper and lower explosion limits; and that all of this knowledge has been reality-validated as specific hypotheses and thus differentiates itself from all counter-beliefs which it thus reality-refutes.

Article 123

As to prediction of the general fate and effects of all released oils/HNS and of the most effective response techniques and equipment, we know that buoyancy, sinking and solidification depend on the physicochemical properties manifested as density, pour point and melting point; that the extents of evaporation for oils depend on those properties manifested as distillation-temperature profiles; that the extents of water-in-oil emulsifications and resulting viscosities, depend on initial viscosities and on water-content and on whether the oil is crude, distillate or residual-fuel; that individual HNS are not emulsion forming, retain their initial viscosities and evaporate at rates dependent on their boiling points; that insoluble/non-volatile slicks of oils/HNS disperse at rates dependent on their viscosity-dependent half-lives whether emulsified or not; that these half-lives determine the fractions likely to strand on known wind/tide vectors; that soluble HNS dissolve at rates dependent on their known solubility to diluting/biodegrading seawater concentrations similar to those dispersing/biodegrading oils; and that consequently these predictions are no cause for panic whichever oil/HNS has been released.

Thus, whatever may be counter-believed, we know that oils/HNS are either liquids or solids at ambient temperatures; that they either float while evaporating, dispersing, dissolving. or sink while doing so; that evaporation is followed by atmospheric dilution and photolytic degradation; that while the non-volatile components of floating oils or individual HNS may coat shorelines and organisms of particular species, their subsequent dispersion and/or solution from shorelines to seawater simply resumes their earlier dispersion, solution, dilution and biodegradation within the seawater ecosystem in which organisms utilise preformed organic molecules as food before themselves dying, degrading or being eaten by others which themselves will later die, degrade or be eaten; and that consequently there is no cause to believe in species-extinction/ecological-disaster arising from any oil or organic HNS release or from any inorganic HNS release, the latter also being subject to dilution and to neutralisation by the buffered pH mineralisation of seawater with any future exceptions being identifiable by their known physicochemical properties.

Again, while the coating of shorelines and individual organisms cause commercial loss by interrupting amenity enjoyment and fishing activities for which compensation is available, we know whatever may be counter-believed, that the above fate, effects and non-effects can be reliably used to predict the commercial impact which claimants could cite had no response been mounted; that such prediction can be compared with the known reduction in impact achieved by the knowledge-only/cost-effective response actually mounted before and after stranding; that response costs ought to be proportionate to the reduction in claims thus achieved; that such reductions are best achieved by enhancing natural dispersion, dilution and biodegradation within the water column by application of viscosity-amenable dispersants to the extent possible/necessary before and after stranding; that higher pollutant viscosities may necessitate mechanical removal at sea and onshore; but that all such removal involves processing, recycling and ultimate disposal costs, avoidable only by successful dispersant use.

Thus, environmental response planning must reject belief in species-extinction/ecological-disaster in the knowledge that seawater and atmospheric concentrations of released oils/HNS are too low, too localised, and too transient to have such species-wide or ecological effects; that the number of individual organisms physically coated by released oils/HNS are too few to have any such effects; that dispersant-use prevents or reduces localised physical coating of shorelines and organisms without significantly increasing their seawater concentrations beyond those of the natural dispersion which otherwise prevents or reduces such physical coating; and that such natural dispersion occurs under the entire slick area while dispersant-use is physically limited to a fraction, often a very small fraction of the total slick area, as is seaborne mechanical removal. Again, the total quantity of oils or organic HNS dispersed or dissolved into the sea in any one incident is a miniscule fraction of the total marine food source which recycles the total marine biomass through the atmosphere as carbon dioxide while inorganic HNS are diluted/neutralised by overwhelming quantities of seawater, any future exceptions being identifiable as they arise from developments in industrial chemical synthesis.

Thus, whatever may be believed to the contrary, we know that oils/HNS evaporate, disperse and/or dissolve to concentrations at which only an identifiable few HNS might be considered locally and transiently toxic at worst; that no oil component or individual HNS which has evaporated, dispersed and/or dissolved can be collected; that nonetheless no species-extinction/ecological-disaster has yet been observed from the *Torrey Canyon* incident of 1967 to the present inclusive; that only the oil components and individual HNS which have not already evaporated, dispersed or dissolved come ashore in amounts dependent on the proximity of shore to release-point and on their viscosity-dependent persistence as floating slicks; and that consequently dispersant-use to return stranded pollutants to the sea would simply resume the natural dispersion which would have occurred with no ill effects had the source-to-shore distance permitted its completion before stranding could occur.

Article 124

Having rejected the belief in species-extinction/ecological-disaster by citing our knowledge of the oils/ HNS themselves, and our relevant knowledge of ecology, oceanography and geology, we see that the belief in anthropogenic global warming ought now to be suspended pending reality-evaluation of specific hypotheses derived from our knowledge of oils/HNS, ecology, oceanography and geology (Foreword, Preface and articles 121 - 123).

In confirmation of the above rejection, we know that the LC_{50} value is the lowest concentration which will cause 50% death of test-organism populations; that this has been laboratory-determined by raising the exposure-concentration to achieve it in a convenient standard-time; that while such testing gives a ranking of the intrinsic toxicities of substances so compared, it does not measure actual toxicity at exposure-concentrations in the real environment; that the critical body residue (CBR) approach does measure the whole-body concentrations associated with observed toxic effects at the actual exposure-concentrations which produce them; and that while the so-called group of experts on scientific aspects of marine pollution (GESAMP) quotes LC_{50} values which rank the intrinsic toxicities of cargoes, it misleadingly implies that these predict actual release toxicities in the environment. Thus, we know that such measurement and this implication do nothing to advance knowledge of biological effects in the marine environment; and that the sole beneficiaries are those who persist in believing in species-extinction/ecological-disaster despite its reality-refutation by the direct measurement of environmental concentrations which show them to be too low to be toxic in reality (articles 14 - 15 and 47 - 49).

Indeed, we have long known that UK measurement of comparative LC_{50} values for concentrate dispersants required exposure of test organisms to concentrations of 1000ppm of a standard oil, the toxicity of the dispersant itself at its operational concentrations being un-measurable, while we also know that the actual concentrations of oil in the top metre of the water column under dispersing slicks are no more than ~ 10ppm before rapidly diluting/biodegrading throughout the entire column whatever its depth and rate of tidal movement; and that consequently belief in species-extinction/ecological-disaster from such exposure can be rejected. Thus, we know that simultaneous exposure to oil and dispersant in the test, arose from the dispersants themselves being too non-toxic to be measurable at any convenient test concentration and that consequently the only parameter actually measured in the test was the LC_{50} value of the test oil; that this was thus being measured over and over again in the hope of its being influenced by the presence of the dispersant under test; and that if any differences were observed the result would be to fail the most effective and to pass the least effective dispersants, despite the knowledge that dispersants, regardless of their effectiveness/non-effectiveness, were non-toxic as were the oils at their actual concentrations in seawater. Such testing reveals scientists as being as incapable of differentiating belief from knowledge as non-scientists (articles 43 - 49).

As to the physical coating of birds and other mobile organisms by floating or stranded pollutants, we know that the significance/insignificance of such coating for oils and their emulsions could be reality-evaluated by comparing the numbers thus dying in incidents with the numbers naturally dying and birthing annually in maintaining species populations at current levels; and that the absence of species-extinction/ecological-disaster at all incidents thus far has itself reality-refuted this belief. As to the physical coating of sedentary shoreline organisms, we know that the best defence is natural/induced dispersion or mechanical removal when pollutant viscosity precludes dispersant-use; that biological/ oxidative degradation of pollutants is faster as dispersed droplets in seawater than as continuous layers onshore; that stranded pollutant should thus be returned to the sea as dispersed droplets whenever/ wherever physically possible; that shorelines are re-colonised as are scrubbed boat-slips by planktonic life-stages of their naturally resident species, and as are weeded gardens by windborne seeds; that whichever techniques are known to return commercial amenity-enjoyment and fishing to pre-release levels quickly and cost-effectively should be universally endorsed; and that belief in species-extinction/ ecological-disaster arising from physical coating should henceforth be rejected (Foreword, Preface and articles 50 - 115).

As to the relationship between anthropogenic species-extinction, ecological-disaster and global-warming, we know that the biological carbon cycle absorbs carbon dioxide and water from the atmosphere to photosynthesise all plant matter on land and in the sea; that all animal matter depends ultimately on the plant matter as food source; that all animals respire food of plant or animal origin to carbon dioxide and water in generating energy while alive as do all heat engines while active; that all plant and animal matter undergoes bio-oxidative degradation to carbon dioxide and water when dead unless oxygen-deprivation interrupts this degradation to form peat, natural gas, petroleum and coal; that micro-organisms at the bottom of the food-chain/ecological-system degrade all accessible organic matter whether pre- or post-fossilisation to carbon dioxide and water without harm to themselves; and that combustion of fossil fuels returns to the atmosphere the carbon dioxide and water which but for the fossilisation would already have been recycling through it and the total biomasses of land and sea .

Again, we know that tectonic plate movement drives the geological carbon cycle which raises mountain ranges with abstraction of atmospheric carbon dioxide and water to form carbonate rock while its weathered sediments are river-transported to seafloors tectonically sub-ducted beneath continental margins while associated volcanic activity decomposes their carbonates thus returning carbon dioxide and water to the atmosphere; that were this geological abstraction to have no atmospheric return, it would mineralise all atmospheric carbon dioxide and terminate all plant, animal and human life; and that consequently, belief in anthropogenic global-warning can be suspended pending reality-evaluation of hypotheses as to how the rates of carbon dioxide abstraction and return within these two cycles respond separately or together to changes in its return rate by fossil fuel combustion and/or to changes in its return by biodegradation alone over geological timescales (Preface and articles 43 - 46).

Article 125

While restoration of localities to their pre-release conditions requires knowledge of effects and means of prevention and response, counter-beliefs already refuted by knowledge or awaiting reality-evaluation to positive or negative knowledge, produce nothing other than regulations preventive of restoration, and causative of needless response costs. Thus, having shown in articles 116 - 120 that the thwarting of knowledge by its counter-beliefs squanders on unreality resources better spent on reality, and having differentiated knowledge from the counter-beliefs respecting ecology and anthropogenic global warming (Foreword and articles 121-124), I now expand on the extent to which definitive knowledge has thus far gone unrecognised by its definitive counter-believers.

Thus, while WSL was reality-evaluating the effectiveness of dispersants for application by its ship-mounted spraying equipment in the aftermath of the *Torrey Canyon* incident of 1967, dispersants were already being banned elsewhere in the belief that their use would cause species-extinction/ecological-disaster, despite natural dispersion during the incident being already known not to have caused either and despite dispersants being already known by their evaluators to be non-toxic at their concentrations of exposure to marine organisms. Again, while WSL was evaluating the means of reducing operational oil discharges from ships, it acquired the knowledge (articles 18 - 21) that the bilge water beneath its gravity-separated floating oil layer in the four ships taken as examples, had an average oil-content of 21ppm throughout its discharge, though it averaged 56ppm at the outset of discharge until the pipes were cleared of adhering oil from contact with the floating layer at termination of the previous discharge. Again, while WSL was acquiring knowledge as to the possible impact of operational discharges on shorelines before deciding how dispersants might assist in shoreline restoration, belief had already regulated the oil-content of operational discharges through onboard gravity separators to a maximum of 100ppm without knowing whether this was necessary or not, or how it might be achieved for all potential oil-contents were it to be necessary. Yet again, belief has more recently banned *in situ* decanting of water similarly separated from collected oil/emulsions in release-response, despite its oil content being in a lower ppm range than that to which the slick itself is naturally dispersing while localised removal operations proceed. Clearly, knowledge has long been unrecognised, suppressed, thwarted, or ignored by belief.

Again, while the absence of species-extinction/ecological-disaster at all incidents thus far, could easily be explained by the knowledge that the numbers of organisms killed by physical coating are too low to have such effects, believers use these numbers to imply that such effects are a reality. Yet again, while the absence of species-extinction/ecological-disaster at all incidents thus far could easily be explained by the knowledge that seawater concentrations arising from natural and dispersant-induced dispersion of floating layer thicknesses are too low to have any such effects, believers use unspecified concentrations to imply that such effects are a reality. Thus, we know that while believers gain credit from the general public for protecting the environment from non-existent species-extinction/ecological-disaster, they deliberately induce fear of these unreal effects to ban or restrict the dispersant-use which would restore environments to their pre-incident states quickly and cost-effectively. As to their expressed fear that safe-haven cargo/bunker transfer could cause species-extinction/ecological-disaster, one wonders what effects would justify preventing a response which prevents these effects.

Yet again, while belief in anthropogenic global warming cannot be reality-evaluated merely by observing localised surface temperatures over a few decades given the natural variation over centuries and millennia, we know that such temperature measurements are used by believers to imply not only that global warming is a current reality but also that it is anthropogenic. However, we know that this belief could be broken down to specific hypotheses for reality-evaluation by designed experimentation, these hypotheses being directed to quantifying the rates at which the biological and geological carbon dioxide cycles respond to changes in the rates of carbon dioxide abstraction and release within one or the other, the rate at which the abstraction of carbon dioxide by either or both responds to release from fossil fuel combustion, and the rate at which predicted global average temperatures would thus rise and fall with net increase and net decrease in measured atmospheric carbon dioxide concentrations.

In such ways, the sensitivity of global warming/cooling mechanisms to anthropogenic releases of carbon dioxide could be elucidated. However, instead of adopting this scientific approach, we know that while believers wish to gain credit from the general public for protecting the environment from an as yet non reality-validated anthropogenesis, they use their deliberately induced fear of it to distract attention from the internal control mechanisms which ultimately restore environments to their pre-disturbance conditions and thus to destroy all hope of the harmonisation of technology and environment on which our future welfare depends. Thus, we know that resources better spent on real problems are being squandered on unreal problems such as those believed to arise from the fossil fuel combustion which merely resumes the degradation earlier interrupted by localised oxygen depletion.

Thus, believers in AGW, must now accept that their self-styled mathematical model of global temperature increase with increase in fossil fuel combustion is not confirmed by current temperatures being measured locally on the Earth's surface, given the range of past variations over centuries and millennia; that such modelling merely recycles its initiating belief; that the lack of reality-validation of this initiating belief can only produce belief-driven predictions which themselves need reality-validation or reality-refutation; that in any case, science takes a failure of model prediction as indicative of incomplete initiating knowledge of the phenomena being modelled, while pseudoscience is always content to ignore such failure or to cite other belief-selected correlations to obscure it; that science treats correlations as fortuitous or spurious until cause-effect is established, no prediction being possible until the cause-effect relationship is quantified, while pseudoscience mistakes arbitrary correlation for cause-effect and can thus predict nothing. Indeed, believers in AGW give their game away in speaking of belief and disbelief, of conviction and scepticism and of acceptance and denial and thus denote the absence of science in particular and of knowledge in general (articles 43 - 46).

Thus, we know that current knowledge can produce a cost-effective response plan for marine incidents simply by rejecting its counter-beliefs; and that such a plan can restore localities to their pre-incident conditions quickly and cost-effectively without incurring species-extinction/ecological-disaster, because no such extinction/disaster has yet occurred despite the ineptitude of belief-driven response having been more than enough to cause such extinction/disaster had the releases been capable of causing them. Again, we know that our planet has experienced many periods of warming and cooling before and after hominid inception; that the belief/disbelief debate on AGW can be resolved only by reality-evaluation of specific hypotheses; that meanwhile this debate could be bypassed by decreasing carbon dioxide emissions by increases in engine and hull efficiencies encouraged by the cost-savings of decreased fuel consumption, whether AGW is believed or disbelieved; and that imposition of emission-charges cannot be justified by belief-consensus, global temperature being unlikely to increase significantly by combusting part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through atmosphere and biomass (Foreword and Preface and articles 43 - 46).

Article 126

Having shown in articles 121-125 that all beliefs counter to knowledge should be ignored until reality-validated or reality-refuted as specific hypotheses by their believers, I now recall the *Sea Empress* incident of 1996 (articles 107-120) as a reminder that beliefs counter to knowledge not only prevent quick and cost-effective restoration of environments to their pre-incident states, but also make them very much worse than they need have been in respect of interruptions to commercial coastal activities, though still incapable of creating species-extinction/ecological-disaster (articles 116 - 125). However I do not seek to differentiate this incident from any other, all including that of the *Deep Water Horizon*, having thus far been examples of belief-driven action rather than of knowledge-driven action.

As to tank-damage, we know that some cargo can be released on grounding until the denser seawater enters to create a water-bottom on which the remaining tank contents float and are thus retained by pressure-equilibrium; that IMO tank-construction rules are designed to ensure such releases are ≤5,000 tonnes; that initial release estimates for the *Sea Empress* grounding in the mouth of Milford Haven were ~ 2,000-4,000 tonnes, later raised to 6,000 tonnes; that the ship re-floated on the incoming tide and was then anchored; that such a floating ship could have proceeded or been towed to its intended discharge berth within the Haven without any further release of significance; but that this was not permitted. Instead, we know that she repeatedly grounded and re-floated in successive tides until a further ~ 68,000 tonnes were released before she was berthed for discharge of the then remaining 58,000 tonnes; and that she was then towed to Belfast for dry-docking and repair. Thus, we must conclude that knowledge would have berthed the ship and fully discharged it but for the initial damage-related release of 3,000-5,000 tonnes; and that the only barrier to this option was the species-extinction/ecological-disaster which belief expects and which reality fails to deliver regardless of the quantity released.

However, the task of restoring localities to their pre-incident conditions very much depends on the quantity released, though it may be reduced by evaporation, dispersion or solution of the released substance(s). Thus, for each released oil, our available knowledge can predict the rate and the extent of volatile loss from its distillation profile; the rate of natural dispersion of its non-volatile components from the viscosity related half-life of its emulsion; the water-content of its emulsion from whether it is a crude or product oil; and the quantity likely to reach shore on wind and tide from any release position (articles 39 - 42). Again, knowledge gives assurance that neither the initial sub-surface concentrations, nor those of their subsequent dilution, photolysis and biodegradation cause species-extinction/ ecological-disaster.

Thus, we know that believers in such extinction/disaster, choose not to reality-evaluate their beliefs to debate-terminating knowledge whether positive or negative; that they choose instead to ignore all such reality-evaluation and the biological and geological carbon cycles themselves in order to maintain the belief/counter-belief debate which is their sole means of attracting attention for their belief-only bans on haven-entry, dispersant-use and *in situ* decanting of downstream process waters; and that they themselves recognise the supremacy of knowledge over belief in their recognition of the need to ignore the former in order to maintain the latter as an interminably debatable belief-consensus while they acquire public subsidies for non-fossil fuel energy-generation, all of which would be terminated were the debate to be terminated by the belief being reality-refuted.

Further to the maintenance of self-serving debate, we know that the prohibition of dispersant-use within one mile of the shore was seriously restrictive within Milford Haven and along the coasts external to it under onshore winds; and that this resulted in very little dispersant being used despite oil coming ashore almost immediately after the 15th February grounding and despite the total release being 72,000 tonnes. Indeed, we know from the official report that only trial applications of 2 tonnes of dispersant were permitted on the 16th and 17th February, despite the Forties oil viscosity of 9.6 cSt at 10 C°making trials unnecessary; that subsequently only 29 tonnes were applied on the 18th, 110 tonnes on the 19th, 57 tonnes on the 20th, 179 tonnes on the 21st, 66 tonnes on the 22nd and none thereafter, despite the presence of seven DC aircraft capable of delivering 14 tonnes of dispersant per sortie for a designed treatment rate of 2,800 tonnes of oil per 10 sorties per day, and despite the part-time presence of a C130 capable of delivering an additional 12 tonnes of dispersant per sortie (articles 107 - 115). Nonetheless, we also know that this state of affairs contributed to extensive debate and even to an official enquiry; that neither debate nor enquiry resolved anything; but that both could be cited in support of the environmentalist self-interested belief in technology/environment disharmony (articles 1 - 10).

On the other hand, we know that the spraying capacity of the seven DC3 aircraft at this incident was enough to match a daily release of 5,000 tonnes diminished by evaporative loss and natural dispersion, and could thus have been expected to prevent the reported stranding of 3,000-5,000 tonnes, had dispersant-use been permitted into the surf-line. Again, with evaporative loss having accounted for 24,000 tonnes, dispersant-spraying for about 5,000-6,000 tonnes, and waterborne mechanical recovery for about 2,000 tonnes, it follows from the mass balance that natural dispersion accounted for some 37,000 - 39,000 tonnes consistent with its estimated half-life and the separate time lapses to stranding of differing quantities under differing onshore/offshore winds (articles 39-42 and 121-124); and that the biological carbon cycle thus dealt with these releases, except for the sea and shore removals, though, even these were mostly dealt with by the carbon-cycle after much needless collection and transportation (article 115). However, we know that application of release response knowledge coupled with the known benefits of expeditious cargo/bunker transfer would have done little to support the environmentalist self-interested belief in technology/environment disharmony (articles 1 - 10)

Article 127

Further to the outcome of the *Sea Empress* incident, we know that the tonnage removed by the mechanical means preferred by environmentalist belief, compared unfavourably with that of dispersant-use and thus did nothing to support this preference. Thus, while the WSL *Springsweep* system was capable of encountering/removing ~ 3 tonnes of oil per hour at a layer thickness of 0.1mm at 1 knot, and thus might have removed 420 tonnes of oil per week of 10 hour days were one ship to have been equipped with two Blomberg Circuses (articles 73, 76, 86 and 88) we know as officially reported that the six seagoing ships present at this incident, 2 French, 2 ND and 2 UK discharged only 725 tonnes while 1275 tonnes of oil were removed by two inshore skimmers operated within the Haven by the harbour authority, and while after the first ten days other inshore recovery units operating external to the Haven contributed to the 725 tonnes by transference to the ships external to the Haven. Thus, while the total waterborne recovery of only 2,000 tonnes of oil was not a very persuasive advert for the mechanical removal option, it was still supportive of the environmentalist belief in the incompatibility technology and environment.

In addition, we know that substantial quantities of free water are always co-collected depending on the differing design principles of removal systems; that removed emulsions must be separated from their co-collected free water and separated into their oil and water phases either by passage through online static mixers before entering onboard storage tanks or by installed heat exchangers after tank entry (articles 16 - 30); that the volume of aqueous phase thus produced can be up to four times that of the oil phase; that this water together with the co-collected free water (perhaps as much again) must be decanted from beneath the accumulating oil phase within the tank as from an API oil-water separator (articles 16 - 30 and 76 - 80) in order to conserve storage space which otherwise would contain more water than oil; that such decanted water would only contain significant oil concentration as droplets were the oil-water interface allowed to reach the tank extraction point (articles 16 - 21); and that this tendency can be reduced by ballasting the tank at the outset (articles 90 - 91). However, counter-belief now prohibits all such *in* *situ* water discharge even to an already polluted area, unless permitted by discretionary dispensation. Thus, we know that had recovery from water surfaces at the *Sea Empress Incident* been more efficient than it was, this prohibition of *in situ* discharge of process water would have made refinery processing even more time consuming and expensive than it was.

As to the 10,000-15,000 tonnes of emulsion removed from shorelines at the *Sea Empress Incident*, we know that the processing thereof was in no way facilitated by these new belief-only regulations in respect of emulsions and oil-water separation all of which had been introduced since the *Eleni V* had released its heavy fuel oil in the vicinity of Lowestoft in 1978, among which is the prohibition on discharging co-collected and previously emulsified water direct to the shore or contiguous seawater; that consequently some 20,000 tonnes of liquid wastes from the waterborne and shoreline operations were transported to the Texaco refinery in Milford Haven; that on arrival, this was reported to be associated with 13,000 tonnes of water at an average oil content of ~ 15ppm, while of the 10,800 tonnes of polluted beach material, 7,300 went for bioremediation at the Texaco land-farming site while some 3,500 tonnes were land-filled; that some 120 tonnes of polluted sand were cold-mixed to produce a 50/20 HRA type road surface material; and that temporary storage at Pembroke Dock and Pendine Sands attracted Environmental Agency attention as being non-compliant with its regulations.

Thus, knowing that some, 20,000 tonnes of oil had evaporated naturally and that some 40,000 tonnes had dispersed naturally from the 15th to 22nd February; we are entitled to ask why dispersant which had meanwhile dispersed some 5,000-6,000 tonnes of oil was not permitted to disperse another 3,000-5,000 tonnes either before or after it stranded, given the difficulties of shoreline mechanical removal and downstream processing (articles 47-61 and 92-102) which took over a year, compounded as they were by these belief-driven regulations of self-appointed environment-protectors (articles 107 -120).

Suppression of Knowledge by Belief: Terminated in Principle.

Article 128

Articles 116-127 have shown that since the *Torrey Canyon* incident of 1967, knowledge capable of restoring the environment to its pre-incident state quickly and cost-effectively has been suppressed thwarted or ignored by belief in species-extinction/ecological-disaster being caused by water column concentrations and/or physical coating of oil/HNS, despite such extinction/disaster never having arisen from any incident thus far, however inefficient and non-effective the response, or however much it has been protracted by the various derivatives of this overarching belief. Thus, while early newcomers to marine environmental affairs might have found a preference for belief over knowledge to be surprising, later newcomers ought to have been even more surprised to learn that the knowledge progressively acquired by the UK's Warren Spring Laboratory into release-response and operational discharge-regulation from the 1960s onwards, was being successively suppressed, thwarted or ignored by the beliefs which it refuted.

The first step taken by WSL towards knowledge acquisition respecting operational discharges from onboard gravity separators was in 1962, while from 1975 it was acquiring the knowledge that fully spread layers of oils/HNS from accidental releases are too thin and too slowly dispersing to produce more than a few parts per million in the top metre of the water column; that these concentrations subsequently tend to zero by dilution and biodegradation within the column as a whole without toxic effects; that the numbers of heterotrophic bacteria at the base of the ecosystem/food-chain actually increase where oil component concentrations extend their food supply beyond the degradation-products of themselves and the more complex species within the ecosystem's organic carbon cycle; that while oil slicks coat individual birds, the significance of the numbers dying is assessable only by comparison with the birth/death rates which maintain species populations; that environmentalists publish no such comparisons; and that, in any case, no incident has thus far produced the species-extinction/ecological disaster which belief expects and reality fails to deliver.

Nonetheless, it is this belief in species-extinction/ecological-disaster which suppresses all knowledge to the contrary and thus prevents the use of dispersants and even the release of oils/HNS for R&D purposes, while banning commercial fishing regardless of the absence of taint. It also, paradoxically, inhibits use of safe havens for the cargo/bunker transfer which prevents further releases from physical coating shorelines and organisms; fails to recognise dispersant-use as the means of increasing the natural dispersion and biodegradation rates which prevent the coating of shorelines and organisms; and seriously reduces storage and transport capacities for removed oil by prohibiting the *in situ* discharge of co-collected and emulsion-broken water. Again, in preventing dispersant-use, this belief fails to recognise that neither dispersant-use nor mechanical removal are other than locally applicable while the entire slick is dispersing at hourly rates vastly in excess of those achievable by these techniques, their respective pollutant encounter rates being limited by the layer-thinness which keeps dispersion concentrations well below toxic levels whether natural or dispersant-induced; that natural slick-dispersion rates are more in excess of intervention rates the greater the release; and that these inherently limited response capacities make provision for safe haven cargo/bunker transfer all the more essential.

Thus, having compiled the knowledge acquired *inter alia* by WSL in articles 1-115, and having identified the beliefs which thus far oppose it in articles 116 - 127, both newcomers and longstanding believers have now no alternative other than to accept knowledge and to reject opposing belief; and thus to accept all aspects of my knowledge-only contingency and incident-specific planning approach, the term 'knowledge-only' denoting the absence of all belief and opinion. Thus, in compliance with the foregoing knowledge repository, this new approach to contingency planning (articles 156-160) identifies the physicochemical parameters of oils/HNS which control the floating, sinking, evaporating, emulsifying, dispersing and dissolving rates of pollutants at sea, and which predict the amounts remaining for dispersant treatment, mechanical removal and/or stranding as functions of time and wind/ tide vectors. As to stranding, this new approach identifies the shoreline properties which govern pollutant adhesion/penetration, natural and induced dispersion, removal, downstream-processing, heterotrophic bioremediation, recycling and/or disposal. Thus, this new contingency planning approach is a summary of the knowledge repository respecting fates, effects, and responses as now available for all who need and want to know, while the incident-specific values of the parameters of the specific substances released, determine their incident-specific fates, effects, and response feasibility at sea and on incident-specific shoreline types, thus providing an incident-specific action/inaction plan for each and every incident as it arises (articles 161 - 162).

Again, record-keeping as to the implementation of incident-specific plans and their resulting outcomes will keep the general-contingency plan up-to-date, thus compensating for staff-change frequency and incident infrequency and thus institutionalising this ever-growing knowledge repository. Thus, my intention is to bring this knowledge-accepting/belief-rejecting approach to the attention of all organisations and individuals desirous of responding to marine incidents quickly and cost-effectively on available knowledge rather than on the current high-cost/non-effective belief-driven alternative.

Article 129

The contingency plan referred to in article 128 is intended to terminate the previously long term suppression of knowledge by belief. It is based on knowledge of the fate and effects of oils and so-called hazardous/noxious substances (HNS) as controlled by the interaction of their physicochemical properties with atmosphere, sea and shorelines; on knowledge of the means by which such releases may be curtailed; on knowledge of the effectiveness of release-response techniques and equipment as assisted by natural evaporation, dispersion, solution and dilution acting in harmony with the biodegradation processes of the ecosystem; and on knowledge of the means by which removed materials may be processed for use/disposal should viscosity so necessitate, all such knowledge having been acquired by laboratory, seaborne and shoreline experimentation with oils/HNS or by direct observation at specific incidents (articles 1 - 115).

The achievement of such a knowledge-only contingency planning approach has thus far been suppressed, thwarted or ignored by beliefs derived from belief in species-extinction/ecological-disaster (articles 116 - 120), despite this belief having long since been reality-refuted (articles 121 - 124), and which have thus far prevented quick and cost-effective restoration of the marine localities to their pre-incident conditions (articles 125 - 128).

Thus, the belief in oil/HNS causing species-extinction/ecological-disaster must now be rejected by acceptance of the knowledge that no such effects are possible at the concentrations of exposure; that none have arisen from any incident thus far, even when entire cargo/bunkers disperse naturally just prior to stranding or when residuals do strand; that dispersants are non-toxic at their concentrations of exposure; that dispersants increase natural dispersion rates and hence biodegradation rates; that dispersants prevent/reduce the physical coating of shorelines and organisms; that dispersants also remove pollutants from shorelines; that pollutants naturally biodegrade onshore as they do more quickly as dispersed droplets in seawater; that with water depth being irrelevant, stranded pollutants may thus be dispersed from shorelines to increase their biodegradation rates; and that the biodegradation of released oils/HNS is but a very small part of the entire global biomass of which the biodegradation is interrupted only by the oxygen depletion which forms 'fossil' fuels in the first place.

However, to secure the termination of knowledge suppression by belief this time round, I have definitively differentiated belief from knowledge by the reality-evaluation which transforms the former to the latter as in craftsmanship, science and technology, while the absence of this reality-evaluation leaves belief as belief (Foreword, Preface and articles 116 - 128). Thus, having differentiated environmental knowledge from environmentalist belief and science from pseudoscience by noting the respective presence or absence of this co-defined reality-evaluation, my new planning approach accepts the environmental knowledge which refutes environmentalist beliefs, and suspends all remaining beliefs as hypotheses yet to be reality-validated or reality-refuted to positive or negative knowledge.

As to believers who would object to this rejection/suspension, I pose the following questions (Preface). Why should we expect species-extinction/ecological-disaster when neither has arisen in the 49 years since the *Torrey Canyon Incident*? As to physical coating by oil/HNS, why should we believe in such extinction/disaster while the numbers of individuals thus killed per species have yet to be compared by believers with the annual death/birth rates which maintain species populations at viable levels? As to exposure-concentrations to oil/HNS, why should we believe in such extinction/disaster while the thickness of floating layers limits them to producing no more than 100ppm were they to be instantaneously dispersed/dissolved into the top metre of the sea, while the actual concentrations in the top metre are ~ 10ppm of oil and 0.5ppm of dispersant at the operational oil : dispersant application ratio of 20 : 1, while these rapidly diminish to zero by depth-dilution and biodegradation, and while the concentrations needed to measure LC_{50} values are 2-3 orders of magnitude higher and more prolonged than those only transiently present in the top metre? Again, why should we expect such extinction/ disaster onshore while re-colonisation of shorelines by planktonic life-stages is un-ending? Yet again, why should we believe in anthropogenic global warming while photosynthesis and biodegradation continuously recycle carbon dioxide through the atmosphere and the total sea and land biomass, while carbon dioxide is recycled through the atmosphere by the Urey reaction to carbonate rock and decomposition by volcanism, and while we combust only part of a fossilisation but for which its carbon dioxide equivalent would already be recycling through the atmosphere biologically and geologically?

Thus, my new contingency plan accepts knowledge and rejects beliefs already refuted by knowledge; expects all remaining beliefs either to be reality-validated or reality-refuted to positive or negative knowledge; or expects them to be suspended pending such reality-evaluation, at which point they may be implemented or not depending on whether they are thus reality-validated or reality-refuted. Accordingly policy-makers have no alternative other than to accept that the suppression of knowledge by belief has thus been terminated in principle, and now remains to be terminated in practice.

TOWARDS KNOWLEDGE SUPREMACY IN PRACTICE

The Need for Knowledge Supremacy in Practice

Article 130

This need cannot be satisfied in practice unless policy-makers definitively differentiate knowledge from beliefs already reality-refuted; suspend beliefs awaiting reality-validation or reality-refutation; and accept the knowledge and reject the beliefs respectively set out in articles 1-115 and 116 - 129. Thus, policy-makers must accept existing knowledge respecting the stabilisation of casualties for cargo/ bunker transfer in safe havens; the capping of oil wells; and the dispersion and mechanical removal of initial-damage releases at sea and onshore. Again, policy-makers must accept the opportunity to acquire more precise knowledge respecting fates, effects and response-outcomes at each and every future incident. Thus, the stated objective of policy-making must be to apply all available knowledge to the limitation of releases and to the restoration of localities to their pre-release conditions quickly and cost-effectively. In saying ‘must’, I am saying that policy-makers have no alternative other than to accept knowledge and to reject the beliefs which knowledge refutes, as these terms are now definitively defined and used in this website (Foreword, Preface and articles 1 & 129).

Thus, with reference to this newly definitive knowledge/belief differentiation, policy-makers must now accept that the physicochemical parameters of oils/HNS which control the fates and effects of releases and determine the optimal responses to them are already known; that their incident-specific values determine incident-specific fates, effects and responses; that these individual values are already known and readily available from the industries which refine, synthesise and/or use oils/HNS; that in relation to oils, these parameters are distillation profiles; water-immiscibility, viscosity, density, melting point and pour point; that the first parameter controls the rate and extent of component evaporation, the next triplet controls droplet size distribution on agitation, and the last pair controls whether they will be solid or semi-solid at ambient temperatures; and that the specific values of these parameters for individual liquid oils quantify the rate and extent of evaporative-loss from spread layers, the viscosity-dependent half-life rate of natural dispersion of such layers, and the amenability of such layers to dispersant treatment and mechanical removal.

As to individual HNS, policy-makers must accept that the relevant physicochemical parameters are boiling point, vapour pressure, water-immiscibility, viscosity, solubility, melting point and density; that their specific values show that many are identified as evaporators; that those with viscosities < 5cSt at 15°C disperse quickly as do the lighter petroleum distillates; that others are identified as floaters or sinkers which nonetheless disperse or dissolve; that only an identifiable few have viscosities > 5cSt at 15°C; that none form emulsions; and that only an identifiable few are solid at ambient temperatures as further exemplified in article 133.

Thus, policy-makers must accept that tabulations of parameter values are available from which quantitative predictions can be made as to whether released oils/HNS will float, sink, evaporate, disperse or dissolve prior to stranding on known wind/tide vectors; that collection is not possible for evaporated, dispersed or dissolved oils/HNS; that dispersants can locally enhance natural dispersion rates when pollutant viscosity is low enough; that mechanical removal extends to higher viscosity values, though this is dependent on design-principle; and that these localised responses can prevent the stranding of no more than a few thousand tonnes released close to shore or the residuals from larger releases far enough from shore to have evaporated and/or dispersed naturally to this residual quantity during transit to shore on the vector sums of wind and tide.

As to the effects of all such mediated fates, policy-makers must accept that the controlling physicochemical parameter values initially limit and subsequently dilute post-release concentrations of vapours/gases in the atmosphere and of dispersed droplets and solutes in seawater to levels of exposure several orders of magnitude below those of species-extinction/ecological-disaster even were they to be locally toxic at the local concentrations of initial release; that all organic compounds initially arise from the photosynthesis of carbon dioxide and water and degrade back to them by direct oxidation or by biodegradation within the ecological food chain as do the land and sea biomasses themselves; that while physical coating with pollutant layers prior to natural dispersion and biodegradation can kill individual organisms, such deaths have not caused species-extinction/ecological-disaster; that while such layers on shorelines can disrupt commercial activity, compensation is available for associated financial loss; and that any organism-loss is restored by natural re-colonisation .

As to potential release-volumes, policy-makers must accept that these are initially limited by tank-volume and water ingress, by the smaller volumes otherwise packaged, and by subsequent cargo/bunker transfer and blow-out capping. As to release-prevention, policy-makers must accept that releases from other than initial tank-damage or from other than initial blow-outs are preventable by cargo/bunker transfer or by expeditious well-capping; that such post-accident release-prevention reduces the potential for commercial impacts in inshore waters and shorelines while benefiting individual organisms otherwise liable to coating. As to biodegradation, policy-makers must accept that stranded slicks degrade more slowly than those dispersed, dissolved and diluted in seawater before stranding, or after return to the sea from stranding; and that these seawater processes are by far the greatest avoiders and removers of the physical-coating of shorelines and individual organisms.

As to potential release-response, policy-makers must accept that while nothing can be done to collect dispersed droplets or dissolved/evaporated molecules, no harm arises from the degradation of such within the ecology of sea, shore, land, or atmosphere; that success or failure in avoiding the stranding of non-soluble/non-volatile pollutants depends on the proximity of the release-point, the quantity released, the loss of volatile fractions, and the viscosities which determine the rates of natural dispersion, dispersant-induced dispersion and mechanical-removal; that no cost-effectively achievable intervention can prevent some stranding from releases > ~5,000 tonnes close to shore under onshore winds, encounter rates for dispersant treatment and mechanical removal being only ~0.2 tonnes per hour per metre swath-width per knot of advance per 0.1mm of slick thickness, thus making the encounter rates of mechanical removal comparable to those of dispersant-aircraft on a daily basis, the former being limited by the 1 knot escape velocity of towed booms and the latter by their frequent need to reload. Thus, policy-makers must accept that the provision of response equipment is cost-effective only when scaled to releases of 3,000 - 5,000 tonnes; and that cargo/bunker transfer is consequently an essential element of incident-response.

However, for pollutants which do strand despite releases from initial tank-damage being limited by design and subsequently by natural evaporation, dispersion or solution, policy-makers must accept that the best response to stranded residuals is to return them to the sea for resumption of the natural and intervention processes which had insufficient time to prevent the said stranding, and which could have prevented it had the slick had further to travel before stranding; that water-depth limitations imposed on dispersant-use close to shore are thus both unnecessary and counter-productive; that dispersant-use onshore returns stranded pollutant from the low onshore rates of biodegradation to the higher rates available for droplets in seawater; that dispersant-induced return is more effective than mechanical return, and is more cost-effective than the physical separation of pollutant from beach material and the downstream processing otherwise unavoidable when pollutant viscosity is too high for successful dispersant treatment.

Article 131

As to operative exposure to volatile oil components and individual HNS, policy-makers must accept that those with boiling points ≤150°C evaporate totally in 1 hour from fully extended floating layers of 0.1mm thickness; that all oil components with boiling points ≤250°C evaporate from layers of this thickness in ~5 hours despite the non-volatile components of oils forming water-in-oil emulsions in the meantime. Again, policy-makers must accept, for example, that an 0.1 mm layer of the nine-carbon compound nonane evaporates entirely in 3 minutes, and from a 1.0mm layer in 30 minutes; and that components of up to nine carbon atoms and up to six comprise only 20-30% of crude oils and only 5% respectively, their equivalent thicknesses on release being respectively 0.02-0.03mm and 0.005mm.

Thus, policy-makers must accept that while vapours from such slicks burn in the open air when ignited, explosions are only possible in confined spaces where layer thickness may be sufficient to create saturated vapour pressures and/or concentrations in air within the explosive envelop bounded by the higher and lower explosive limits of the released substance or mixture of substances; that open air approach through floating layers is not therefore subject to explosive risk; and that explosive risk in confined spaces can be quantified by reference to long-known relationships of volatility, mass-transfer and concentration. Thus, policy-makers must accept that the association of substances with explosion icons in guide-books with no reference to concentrations attainable in reality, is only indicative of possibility, as is the association of others with the toxic skull/cross-bones icon with no reference to concentration, and that beyond substance identification, safety in enclosed-spaces is ensured only by direct measurement of exposure-concentration and otherwise by the precautionary wearing of appropriate protective clothing and breathing equipment when and where necessary.

As to gases, as distinct from the vapours of volatile-liquids, policy-makers must accept that these are transported in pressurised containment and are released from damaged containment as pressurised jets; that these jets expand as cones of increasing diameter as they dilute with entrained-air with increasing distance from source; that plumes heavier than air tend to slump and spread as fans in contact with the surface of sea or land while diluting with distance from source; that such releases cannot be collected; that explosion/toxicity risks are concentration-dependent; that concentrations can be measured downwind of the advancing front and towards the sides at sea/ground level; and that while coastal populations cannot be issued with breathing equipment, exposure-concentrations from ship-source release may require short term window-closure rather than evacuation.

As to prediction of concentrations both temporal and spatial as a function of release-quantity, further knowledge could be provided from wind-tunnel experiments with buoyant and slumping gas plumes, though with respect to vapours from floating slicks, policy-makers must accept that 100 m^3 of liquid at a layer thickness of 0.1mm covers 1 km^2; that were this to evaporate instantaneously to a height of 1m, the concentration would be no more than 100ppm with further dilution with height and distance from the source layer. Of course, such estimates for vapours are unrelated to the concentrations directly measurable for gas plumes as further exemplified in article 133.

As to sampling and measurement equipment for use onboard casualties, policy-makers must accept that tank atmospheres may be monitored by oxygen analysers each equipped with a suction hose and hand-operated sampling bellows; that individual HNS contaminants can be identified and quantified in air by a wide range of packed reaction (Dreger) tubes operated in conjunction with calibrated pumps; that total hydrocarbon analysers are available as are compressed-air driven ventilation fans, lengths of flexible ducting and injection nozzles, all such powered equipment being required to be intrinsically safe; and that suitable breathing and resuscitation apparatus, protective clothing of various grades and specificities are also available together with fire-fighting and intrinsically safe emergency-lighting and portable-radio equipment (articles 105 - 106); and that sampling and reaction tubes are also applicable to atmospheric monitoring in respect of ensuring the safety of shore side populations in incidents of gas release. Guidance on personnel protection and atmospheric sampling and analysis is available from the Chemical Response Manual of Koops and Reinstra, but reference to the routine precautions of the oil/HNS industries is advisable.

Article 132

As to the salvage of casualty and cargo/bunkers, policy-makers must accept that after collision or grounding, damage-control will normally have been undertaken by the crew to the maximum extent possible; that beyond this stage, the public interest is best served when the coastal State's marine survey service collects as much knowledge as possible on the condition of the casualty before salvors arrive on-scene; and that the combined knowledge and experience of crew, survey service and salvors is the only means by which the coastal State can assume ownership/endorsement of the ensuing incident-specific salvage plan, and use its Powers of Intervention to overcome the belief-driven objections which make matters worse as more than amply shown by reviewing past incidents as exemplified by articles 107 - 120, and 126 - 127).

Thus, policy-makers must accept that the options are *in situ* ship-to-ship cargo/bunker transfer, movement to a safe haven for such transfer, or to an oil port for discharge to shore; that these options include subsequent casualty removal; that the choice can only be made on the basis of knowledge of the casualty-condition; that cargo/bunker transfer is the only means of reducing or eliminating post-damage releases, of minimising impact on commercial activities and of enabling localities to be restored to their pre-incident conditions as quickly and as cost-effectively as possible. As to achieving these objectives with oil-wells, policy-makers must accept the need for rapidly effective blow-out prevention and capping, given that realistic post-release response by dispersant application and mechanical removal is limited to a few thousand tonnes per day (articles 50 - 55, 70 and 130).

As to the options for cargo/bunker transfer, policy-makers must accept that the open sea option is the least favourable; that progressive tank damage is more likely in such locations than in a safe haven; that further release from damaged tanks is prevented by their oil-replacing water bottoms, while none is to be expected from undamaged tanks; and that any inadvertent releases during cargo/bunker transfer will be small in comparison with those from successively damaged tanks in exposed locations. Again, policy-makers must accept that any releases necessarily occurring from damaged tanks when pressurised to re-float the casualty in the exposed location, or indeed within a safe haven as was the *Sea Empress*, will be small and rate-controllable. In addition, policy-makers must accept that removal of casualties from risk of subsequent tank-damage, also removes them from risk of engine-room flooding and loss of onboard pumping power; and that preservation of such power avoids need for emergency transfer pumps and associated equipment. As to containers and packages, policy-makers must accept that the contents of undamaged packages cannot enter the sea on transfer; that release arises only from damage; and that any effects from such inadvertent releases during transfer are local and transient.

As to access to the widest possible knowledge, policy-makers must accept that State/salvor co-ownership of incident-specific salvage plans would facilitate consultation with the International Salvage Union (ISU) or the American Salvage Association (ASA) in respect of damage-stability calculations and of release-limitation during re-flotation by partial removal of cargo/bunkers and by pressurisation of tank water-bottoms before entry to a safe haven or within one as was the *Sea Empress.*

As to the Powers of Intervention, policy-makers must accept that while the Powers are adequate, intervention remains inadequate so long as those invoking the Powers remain ignorant of the knowledge necessary to countermand beliefs which prevent release-limiting cargo/bunker transfer and thus increase the subsequent task of restoring localities to their pre-incident conditions as quickly and as cost-effectively as possible; that these beliefs have prevented use of this knowledge and its associated equipment for as long as these have existed; that while this salvage and cargo/bunker transfer technology is more reliable than the technology of blow-out prevention and well-capping appears to be, believers in species-extinction/ecological-disaster appear to derive more self-serving benefit from paralysing the former than from advocating improvement in the latter or in effective release response in general; and that policy-makers must accept the need for knowledge-acceptance and belief-rejection, these terms having recently been definitively differentiated for this and all parallel purposes (Foreword/Preface).

As to the provision of cargo/bunker transfer equipment to salvors temporarily over-extended by business-pressures, policy-makers must accept that national stockpiles could consist of submerged oil/ HNS transfer pumps for insertion through standard deck openings; heat exchangers to maintain cargo/ bunkers in the liquid state; pallet-stored inflatable ship-ship fenders; boxed lay-flat floating transfer hoses, couplings, spares and connection tools; carbon dioxide generators to fill void spaces created by known discharge rates; oxygen, hydrocarbon and chemical-specific detectors/analysers; compressed air driven ventilation fans and associated equipment all of which must be intrinsically safe; breathing/ resuscitation apparatus and protective clothing; fire-fighting and intrinsically safe emergency-lighting and emergency-radio equipment (articles 105 - 106, and sections 8 and 9 of the Chemical Response Manual of Koops and Zeinstra).

In general, policy-makers must accept that the transfer of oils/HNS cargoes from casualties to their intended or alternate recipients and the transfer of bunkers to alternate fuel-use are by far the best means, indeed the only means of recycling them; that risking the total release of transferable cargo and bunkers while calling post-release 'recycling', an expression of concern for the environment, is surely the irrationality of definitive of madness; and that self-styled experts who derive their proffered advice solely from their reality-refuted belief in the toxicity of dispersants, oil, and HNS, regardless of concentration, have deprived policy-makers of the knowledge which could have achieved cost-effective restoration of localities to their pre-incident conditions from the mid 1980s or even earlier.

Article 133

Further to HNS releases, policy-makers must accept that while nothing can be done to collect released gases, these are variously transported in pressurised bottles/cylinders which are consequently of localised-diluting effect when damaged; that otherwise, natural gas is transported in specialised ships' tanks none of which has thus far been damaged; that flammable gases might be flared at source as in routine oil-field operation; that further knowledge as to the rate of the atmospheric dilution of un-flared plumes could be acquired from wind-tunnel experiments and confirmed or modified by direct measurement of gas/air concentrations at future incidents; and that while evacuation of proximate downwind populations may be necessary, temporary window-closure would be adequate where natural dilution by entrained air is sufficiently advanced.

As to volatile floating layers of oils/HNS at the 0.1mm thickness of Fay's Phase II spreading, policy-makers must accept that evaporation will be complete within a few hours; that nothing can be done to collect such vapours; that their atmospheric concentrations are insignificant; and that while such layers may burn if ignited, there is no danger of explosion. As to non-volatile/non-soluble layers of HNS, policy-makers must accept that these disperse faster than non-volatile/non-soluble oil components because the former have lower viscosities than the latter mixtures and do not form emulsions of yet higher viscosity; that the vast majority of non-soluble liquid HNS have viscosities ≤5cSt and dispersion half-lives of no more than 4 hours similar to those of gasoline, kerosene and diesel of Oil Group I (articles 39 - 42) and thus do not call for response, only ~1% remaining after the lapse of ~7 half-lives; that those of higher viscosities such as mono-isopropanolamine (750cSt), branch-chain alkyl benzene sulphonates (600-700cSt), di-iso-propanolamine (200cSt at 45°C) and straight-chain alkyl benzene sulphonates (80-100cSt), would have half-lives of 12 -24 hours were they emulsion-forming oils and could be possible candidates for dispersant treatment or mechanical removal; but that this possible need will be directly observable should any be released. As to solid HNS, policy-makers must accept that there are very few, such as phthalic anhydride (mp 131.6°C), chloro-acetic acid (63°C), di-iso-prolylamine (44°C), hexa-methylenediamine (41°C) and phenol (40.9°C).

As to soluble HNS, policy-makers must accept that rates of solution are determined by individual solubility values and mass transfer coefficients whether arising from floating layers, from neutrally buoyant compact volumes, or from sunken layers on the seabed, that seawater concentrations proximate to the surface of the dissolving phase can never be higher than those of their saturated solutions; that these dilute effectively to zero by diffusion and turbulence while the organic biodegrade to carbon dioxide and water, and while the inorganic neutralise as solution proceeds to completion; that concentrations under floating layer thicknesses of 0.1 mm are never >100ppm even for complete solution; that the concentrations arising from soluble sunken HNS layers are equally subject to these initial-limits, and to subsequent dilutions, biodegradations and neutralisations; that time to complete solution depends on the localised surface-area : volume ratios imposed by seabed undulations; that while nothing can be done to collect dissolved HNS, mechanical removal may be cost-effective where seabed hollows retain adequate layer thicknesses for direct pumping; and that in any case, decrease in surface : volume ratio as removal progresses, will reduce the area over which solution/dispersion occurs, thus localising their effect while concentrations continue to dilute, degrade or neutralise.

As to packaged HNS, policy-makers must accept that the individual volumes are smaller than those of bulk HNS shipment, which in turn are smaller than those of the bulk shipment of oil; that while packages containerised on deck do enter the sea and may strand, the contents are not released unless containment is damaged; that the quantities thus released are too small to have other than localised and transient effects; and that it behoves those who believe in species-extinction/ecological-disaster to reality-evaluate their beliefs against the known concentrations to which individual organisms are exposed in the real environment and against the localised volumes within which they are thus exposed.

As to potential response, policy-makers must accept that oils are liquid or solid, floaters, evaporators or dispersers, depending on their melting and/or pour points, densities, distillation-profiles and/or viscosities; that individual HNS are gases, liquids, evaporators or solids, floaters, sinkers, dissolvers and/or dispersers, depending on their boiling or melting points, densities, solubilities, and/or viscosities; that their rates of evaporation, dispersion and solution depend on the substance-specific values of the parameters on which these processes depend; that the first steps in any incident are to identify the oils/ HNS involved, and to obtain the values for their controlling parameters; and that only then is it possible to create the incident-specific plan for response to those aspects of the incident for which response is possible and necessary for restoration of localities to their pre-incident conditions as quickly and as cost-effectively as possible (articles 16 - 33, 39 - 59, 70 - 102, 156 - 162 and 177).

Article 134

As to actual release-response, policy-makers must accept that this is needed only for pollutants persistent enough to require localities to be restored to their pre-release state as quickly and as cost-effectively as possible; that after the fraction of oil components boiling below 250°C is lost by natural evaporation in about 5 hours, persistence becomes solely a matter of the viscosity-dependent natural dispersion half-life of the non-volatile fraction. Accordingly, policy-makers must accept that the oils have been tabulated in Groups I-IV for specific gravity bands 0.8, 0.8-0.85, 0.80.95 and 0.95 together with their viscosities or their solidity at ambient temperatures and their weight percentages of components boiling below 200°C and above 375°C; that half-life values and ranges of 4, 12, 24 - 48 and ≥48 hours have been allocated to these Groups; that half-lives of 2-4, 4-6 and 6-8 days have been allocated to heavy fuel oils for corresponding viscosity bands (articles 39-42); and that while such allocations are as yet imprecise, they provide planning guidance, the precision of which can be improved by future incident-specific observations (articles 39 - 42, 107 - 115 and 156 - 162).

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As to the predictive assessment of response needs, policy-makers must accept that the first step is to ascertain the values for the incident-specific physicochemical parameters identified in article 133, in order to determine whether the release floats, evaporates, disperses, dissolves or sinks; the second is to compute the release percentage which having evaporated, dispersed or dissolved is already beyond treatment by any conceivable means; that the third is to compute the percentage, adjusted for emulsified water-content, which remains for potential dispersant treatment and/or mechanical-removal as a function of viscosity-dependent half-life and time-dependent stranding on known wind/tide vectors, such movement being the vector sum of 3% of the former and 100% of the latter; that the fourth is to estimate the viscosity and sea-state dependent efficiency of dispersants and/or mechanical removal; that the fifth is to identify the most effective dispersant/removal means by which stranding may be prevented; that the sixth is to compute the physicochemical advantages/disadvantages of returning stranded pollutants to inshore waters for resumption of dispersant-treatment/mechanical removal, given the computed release-percentage which dispersed naturally at sea prior to stranding while at-sea dispersant/removal operations were continuing to reduce it; and that the seventh is to record all results of the above computations for comparison with the record of their outcomes in reality, in order to refine any estimated values used, and thus to secure and accumulate experiential knowledge for existing and replacement staff (articles 47-61, 70-102, 156 - 162, and 177).

As to dispersant application and mechanical removal, policy-makers must accept that apart from viscosity and wave limitations, the main difficulty is the thinness of the pollutant layer which limits encounter-rate to 0.18 m^3h^{-1} per knot, per metre swath width, per 0.1mm of slick thickness (Fay’s Phase II spreading); that while layer thickness increases by up to a factor of four with emulsion water-contents of 80%, the oil-content remains that of the un-emulsified layer; and that while windrow thickness can increase by a further factor of 5 - 10, it does so at the expense of the pollutant-free ribbons between the rows, articles 39 - 42, 50 - 61, and 71 - 99).

Further to dispersant application, policy-makers must accept that after the *Torrey Canyon Incident* of 1967, WSL designed a tug-mountable dispersant-spraying system consisting two rigid tubes each with equally spaced fan-jet nozzles; that these could be swung outboard on a bulwark-pivot to give continuous dispersant coverage beneath the tubes as the tug moved forward; that the dispersant discharge rate was fixed at 20gallons per minute over a swath width of 20metres (two tube spans and the tug's beam) which at 10knots applied an oil: dispersant ratio of 2:1 for the then hydrocarbon-based dispersants; that WSL subsequently converted this system to dilute dispersant concentrates with seawater in the ratio of 1:10 thus extending endurance between replenishments; that later still, WSL demonstrated the feasibility of applying undiluted concentrates from aircraft, its trials over airfields having confirmed the nozzle-modification needed for the droplet size-range required for uniform slick coverage; that the UK initially retained six Islander and two DC3 aircraft, the intention having been to treat the residuals from releases of 3000 - 5,000 tonnes of oil per day close to and onshore from replenishment bases at coastal intervals of 200miles (articles 50 - 61). Again, policy-makers must accept that by the mid 1970s, WSL had also produced spray-sets delivering 7gallons per minute for use on inshore launches and for manual lance operation on beaches and that this had been quickly supported by a range of commercially available spraying vehicles and other modifications (articles 94 - 95)

Nonetheless, policy-makers must also accept that while treatment rate had been raised from 10 tonnes of dispersant per sortie to 14 tonnes per sortie by replacing the six Islanders with five more DC3s prior to the *Sea Empress Incident*, and while a C130 with a capacity to deliver 12 tonnes per sortie was available for part of this incident, the reality-refuted belief in species-extinction/ecological-disaster prevented spraying within arbitrary depth-related distances from shore, despite everything in this incident being close to shore (articles 107-120). Again, policy-makers must accept that WSL had related the images of side-looking airborne radar (SLAR) and infrared and ultraviolet line scanners (IR/UV/LS) to independently measured slick thicknesses at sea; and that two of the UK spraying aircraft were thus equipped to direct all response units to areas of optimal thickness for dispersant spraying and for mechanical removal (articles 62 - 69) though no reference to such use appeared in any *Sea Empress* incident report.

Article 135

As to recovery at sea, policy-makers must accept that from the early 1980s the UK had three WSL-designed and reality-evaluated *Springsweep Systems*; that these comprised a *Troilboom* side-deployed from a sheer-leg supported jib to present a 15metre wide collection mouth and a *Renvac* air-conveyer to transfer pollutant from a free-floating hose-end within the boom to the tanks of the deploying ship; that these were intended for single-ship operation on *Seaspring* and on coastal tankers of opportunity; that later the UK acquired a WSL evaluated *Force Seven Oil Mop* for operation on the after-deck of offshore supply ships of opportunity; that at the Ekofisk Blow-out of 1976, just such a *Troilboom* mouth, a floating hose-end and a deck-mounted 4-inch *Spate* pump had collected $9m^3h^{-1}$ of 70% water-content emulsion, thus confirming that recovery at sea collects only 0.2 tonnes of oil per hour per metre of swath width, the encountered layer thickness being 0.1mm or 0.4mm of 80% water-content emulsion (articles 70-91); but that there is no official record of any subsequent attempt to quantitatively evaluate mechanical removal in these terms at the *Sea Empress* incident or anywhere else.

As to onshore recovery, policy-makers must accept that emulsion layer thickness and hence encounter rate can increase from 10-50 times when emulsified slicks are pressed against shorelines by onshore winds while stranding on the ebb tide; that such layers can be collected from wet (poorly drained) sand beaches by water flushing into purpose-dug trench-systems for removal by viscosity-tolerant pumping; that pollutant layers are difficult to separate from shingle or pebbles as are residual and initially thinner layers from sand without specially designed equipment, though heavy rubber strips attached to the lower edge of mechanised scraper blades can be effective on firm sand; that non-separated pollutant-sand mixtures can be mixed with lime to form cement/concrete when suitable building projects are concurrent; that pollutant can be separated from particulate mixtures by modified mineral processing equipment or sieved from sand if in tar-ball form; that otherwise the options are *in situ* bioremediation, land-farming bioremediation at oil refineries, bioremediation in landfill, or return to the sea for resumption of the dispersion/biodegradation which reduces/prevents stranding in the first place; and that nonetheless, no such comparative considerations have ever been reported for any incident thus far.

However, when viscosity is high enough to require inshore mechanical removal of pollutants thus returned to the sea, policy-makers must reject the belief that *in situ* discharge of the waters arising from their subsequent processing is unacceptable, and must now accept that *in situ* discharge of co-collected and de-emulsified water, whether arising from water surfaces or from emulsion/beach-material separation, avoids the otherwise needlessly costly transport to approved processing sites such as oil refineries (articles 92-102); that anything which strands is more trouble than it is worth, without being made more so by reality-refuted belief-driven regulation; that 'recycling' of recovered pollutants costs more than the value thus 'recycled'; that such definitive waste should not be collected other than to remove pollutant which cannot be dispersed to dilute and biodegrade naturally, because of its solidity or non-dispersible viscosity; that the only cost-effective recycling is cargo/bunker transfer to a refinery or to the fuel or chemical uses of their intended or alternate customers; that leaking HNS containers should be over-contained for transportation to routine chemical waste disposal; and that response to released pollutants should aim to minimise commercial loss by restoring localities to their pre-incident conditions as quickly and as cost-effectively as possible by maximising their natural rates of biodegradation, any so-called recycling being merely an added cost (articles 116 - 129 and 145).

Thus, policy-makers must accept that cargo/bunker transfer of oils/HNS from damaged or at-risk containment, is the most cost-effective means of shoreline protection; that the protection provided by at-sea dispersant-treatment and/or mechanical-removal is far-exceeded by the natural evaporation, dispersion, solution, dilution and biodegradation of released oils/HNS; that despite the effectiveness of dispersants and mechanical removal being limited by pollutant viscosity (articles 47-61 and 70-91) and despite the latter being further limited by wave-height, they can nonetheless provide shoreline protection otherwise unavailable; and that mechanical removal prior to stranding is less troublesome than post-stranding removal from shorelines; that stranded pollutants can be dispersed back to the sea or physically returned to inshore waters for mechanical removal with prior application of surface film chemicals facilitating this return. However, policy-makers must also accept that downstream emulsion-processing is more multistage and less cost-effective than dispersing into the surf for natural dilution/ biodegradation when viscosities permit; that even if the multi-stage alternative is unavoidable and completed despite its currently unhelpful belief-driven regulation, no one wants to use its product; that charges are levied for disposal; that such disposal is usually by land-farm bioremediation; and that the banning of dispersant-induced bioremediation in coastal waters is thus wholly counter-productive.

As to organism contamination, policy-makers must accept that pollutant-coated shellfish on shores and cultivation stakes, and fish drawn in nets through floating slicks can be differentiated from depurated shellfish previously exposed to concentrations in the ppm to ppb ranges and from fish which having derived no taint from such concentrations are netted through slick-free surfaces; and that recognition of such obvious differentiation would reduce compensation claims for fishing-interruptions which have more to do with bans *per se* than with real need.

Article 136

As examples of the solid surfaces from which oils/HNS may need to be removed, policy-makers must accept that these include mangroves, coral, salt marshes, mudflats sand, shingle, pebbles, rocks, cliffs, land-fast/seasonable ice, and manmade structures such as harbour walls, marinas, esplanades *etc*; that such solid surfaces are contiguous with their respective inshore waters; that the cleaning techniques available for both are chemical or physical; that the former includes dispersants, surface film chemicals, thinning agents, emulsion breakers and swelling/non-swelling absorbents; that the latter includes low and high pressure water jets, steam generators, scrapers, graders, elevating-buckets, sieving-screens, conveyer-belts, shovels, buckets and other hand-tools; beach material washing machines, lime-mixers, mechanical pollutant/particulate separators, sieves; booms, skimmers, pumps, vacuum systems and air conveyers; online static-mixers and oil/water separators; that chemical and physical means may be combined; and that the choice should be the most cost-effective in each and every case (articles 92 - 102).

As to dispersant spraying in inshore waters by local authorities, policy-makers must accept the cost-effectiveness of such as the small-boat version of the WSL tug-mountable spray-set, the dispersant being carried in the smaller version of the pillow-tanks used by seagoing tugs lacking integral tanks, and the dispersant application rate being 7 gallons per minute in proportion to boat speed, swath width and 0.1 mm slick thickness. Again, for onshore spraying policy-makers must accept the cost-effective adaptation of this inshore spray set which replaced its rigid tubes and spray nozzles with two operator-held lances and transfer hoses to deliver the 7 gallons per minute over two independent 2 metre swath widths, coverage per unit area varying with walking speed according to the greater layer thicknesses encountered ashore.

Again, policy-makers must accept such as the WSL-evaluated *Beachguard* and *Invictacat* sprayers, the first providing four operators with hand-lances and 100 metres of delivery hose, to apply dispersant over 2 metre swath widths at a total application rate of 2,700 litres per hour; the second being an eight-wheeled low tyre-pressure self-propelled difficult-terrain vehicle which supplied its own dispersant to a rigid tube on each side or to hand-lances by which pedestrian operators could go beyond the terrain-limits of the vehicle itself to apply 1,620 litres per hour over two swath widths of 2 metres: these vehicles being of variable speed or capable of making repeat passes to increase applications for greater layer thicknesses, WSL having shown that layer thicknesses compressed on stranding to 4-6mm could be successfully treated in this way ahead of incoming surf, provided pollutant viscosity was thus amenable (articles 47-61 and 94 - 95).

Yet again, policy-makers must accept such as the *Knapsack* sprayer shown by WSL to be appropriate for dispersant application in the most difficult terrain, while its low application rate of 135litres per hour was appropriate for applying surface film chemicals to beaches at 8 litres per 100m at a swath width of 2 metres ahead of the incoming tide to prevent pollutant adhesion to the shore on the ebb and thus to facilitate its return to inshore waters for removal within suitably deployed booms when pollutant viscosity is beyond the limit of dispersant-use or when the calmness needed for such boom deployment provides insufficient agitation for dispersion (articles 93 and 95).

Again, policy-makers must accept that such equipment was convenient for applying dispersant-gel to pollutants adhering to vertical or inclined surfaces prior to water-washing, the most suitable gelling agents being non-ionic surfactants such as alkyl phenyl ethers of poly-ethoxylated glycols; that, in practice, 9 gallons of dispersant were removed from a 45 gallon drum and replaced with the gelling agent to produce a 20% solution; that this was then mixed with sea water in a combined mixing/ application unit in the ratio of 3:2; and that this was easily achieved by feeding these two components from separate pressurised *Knapsacks* to the spray gun's mixing chamber, the concentric inlets and flow-control valves of which permit adjustment to the desired gel consistency, a welding-torch being easily modified to serve as such a spray gun (article 95).

As to dispersant limitations, policy-makers must accept that WSL found higher pollutant viscosities to be amenable to dispersant treatment onshore than at sea, presumably because of longer contact times onshore prior to agitation by incoming surf in a version of premixing (articles 22-25 and 60-61); that thinners such as the kerosene of early dispersant formulations are helpful, though concentrates are essential for aircraft application; that while mechanical removal from water surfaces is more tolerant of higher viscosities than are dispersants, skimmer and transfer pump design is viscosity-dependent to the extent of disc skimmers being no more effective than dispersants, of adsorption ropes being limited only by the heat required to release the more adhesive pollutants, and of specially-designed Archimedean screws being bettered only by partial vacuum conveyers (articles 47 - 61, 76 - 80, 92 - 93 and 96-98).

Article 137

Having reviewed the available knowledge of casualty-response in articles 1 - 115, having reviewed the extent to which it has been thwarted by reality-refuted belief and by belief yet to be reality-evaluated in articles 116 - 129, and having identified in articles 130 -136 the extent to which this knowledge must be accepted by policy-makers who have thus far preferred knowledge thwarting beliefs to available knowledge, the victims of previous and current policy-making are entitled to some explanation for this non-cost-effective preference. The only possible explanation is that policy-makers have themselves been victims of the continuous propagation of these beliefs by environmentalist pressure groups. Thus, the only possible corrective is for policy-makers to reject this on-going belief-propagation and to accept my newly definitive knowledge/belief differentiation which now makes belief-acceptance impossible for all who would claim to be rational (Foreword, Preface and articles 1 and 121 - 129).

Thus, policy-makers must accept that that prior to this definitive differentiation, the knowledge being acquired by Warren Spring Laboratory (WSL) up to 1979, was being opposed, suppressed or ignored by belief-consensual pressure groups despite its acquisition being funded by the UK government in response to the *Torrey Canyon Incident* of 1967 (articles 1 - 61), and despite the resulting equipment-stockpiles and service-contracts having been established by 1983 by that government (articles 62 - 115) before it bowed to the belief-consensus of the environmentalists in failing to endorse their use in a knowledge preserving contingency plan (Preface, Acknowledgements and articles 103 - 106).

Thus, policy-makers must further accept that these stockpiles and contracts have never yet been fully applied by the UK nor has the knowledge which produced them been applied by any other coastal State, all having allied themselves to varying extents with the reality-refuted belief in oil/HNS releases being the cause of species-extinction/ecological-disaster despite their causing no more than interruptions of commercial activities at worst (articles 103 - 104). Yet again, policy-makers must accept that despite this belief having been reality-refuted by WSL in the mid 1970s, its derivative beliefs have remained obstacles to cargo/bunker transfer in safe havens; dispersant-use; and *in situ* decanting of process waters arising from pollutant removal: all of which are serious obstacles to application of the knowledge of incident response which would restore localities to their pre-incident conditions quickly and cost-effectively in association with the natural biodegradation which belief refuses to accept despite biodegradation doing more to limit the physical coating of organisms and shorelines than does the belief in mechanical removal as exemplified in articles 107 - 115, such belief now being long over-due for termination (articles 116 - 136).

Thus, policy-makers must identify knowledge as that which harmonises technology with the environment as set out in articles 1 - 15; that which provides understanding of water-immiscible systems as reviewed in articles 16-30; that which explains the natural fate of accidentally released and operationally discharged oils and HNS as described in articles 31-46; and that which would remove all belief-only obstacles were it to be fully utilised in response. Again, it is the knowledge which provides understanding of dispersant-use as set out in articles 47-61; of remote sensing, sampling and identification of oils/HNS as reviewed in articles 62 - 69; of mechanical recovery from water surfaces as described in articles 70-91; and of shoreline-cleaning by chemical and physical means as described in articles 92-102. Yet again, it is the knowledge which provides understanding of the deficiencies of current contingency plans as in articles 103-106, of these deficiencies in practice as exemplified by the *Sea Empress Incident* in articles 107-115, and of the ways in which effective response techniques are thwarted in their application by the reality-refuted belief-driven regulations identified in articles 116-120. Furthermore, it is the knowledge which has recently invited the environmentalist lobby to reality-validate its counter-beliefs where possible or to denounce them as already reality-refuted by the reality-evaluation which definitively differentiates the knowledge/belief dichotomy (Foreword, Preface and articles 121-129) and it is the knowledge which has been opposed by belief and only partly implemented to establish the MPCU stockpiles and aircraft contract, but not implemented to create a contingency plan for their use (articles 47 - 49, 90 - 91, Acknowledgements, and articles 103 - 106).

As to the beliefs to be rejected, policy-makers must now recall that contingency plans have thus far been merely vehicles for debating belief/counter-belief as reviewed in articles 103 - 106; that apart from listing the contact details of the parties to such debate, these plans mainly describe arrangements for communication between incident site and HQ, and for public dissemination of incident news as controlled by HQ public relations managers; and that the politics of belief/counter-belief management is thus more important to those in charge, than is knowledge of casualty-response. As with everything else in the higher administration, knowledge has been assessed as too constraining and/or as conferring too much responsibility for comfort; and that their response plans have thus been concerned only with handling the environmentalist belief-consensus from a public relations point of view, and thus have had no concern for the formulation of knowledge-only policy. Of course, having only read of, or been present only at politically handled incidents at home or abroad, they are unlikely to have seen any need for knowledge. Indeed, in this, as in other technical contexts, I have heard administrative generalists (policy-makers) proclaim their ability to take decisions without knowing any science or engineering, to which my usual response was that they got away with it by dealing only with the similarly ignorant.

Thus, policy-makers must recognise that their ignorance of incident-response has offered no opposition to the environmentalist lobby's reality-refuted beliefs and those as yet without reality-evaluation; that the resulting absence of referential knowledge in current contingency plans is agreeable to both officialdom and to the environmentalist lobby, because belief-consensus can be adjusted from day to day with publicly unsatisfactory outcomes being excused by claiming novelty of incident and by placing all responsibility on an identifiable industry. In contrast, however, policy-makers must now recognise that the newly definitive differentiation of knowledge from belief as utilised in articles 1 - 136 provides for the creation of a contingency plan embodying all available knowledge and rejecting all beliefs which thwart its implementation; and that this knowledge-acceptance/belief-rejection will enable future incidents to be dealt with cost-effectively, the roles of lobbyists and public relations managers having been thus rendered obsolete. Thus, the preference for implementing belief over the knowledge which refutes it, has been terminated - in principle - if not yet in practice.

Towards Knowledge Supremacy in Practice

Article 138

To achieve knowledge supremacy in practice, policy-makers are now required by the new knowledge/ belief differentiation to recognise that all matter exists as gases, liquids, or solids at ambient temperatures; that when released from containment, gases dilute in the atmosphere, liquids dissolve in water or disperse in it as droplets if immiscible; that they float or sink while dissolving or remaining un-dissolved; that gases diluting in the atmosphere, liquids dissolving and diluting in seawater, or dispersing and diluting in seawater as non-coalescing droplets, are all non-collectable; that only non-soluble/non-dispersed liquids and solids are candidates for possible collection; that insoluble liquids dispersing naturally as droplets are possible candidates for enhanced dispersion by dispersant application; that none of these fates has ever caused species-extinction/ecological-disaster; and that neither removal nor induced dispersion can prevent or cause that which exists only in belief.

Again, the new knowledge/belief differentiation requires policy-makers to accept that the entire global biomass of land and sea recycles through the atmosphere as carbon dioxide and water by photosynthesis and biodegradation; that the biodegradation of operational discharges and accidental releases of oils or organic HNS liquids complete the biodegradation hemicycle previously interrupted by 'fossilisation' by thus rejoining the ongoing biodegradation which is the fate of the entire oceanic biomass when dead without any of it being toxic, as is confirmed by the seawater concentrations of the latter being too low to be toxic in contrast to the orders of magnitude greater concentrations required to produce measurable toxicity in the so-called toxicity-testing of oil and dispersants; that their sulphur-contents recycle through atmosphere and biomass by incorporation in photosynthesis/biodegradation as sulphite, sulphate and sulphur dioxide, while nitrogen-contents similarly recycle through atmosphere and biomass by microbial fixation of atmospheric nitrogen and oxygen and/or by the symbiosis of plant and microbial life and by subsequent biodegradation back to nitrogen oxides, nitrite and nitrate; that dissolved inorganic HNS are diluted and neutralised in the buffered pH system which is seawater; and that the numbers of birds and animals killed by physical coating are too low to cause species-extinction/ ecological-disaster at sea or onshore because re-colonisation replaces losses (Preface and articles 1 and 121 - 127).

Further to dispersing-slicks being incapable of causing species-extinction/ecological-disaster, the new knowledge/belief differentiation requires policy-makers to accept that with Fay's phase II spreading thickness being ~ 0.1mm, the concentration in the bottom/top metre of atmosphere/water-column could never be more than 100ppm initially, and is subject to unrestricted dilution/biodegradation to zero; that these concentrations could never cause such extinction/disaster even if they were not biodegraded; that dispersants (themselves non-toxic/biodegradable) are applied at dispersant : oil ratios of 1 : 20 and thus cannot significantly alter a concentration-depth profile which untreated by dispersant runs from < 10ppm to zero through dilution and biodegradation; that the combined toxicity of oil dispersant mixtures at this ratio can be measured only by adjusting concentration to the LC_{50} value which is at least 2 - 3 orders of magnitude higher than those measured in the top metre of the water column, let alone at greater depths (articles 47 - 49); and that this same disregard for exposure concentrations is exhibited by those who quote LC_{50} values for individual HNS in support of their self-serving beliefs and in total disregard for knowledge.

As to the inherent limitations of response techniques, the new knowledge/belief differentiation requires policy-makers to accept that the slick thickness of 0.1mm, limits the encounter rate of response units to $0.18m^3h^{-1}$ per metre swath-width per knot of advance, there being only $100m^3$ of pollutant per km^2 of sea surface; that response techniques can only be applied to small fractions of total slick areas while evaporation, solution or dispersion occurs over the entire area; that consequently, the quantity removed from the surface per hour without human intervention is proportional to the total slick area and is thus much greater than the quantity encountered by the localised human response within it. Thus policy-makers are required to accept that while slicks may be moving towards shore as the sum of the tide vector and 3% of the wind vector, evaporation will remove about 25-30% of crude oils in < 5 hours while natural dispersion will remove half of the non-volatiles as water-in-oil emulsion droplets in successive half-live periods of 4 to > 48 hours; that heavy fuel oils have half-lives of 4 - 8 days; that insoluble non-volatile HNS do not form emulsions and, apart from about 15 of them, have viscosities < 5cSt at 15°C and thus have half-lives < 4 hours with only an identifiable few being solid at ambient temperatures; that volatile HNS evaporate entirely while soluble HNS dissolve entirely; that given the inherently low encounter rate, no at-sea response is likely to deal with more oil prior to stranding than is released from a single damaged-tank; and that there is thus an unavoidable need for cargo/bunker transfer, preferably in safe havens.

Further to released quantities, the new knowledge/belief differentiation requires policy-makers to accept that HNS tanks are smaller than oil tanks, that bunker tanks are smaller than cargo tanks, that cylinders and packages within containers are progressively smaller still; that releases are thus ever more localised; that none arise from undamaged containment; that gas releases can only be monitored as to concentration or flared to diluting carbon dioxide and water; that vapours from volatile slicks are insignificant; and that that which has evaporated, dissolved or dispersed cannot be collected

Article 139

As to shoreline response, the new knowledge/belief differentiation requires policy-makers to accept that national shipping administrations are only concerned with response prior to stranding; that local government takes over after stranding; that under the influence of offshore winds, the natural processes of evaporation, solution and dispersion do more to prevent stranding than does the deployed response equipment; that consequently the best way to return the environment to its pre-incident state is to return stranded substances to the sea for resumption of these natural processes now aided for a second time by resumption of the earlier at-sea/inshore response as may be appropriate; and that water-column concentrations whether natural or dispersant-induced will biodegrade the second time round as they did in the first, while second time removal from water surfaces will be as easy or as difficult as the first time and less difficult than from shoreline surfaces. Again, the new knowledge/belief differentiation requires policy-makers to accept that free water separated from recovered emulsions or separated from oil after emulsion-breaking is to be directly discharged to sea or to shorelines/inshore-waters for natural dilution and biodegradation of any un-coalesced droplets as were those from the slick itself prior to stranding.

Further to sea surface response, the new knowledge/belief differentiation requires policy-makers to accept that while the encounter rate of response units is limited to $0.18m^3h^{-1}m^{-1}$ per 0.1mm slick thickness, windrow formation increases the thickness by creating intervening ribbons of clear water;, and that while this increases the encounter rate for single-ship sweeping of individual windrows with shorter and thus more easily handled boom-lengths, the longer more cumbersome booms of twin-ship sweeping, encounter both ribbons and windrows which loses the thickened-windrow benefit while doubling the ship-use, or trebling it if the collecting ship is additional to those towing the boom; that while water-in-oil emulsion formation to 80% water-content increases 0.1mm thickness to 0.4mm, the oil-content still equates to the 0.1mm thickness but quadruples the downstream processing tonnage, while the co-collected free-water can usually double this tonnage again; and that while emulsions pressed against shorelines by onshore winds have stranded as 4-6mm layers thus increasing the encounter-rate for inshore removal, its stranding adds the task of separating emulsion from shoreline surfaces to those of post-removal processing of emulsions from sea surfaces.

As to overcoming belief-driven obstacles to downstream processing in general, the new knowledge/ belief differentiation requires policy-makers to accept that the removal which necessitates downstream processing, must be avoided as much as possible unless viscosity is too high for effective dispersant-use; that while removal and downstream processing is partly motivated by belief in reuse, biodegradation *in situ* is less troublesome and more cost-effective than at approved post-transport land-farming sites; and that such overall processing costs more than the value recovered, thus rendering re-use more costly than primary-use of transferred cargo/bunkers for whoever ultimately pays, as it is with all belief-only ‘recycling’, though such knowledge is rejected by environmentalist belief (article 145).

Further to belief-induced costs, the new knowledge/belief differentiation requires policy-makers to accept that fishing bans need more thorough consideration than they have received thus far; that sedentary shellfish physically coated by slicks draining down on them in ebbing tides must be differentiated from fish free-swimming in seawater containing concentrations in the ppm-ppb range; that while the former cannot be offered for sale even in the absence of a formal ban, the latter, when caught without being drawn through floating slicks, have been shown to be taint-free; that filter-feeding shellfish containing oil or oil-emulsion droplets from seawater are cleared thereof by routine depuration, and that current compensation claims are thus caused more by the bans themselves than by the effects of oil releases.

Thus, in light of the biodegradation which converts all released organic substances to carbon dioxide and water as it does all dead organisms of the sea and land biomasses without causing species-extinction/ecological-disaster, the new knowledge/belief differentiation requires policy-makers to accept the objective of response as being to increase the accessibility of released organic substances to the micro-organisms which convert them to carbon dioxide and water; and thereby to clear the physical mess which, had it not been directly observable, would never have attracted our attention in the first place. We certainly pay no attention to the unobserved but on-going biodegradation of our surrounding biomasses. Again, the new knowledge/belief differentiation requires policy-makers to accept safe haven cargo/bunker transfer and timely blow-out prevention and oil-well capping as essential complements to the inherently limited capacities of dispersants and mechanical removal even when pollutant viscosity is low enough to permit the former or high enough to require the latter in our efforts to prevent or resume the commercial activities interrupted by such events.

Thus, the new knowledge/belief differentiation requires policy-makers to accept that the objective of response is to return localities to the pre-incident conditions necessary for resumption of interrupted commercial activities as quickly and as cost-effectively as possible; to limit compensation payments to costs incurred on these efforts and to the commercial losses incurred prior to completion of these efforts, while diminishing the costs of both by choosing the most cost-effective response techniques and equipment at operational capacities related to the expected volumes of single tank-damage releases and to the expected rates and durations of oil-well releases.

Article 140

With policy-makers now having no alternative other than to reject all reality-refuted beliefs in species-extinction/ecological-disaster, and having no alternative other than to accept the physicochemical properties of released oils/HNS as determinants of their fates and effects, they must thus accept density as determining whether they float or sink, volatility as determining evaporation, viscosity as determining dispersion, solubility as determining solution, and pour point or melting point as determining whether they are liquid or solid at seawater temperatures. Furthermore policy-makers must also now accept that incident-specific fates and effects are predictable by substituting incident-specific values for the physicochemical parameters relevant to each incident, all such values being already accessibly documented for every substance produced, transported and used in current commerce.

Again, with policy-makers now having no alternative other than to accept the necessity for expeditious cargo/bunker transfer, blow-out prevention and oil-well capping, they must thus accept that these must be the first considerations in incident-specific response. Yet again, with policy-makers having no alternative other than to reject the reality-refuted belief in species-extinction/ecological-disaster, they must thus accept that viscosity-dependent dispersant treatment and mechanical removal of such releases are applied only to the floating residuals which have not yet evaporated and/or dispersed into the sea; that the fraction which has already dispersed into the sea is already biodegrading without causing species-extinction/ecological-disaster; that consequently any untreated/un-removed residuals which subsequently strand may be physically returned to the sea to resume the dispersion/biodegradation or mechanical removal interrupted by the said stranding; that such return is the quickest and most cost-effective means of returning shorelines to their pre-incident condition and of limiting the otherwise associated commercial losses; and that incident-specific values of the relevant physicochemical parameters enable predictions to be made as to the release percentages which will evaporate, disperse, dissolve or sink, the percentages remaining for dispersant application and/or mechanical removal as their slicks move towards shorelines on wind and tide and the percentages which might be removed from shorelines or returned to the by or for dispersion depending on their known viscosity; and that the fates, effects, non-effects and response needs of any new substances will be predictable from the values of their physicochemical parameters as soon as these have been recorded.

Thus, policy-makers have no alternative other than to accept that only the non-volatile components of liquid oils are capable of producing slicks with natural dispersion half-lives of more than four hours; that only about fifteen liquid HNS are capable of such persistence; and that many more are either volatile or soluble; that any requirement to respond to oil/HNS slicks at sea depends on the quantity released, on its viscosity-dependent half-life, on its distance from shore and on the wind and tide vectors which move it to shore. Again, as to quantity, policy-makers have no alternative other than to accept that the tanks of HNS parcel tankers are very much smaller than those of the largest oil tankers; that all other HNS containment is much smaller again; that all non-volatile HNS releases are thus smaller than those of oil and being less persistent are less likely to require at sea response; and that with only some two dozen identifiable HNS being solids at ambient temperatures, their release from packages, whether soluble or not, will be small, localised and relatively insignificant; that released gases are non-collectable and are flammable or non-flammable; that flaring may be possible for pressure-point releases; and that the only other option is to measure atmospheric concentrations as functions of distance from source prior to and after the cessation of release.

Again, with policy-makers having no alternative other than to accept the benefits of returning stranded releases to inshore waters and thus to the sea for resumption of the processes which previously reduced the stranding quantity, they must also accept that incident-specific physicochemical property values will predict whether this return can occur by natural solution or dispersion from shorelines on successive tides; whether the viscosity is low enough for natural dispersion to be enhanced by dispersant treatment whether mechanical removal from inshore water surfaces is possible; whether viscosity is so high as to require removal direct from shorelines by physical scraping without co-collection of beach material or less preferably with it; whether dispersant gels, high pressure water or steam cleaning will be needed for rocks, cliffs and man-made structures; and whether surface film chemicals would prevent stranding in the first place.

Yet again, with policy-makers having no alternative other than to accept the benefits of avoiding such co-collection and downstream processing of water-in-oil emulsions by returning stranded substance(s) to inshore waters with or without associated beach materials, they must also accept that the incident-specific viscosity value can predict the extent to which these benefits can be realised in specific incidents; that while downstream processing can be minimised by minimising onshore collection, it is an integral part of collection from water surfaces particularly when it can be more effective than dispersant application; and that the *in situ* discharge of process waters arising from the separation of co-collected seawater and from the breaking of water-in-oil emulsions is innocuous and cost-effective whether to sea, to inshore waters or to shorelines.

Thus, with the new knowledge/belief differentiation having brought policy-makers to the above acceptances of reality-validated knowledge and to the above rejections of reality-refuted belief, they must now accept that while incident-response contractors could be trained and accredited with respect to this knowledge-accepting/belief-rejecting approach, such training and accreditation could deliver its long overdue benefits only if policy-makers do actively permit their coastal States to realise these knowledge-derived benefits as customers. Accordingly, the intention of this new website is to offer this knowledge-accepting/belief-rejecting planning package to coastal States through the IMO and IOPCF, thereby permitting them to apply it through their own staff or through thus accredited response contractors according to mutually acceptable customer-contractor agreements yet to be considered with insurers and fund administrators.

Towards Knowledge Supremacy in Response Planning, Training and Accreditation

Article 141

Having recalled in articles 103-106 that knowledge is suppressed, thwarted or ignored in current response plans, having exemplified this ignorance by reference to the *Sea Empress Incident* in articles 107-115, having reviewed how application of this knowledge is obstructed by belief-only regulation in articles 116 - 120, having definitively contrasted this knowledge with these counter-beliefs in articles 121-129, having described how this knowledge ought to be applied to all components of incident response in articles 130-136, and having described in articles 137-140 how this knowledge would remove all belief-driven obstacles to implementation of the new knowledge/accepting/belief-rejecting approach to response planning from this point onwards, I will consider in articles 143 - 144 the role of training and accreditation of response contractors in securing the benefits derivable from accepting this knowledge and from rejecting all counter-belief as now definitively differentiated.

Meanwhile, in articles 141 - 142, I use the term ‘knowledge-only’ to denote the absence of belief and hence of opinion, while I use the term ‘belief-only’ to denote the absence of knowledge. Again, to avoid any misunderstanding, I recall that the objectives of the new knowledge-only approach are to minimise incident-impact on commercial activities by curtailing release in order to minimise the task of restoring impacted localities to their pre-incident conditions as quickly and cost-effectively as possible; that these objectives can only be met by acceptance of knowledge and rejection of its counter-beliefs; that while beliefs are non-compliant with reality and hence with each other and thus productive of paradoxical consequences, knowledge is compliant with reality and thus invariant, common to all, and continuous in growth and application; that until knowledge is thus recognised by customers to have supremacy over belief, the above objectives of incident-response can never be met; that in the absence of this recognition, response to successive marine incidents will never become a means of institutionalising knowledge to compensate for staff-change frequency and incident infrequency, nor will it ever become a means of acquiring new and sharable knowledge from successive incidents; and that customers and society in general will thus continue to suffer the ineffectiveness of belief/counter-belief debate at each and every incident. Thus, until the continuity/commonality of knowledge is recognised to be supremely beneficial, incident-response will continue to be as ineffective as it has been thus far, with individual customers and global society continuing to direct thir dissatisfaction to the oil, chemical and shipping industries rather than to the environmentalists who reject knowledge and promulgate its counter-beliefs to publics and State customers alike.

As to meeting the newly stated objectives of response by application of my new knowledge-only approach, we see that the only obstacle is the belief in species-extinction/ecological disaster despite this belief having long since been reality-refuted by our longstanding knowledge that that all petroleum components and all petrochemical HNS derivatives are biodegraded when exposed to aerobic conditions on release; that inorganic HNS are neutralised on exposure to the buffered pH system which is seawater; that localised toxicity would arise only if concentrations of identified substances were high enough; and that this belief in the toxicity of all 'chemicals' is reality-refuted by the knowledge that the seawater concentrations of oils, HNS, and dispersants are too low to be toxic at source and are rapidly diluted with depth while being biodegraded or neutralised by the mineral-content of seawater.

Paradoxically, this belief in oil/HNS toxicity being the cause of species-extinction/ecological-disaster, though long since reality-refuted, has thus far deprived coastal State customers of the known benefits of safe-haven cargo/bunker transfer which limits releases; of the known benefits of the dispersant-use which reduces the physical coating of shorelines and of surface-frequenting organisms; of the known benefits of water column biodegradation which converts releases to carbon dioxide and water; and of the known benefits of *in situ* decanting of free water co-collected with emulsions and of the water broken from emulsions which maximises storage capacity of removed releases. Thus, we know that all of these deprivations decrease the rate and increase the cost at which localities can be returned to their pre-incident conditions for resumption of interrupted commercial activities; that environmentalists proclaim their concerns for the environment while rejecting the knowledge which would prevent or reduce the physical coating of organisms and shorelines and the associated interruptions of commercial activity; and that all we have to do to enjoy the benefits of knowledge continuity/commonality is to reject a belief already reality-refuted.

Again, we know that the derivatives of this reality-refuted belief in species-extinction/ecological-disaster has prevented contingency plans from becoming continuous transmitters of available knowledge and the means of continually acquiring new and sharable knowledge from successive incidents; that the resulting absence of knowledge has made coastal State customers and contractors incapable of demonstrating competence in incident-response, and that they will continue thus, until knowledge is accepted and belief is rejected in all future contingency and incident-specific planning.

Article 142

Further to the absence of knowledge in response planning, this article recalls that staff-change frequency and incident infrequency are incompatible with knowledge-continuity unless specific steps are taken to secure it; that while the equipment stockpiles of the new Marine Pollution Control Unit (MPCU) were established within the UK's marine administration on the knowledge acquired by the R&D programme of Warren Spring Laboratory (WSL), the knowledge also acquired by that R&D programme on how to use the said stockpiles was not secured against staff-changes; that while this latter knowledge could have been institutionalised through a knowledge-only contingency plan, no such plan was created; and that consequently with none of the instigating WSL staff being in the MPCU when the *Sea Empress* incident ensued, the new non-WSL staff were unable to prevent future responses from becoming environmentalist belief-only failures. Thus, had the contingency plan preserved the knowledge of seawater concentrations being non-toxic and of species-extinction/ecological-disaster being absent from all incidents from the *Torrey Canyon* inclusive, the knowledge-countering beliefs of the environmentalist lobby would not have turned the *Sea Empress* incident from the first ever rapid and cost-effective exemplar of future response, into yet another prolonged/cost-ineffective belief-thwarted fiasco as exemplified in articles 107-120.

However, this fiasco is explained by recalling that the *Sea Empress Incident* of 1996 was the first to involve the UK in release response since the founding of the MPCU in March 1979, the intervening *Tarpenbek* having released no oil and the 86,000 tonnes of Gullfacks crude oil released by the *Braer* having dispersed so rapidly as to need no response; that consequently the failure to secure knowledge-continuity within the MPCU contingency plan, resulted in the *Sea Empress* releasing 67,000 - 69,000 tonnes of preventable cargo loss before the then remaining 58,000 tonnes was eventually discharged to its destination refinery (articles 107 - 115); and that knowledge preservation within an MPCU contingency plan would have resulted in these ~ 68,000 tonnes being discharged to the refinery rather than being released. Again, it would have avoided the water depth limitations which thwarted dispersant treatment, and in collaboration with inshore recovery capacity within the Haven, would have prevented the initial release of ~5,000 tonnes from reaching shore or permitted it to be returned to the sea to complete the dispersion or removal operation, thus avoiding what became a very extensive and time consuming removal from both sea and shore, the downstream processing of which was yet again protracted by belief-only prohibition of *in situ* water-decanting.

As to contrasting the above with a knowledge-preserving contingency plan based on the physicochemical properties of oils/HNS which control, fates, effects and possible responses thereto as briefly introduced in article 138, and with the predictive power of incident-specific response plans based on substitution of the actual values for the physicochemical properties relevant to any particular incident as briefly introduced in articles 139 - 140, it is recalled that the physicochemical values relevant to the oils released at the *Sea Empress Incident* enabled retrospective prediction of the amounts stranding from the amounts released to be in agreement with the amounts stranded on the tidal streams and wind conditions of the actual incident (articles 107 - 115). Thus, it is concluded that the quantities floating, sinking, spreading, evaporating, dispersing or dissolving as functions of time prior to stranding on known wind and tide vectors can now be predicted for any specific incident; and that comparison of such incident-specific predictions with actual observation of outcomes will produce new and sharable knowledge which can progressively refine, for example, the current half-life ranges to actual values for specific substances as was initially done for Ekofisk crude oil by WSL at the 1976 blow-out and as was initially done for heavy fuel oil by WSL following the *Katina* Incident (article 42).

Thus, we can recall that this new knowledge-only approach will not only improve the responses to incidents as of now, but will also progressively improve future responses as more detailed knowledge of individual fate, effects and response requirements and non-requirements is progressively acquired, reported, and shared among all involved in incident response; but that none of these benefits can be expected, without general adoption of this new knowledge-only approach to contingency and incident-specific planning, no such collective knowledge repository having been accessible from the *Torrey Canyon* incident until now. However, now that this new approach is open for adoption by States themselves as customers and/or by their contractors, it is possible to look forward to spill reports to IMO being more that over-excited expressions of belief in global collapse in which no knowledge of pollutant properties and their amenability or non-amenability to available response techniques and equipment is ever included. In short, rather than being informatively instructive, they are simply generalised expressions of belief-only aversion to industrial-commercial activities which they believe to be causative of species-extinction/ecological disaster while they paradoxically enact all possible obstacles to the avoidance of these belief-only consequences.

Article 143

With articles 130 - 137 having previewed the new knowledge-only approach to response, and with articles 138 - 142 having previewed its benefits in practice and in staff training, this article considers how it could be the basis for accrediting the competence of response contractors and of coastal States themselves. Through IMO, these States have thus far merely approved the subject-headings for response-training guidance, while the content is left to others as yet un-specified, though presumably intended to be compliant with the belief-consensus which has thus far failed to restore localities to their pre-incident conditions cost-effectively. This undeniable failure thus necessitates consideration as to how my new knowledge-only approach is to be implemented in the response-training of contractors within individual States desirous of adopting this new knowledge-accepting/belief-rejecting approach. Again, while States have thus far required/permitted response contractors to be compliant with what has become by default the international belief-consensus, insurers, IOPCF managers and global society might be expected to welcome a new knowledge-only/cost-effective approach implemented through training and accreditation of response contractors. Acceptance of such knowledge-only training/ accreditation by individual States as customers, could result in ubiquitous acceptance by contractors and in the progressive enhancement of this knowledge repository with further knowledge acquired by thus informed observations at successive incidents and subsequently collated by the IMO secretariat.

As of now, I recall that cargo/bunker transfer and wreck removal, when conducted without belief-consensual interference, are the sole knowledge-only components of incident response; that marine salvage contractors are self-trained by the work they do; and that consequently they would derive no benefit from those currently involved in belief-consensual training for release-response. In contrast, however, we know that professionally competent instructors could confer benefits in all aspects of release response were my new knowledge-only approach to be accepted by State customers in respect of the need to implement a safe-havens policy to avoid the possibility of total cargo/bunker release, operational salvage-related releases, if any, being very much smaller than that from damage to a single cargo tank at the location of initial impact. Again, as to oil-well releases, the new knowledge-only approach recognises that drillers and operators are best placed to design blow-out prevention and well-capping systems, the only concern of my new approach being that knowledge-only regulation will be implemented; and that belief-only options will not be implemented.

As to release-response, the new knowledge-only approach to training and accreditation would recognise that slick area and inverse thickness makes any realistic provision of equipment incapable of preventing stranding when releases close to shore under onshore winds are greater than the ~5,000 tonnes liable to arise from impact-damage to a single cargo tank, the encounter-rate of response units being only 0.18 m^3h^{-1} per metre swath width, per knot of advance; that natural evaporation, solution and dispersion rates are proportional to slick area and are thus vastly greater than the localised dispersion or mechanical removal rates achievable by response units capable of operating only in physically small areas within such slicks; that nonetheless, the resulting concentrations in the atmosphere/seawater, or the physical coating of birds or marine mammals have never caused species-extinction/ecological disaster because the seawater concentrations and numbers coated are too low to cause such effects; that, in any case, all such concentrations are biodegraded to carbon dioxide and water by marine micro-organisms with no toxic effects; and that while free-swimming fish are untainted by such biodegrading concentrations, filter-feeding selfish can be cleansed of any filtered droplets by routine depuration.

Thus, my new knowledge-only approach to training and accreditation would require that coastal States co-implement their release-response policies with their release-prevention policies and that trainees and accredited contractors would recognise that without this policy-integration, polluted localities will never be restored to their pre-incident conditions quickly and cost-effectively. Trainees and accredited contractors would, of course comply with whatever beliefs were retained by coastal States despite their reality-refutation, were such perversity to be encountered by contractors.

As to response to stranded releases and to the downstream processing of releases collected from water surfaces and from shorelines, trainees and accredited contractors would recognise that while it is difficult/impossible to collect releases from water surfaces without co-collection of free-water, it is even more difficult to collect them from shorelines without co-collection of beach-particulate materials; that belief-only regulation now prohibits decanting of subsequently separated free-water and of demulsified water from the subsequently broken emulsions; that while collection of high viscosity emulsions with or without underlying beach material may be unavoidable, those which were naturally dispersing prior to stranding ought to be returned to inshore waters for resumption of natural and/or dispersant-induced dispersion, thus avoiding the downstream processing which is motivated by the questionable belief in the resulting oil being reusable; and that prevention of its initial stranding and/or facilitation of return to the sea can be achieved by prior application of surface active chemicals, while return from rocks, cliffs and manmade structures may be facilitated by application of dispersant gels or by steam or high pressure water treatment. Thus, my new knowledge-only approach to training and accreditation would require contractors to be aware that interrupted commercial activities will never be resumed quickly and cost-effectively as in articles 70 - 104, unless customers permit contractors to adopt the new knowledge-only approach to response, knowledge being otherwise all to easily thwarted by belief.

Article 144

Having sought to encourage coastal states singly or collectively to implement my new knowledge-only approach to incident response and to share this knowledge with accredited contractors and ultimate payees as in article 143, this article outlines what could be done in respect of the training and accreditation of contractors pending such implementation.

Thus, training for competence accreditation would confer on release response contractors the ability to select the physicochemical properties relevant to any particular incident involving oils or HNS and to substitute specific values for them to predict whether they will float or sink, evaporate, dissolve or disperse; to predict the rates and extents of these processes; to predict the quantities likely to disperse prior to stranding in the time taken to reach shorelines under known conditions of wind and tide; to select the most effective response techniques and equipment from those available for dispersant application and mechanical collection from water surfaces and from identified shoreline types; to predict the quantities thus to be dispersed and/or collected; to predict the time and cost requirements involved in returning stranded substances to inshore waters and hence to the sea for resumption of the solution or dispersion which reduced the amount finally stranded and which would have reduced it to zero had time, wind, tide and distance from source permitted; to predict the time and cost requirements involved in collecting stranded substances with or without co-collection of beach material; to predict the time and cost requirements involved in separating emulsion from co-collected free-water, in breaking emulsions and in separating oil from demulsified water and in decanting such waters *in situ* or after transportation to some location approved for such processing such as an oil refinery willing to take it; to predict whether or not such oil can be recycled to cost-effective use; and to predict the relative costs of biodegradation by return to seawater or by transportation to an approved land farming location at an oil refinery willing and able to take it.

Again, training for competence accreditation would confer on release response contractors the ability to report on all of the above for the customer in a format designed to facilitate knowledge maintenance and accrual by the coastal State as customer, thus permitting ever greater mutual understanding and constructive interaction between customers and contractors and ever greater ability of the customer to change contractors on the basis of experiential knowledge. Yet again such knowledge-only reporting by the contractor and evaluation of his predictions by direct observation would clearly be of great value to the ultimate payee while central collection of all such reports by the ultimate payee would progressively increase his ability to adjudicate on all compensation claims based on contractor reports submitted by coastal States to the ultimate payee. Indeed, whether or not the ultimate payee was to have the primary or secondary relationship with the response contractor could become a matter for future consideration. Either way, this new knowledge-only approach would obviate the debate of opinion/counter-opinion which currently employs large teams of opposing lawyers.

However, pending implementation of the new knowledge-only approach to release response, we know that the proposed training for accreditation of contractor competence is equally applicable, whether or not the customer wants to maintain his belief in imminent species-extinction/ecological-disaster. Clearly in the former case, the contractor will accept the consequences of such beliefs, these being to expect no access to save havens; prohibitions on dispersant-use and on returning stranded substances to inshore waters; and insistence on collection and downstream processing despite prohibition of *in situ* water-decanting and the absence of outlets for thus ‘recycled’ oil: at least until the payee objects.

However, for those still believing that response at sea can be matched even to the largest releases, it may be recalled that when the Efofisk well was capped in 1976, the area of the slick was so much larger than individual response units, that had it been scaled down to one square metre, the responding ships within it would have been invisible, and even if visible, their limited removal-movement would have been as imperceptible as that of the tip of the hour-hand a wrist-watch; that such an imperceptible encounter/removal rate has to be compared to the natural evaporation of the volatile 25% of the real slick being complete in 5 hours , and to the natural dispersion of the non-volatile emulsion being about 99% complete in 72 -84 hours (7 half-lives) for Ekofisk oil, however large the release. Again, with many oils being much more persistent than is Ekofisk crude, my new knowledge-only approach emphasises the need for coastal States to implement knowledge-only policies with respect to limiting releases by access to safe havens for cargo/bunker transfer and by expeditious capping of oil well releases, while recognising that the amounts which naturally evaporate, dissolve or disperse, whether of oils or HNS, can neither be mechanically removed nor cause species-extinction/ecological-disaster; and that the real need is to limit releases to within achievable response rates and thus to restore commercial activities to their pre-incident levels as quickly and cost-effectively as possible. Thus, it may be concluded that both customers and contractors must have knowledge-only training, if the current belief-consensus is ever to be rejected.

The Need for Knowledge Supremacy in Waste Management and Energy Generation

Article 145

Having reviewed the negative effects of preferring belief to knowledge in respect of response to releases and discharges of oils/HNS to the marine environment (articles 116 - 137), the positive effects (benefits) of the reverse preference in articles 138 - 140, and the need for corresponding training and competence accreditation (articles 141 - 144), I now review the positive effects of knowledge-acceptance/belief-rejection in respect of ‘recycling’ recovered oils/HNS and of ‘recycling’ in general.

I start by noting that belief-only enthusiasm for recycling has deprived the term ‘waste’ of its meaning, the cost of ‘recycling’ definitive waste being more than the cost of buying fresh supplies. Thus, it ought to be known that to transfer cargoes and bunkers is to recycle them to prevent them from becoming waste in the form of emulsions and mixtures of emulsion and beach-material which cost more to ‘recycle’ than does prior discharge as marketable cargo and bunkers. Again, ultimate response payees ought to know that petroleum fractions, superfluous to those usable in lamps previously designed for whale oil, would have been definitive waste had they not been fractionally distilled for cost-effective use as fuel for automobiles, aircraft, ships and power stations and as coverings for roads; that coal gas would have been a waste from coke production for steel-making, had its sulphur-content not been cost-effectively convertible to marketable sulphuric acid to make the coal gas cost-effectively useable for domestic lighting; and that while such recycling conferred obvious cost-benefits, none were brought about by the agitation of belief-only pressure groups.

Yet again, it ought to be widely known that the hunter-gatherers of prehistory were recycling what would otherwise have been waste skin, fur, feather, bone, horn, tendon, and vegetable fibre to make clothes, shelters, tools, weapons and ornaments without any belief-only agitation for avoidance of waste. Yet again, without any such agitation, our later forebears from the Bronze Age onwards were recycling old artefacts to new by melting and remoulding metals. Nonetheless, it is now widely believed that without pressure-group agitation, society would ignore the benefits of recycling despite having practised it since time immemorial. However, our technological society now benefits additionally from the cost-saving knowledge which substitutes plastics for metals while continuing to recycle the metals still in use. Indeed, it is welfare benefit and cost-savings which harmonise technology with the environment, the former being already harmonised with reality which, of course, includes our environment (articles 1-15).

Further to cost-savings, it ought to be widely known that some items are designed for disposal as waste at the end of their useful lives by ensuring that any recycled-value would be less than the cost of any attempt to recycle it, such discarded items being definitive waste; and that when such disposal does involve loss of value, less costly source-materials are sought to maintain disposability while continuing to avoid the value-loss of recycling them. Thus, that which is designed by science, technology and economics to be disposable as definitive waste at the end of its useful life, cannot be economically recycled by science or technology. Indeed some metal ores cannot produce net positive-value because the metal-content is too low to pay for their processing, while worked-ores become waste before their metal content can be reduced to zero economically. Thus, it ought to be widely known that where recycling fails to produce net positive-value, it can be maintained only by wasteful public subsidy. As to cost-saving by material substitution, it ought to be widely known that plastics and synthetic fibres now replace metals and natural fibres in the manufacture of tubes, pipes, buckets, garden tools, paints, small craft, ropes, cable-insulation, clothing, food-wrappings, blister- packs and bags; and that such artefacts now account for 80% of ‘organic’ chemical production, not all of it profitably recyclable, despite landfill charges being artificially raised in the pretence of making it so.

Thus, it ought to be known that oils/HNS retained in marine casualties can be recycled without prior processing simply by cargo/bunker transfer to refineries, to direct use as bunkers, and to direct use as HNS. However, while oils mechanically removed from water surfaces can be separated from co-collected free water and from demulsified water by downstream processing to heat-producing combustion in various industrial processes, and while stranded emulsions can be separated from underlying beach materials for the same downstream processing, the costs of such removal and processing are included in the overall cost of pollution clearance: the product could only be sold at a loss if at all. Again, while this cost would be reduced by permitting *in situ* water-decanting, such ‘recycling’ still does not recover its costs, and should not of itself justify the prohibition on dispersant-use/biodegradation where otherwise appropriate (article 102).

Moreover, it ought to be widely known that cost-saving from reduced fuel consumption drives knowledge-acquisition for improvement in engine and body/hull design, irrespective of belief/disbelief in anthropogenic global warming. Thus, it ought to be widely known that the 200kg per horsepower of the internal combustion engines of the 1880s had improved to 6kg per hp for the Wright brothers’ flight of 1903, to 1.5kg per hp prior to 1914, to 1.0kg per hp in the 1914-18 war, and to the 0.5kg per hp of the Wright Cyclone engines of the B-29 bombers of 1944. each engine of which developed 2,200 hp and of which each aircraft had four. Again, it ought to be widely known that the first jet-propelled airliner was the de Havilland Comet of 1949, followed by the larger capacity, higher speed and greater range of the Boeing 707 and the DC-8; that the four engine Boeing 747 was replaced by the greater thrust, reduced fuel-consumption and lower emissions of the twin engine Boeing 777; that automotive aircraft and marine fuel consumptions and emissions have been decreasing with ever-increasing efficiency of engines, bodies and hulls; but that to go beyond such cost-saving for the belief-only objective of reducing combustion emissions is to incur definitively wasteful costs, knowledge-acquisition being progressively cost-saving while belief-only regulation wastes resources more usefully consumed towards further knowledge-acquisition and productivity elsewhere, science and technology being harmonious with the environment unless suppressed, thwarted or ignored by belief (articles 1-15 and 102).

Article 146

Having reviewed the negative effects of belief-acceptance/knowledge-rejection in marine casualty response and in recycling, and having reviewed the benefits of the opposite preference with respect to fuel-saving and associated emission-reduction in article 145, I now review the negative effects of this perverse preference in respect of energy sources, the intermittency of which is already known to be incompatible with the need for a steadily reliable electricity supply, the purpose being to show how persistent and widespread this perverse preferment is, and to show that the persistent preference of belief over knowledge in marine-casualty response is not the only manifestation of this self-defeating preference..

Thus, while it ought to be widely known that the sun has a diurnal intensity variation further reduced by cloudiness; that tidal flow-rate changes from hour to hour; that the times of high and low tide change from day to day; that tidal flow varies as a sine-curve from high to low tide and vice versa, that tidal ranges change over a monthly cycle; and that wave-height and wind-speed vary irregularly from calm to storm: it ought also to be widely known that electricity demand, though variable, is never zero and must be satisfied at all times. Consequently, it ought to be widely known that an on-going standby capacity to meet peak and all other levels of demand with immediate response is essential to compensate for reduced sunlight, variable tide-conditions and/or periods of calm or storm whether short or prolonged; that only the fossil fuel, nuclear and hydro-electricity options can provide this standby capacity; that optimising the hydro-option requires a constant head of water very much higher than anything provided by tides or waves; that wind generated electricity is more expensive than the current fossil fuel/ nuclear/hydro mix and would not be available were the losses not turned to profit by wasteful public subsidy; that opposition to fossil fuels is thus driven solely by belief in anthropogenic global warming not as yet reality-validated or reality-refuted; that the current closure-programme for the first two options takes no account of the impossibility of cost-effectively satisfying our energy needs by the so-called renewable options; and that despite this knowledge, the UK is committed to generate 38% of its electricity from renewable options by 2020 while calls for 100% are beginning to be heard. Thus, it ought to be widely known that reversal of this perverse preference for belief over knowledge will need global society to accept my definitive differentiation of the one from the other, and to act on the latter rather than the former (Foreword and articles 116-129).

As to the solar option, the EEC EURILIOS plant in the high solar intensity of Sicily was connected to the grid in 1981 despite the known inefficiencies of a system which reflects solar radiation by sun-tracking mirrors onto a central boiler to drive a steam turbine, despite its operation confirming that 1% of the total land area of Europe (comparable to the existing road system) would be needed to supply its energy requirements on the assumption of constant sunlight. Thus, while 88% and 10% of domestic swimming pools and water systems in the USA were being respectively heated by directed collectors of solar heat by 1985, while 30% of buildings in Israel had direct solar heating, and while this heating was being stipulated for new houses, there was rightly no interest in electricity-generation from solar- generated steam. Again, while electricity had been generated directly from solar radiation by Becquerel (1839) it was 1954 before satellite requirements had produced a silicon cell of 6-10% efficiency, since when gallium arsenide and gallium antimonide cells have given 37% efficiencies for blue and red light respectively. Nonetheless, while cost is evidently not a first-order consideration for satellites, and while transparent photovoltaic panels for installation as window-glass were patented in 1991, only a wastefully subsidised market could support their cost-ineffectiveness against existing alternatives.

Yet again, while the medieval tide-mill and its direct power applications are well-known, there are few locations world-wide where the tidal range is greater than the four metre minimum for minimally effective electricity generation. Thus, while a 750m barrage was built on the Rance in 1966, the French preference for the nuclear option remains intact, while plans for such a barrage in the Bristol channel are opposed by belief in wildlife impacts regardless of whether or not it would be cost-effective. Yet again, believers advocate the harnessing of wave-power which they expect to have low wildlife and visual impacts, even though this option is not yet reality-evaluated to the extent of the tidal option; while other believers advocate wind turbines despite their visual impact, despite their known failure to generate electricity at high and low wind speeds, and despite small scale private-domestic windmills having been acceptable only where intermittent operation is better than nothing. Indeed with no wind farm ever having been built without public subsidy, even their advocates now describe them not as a competitive power-source but as an expression of concern for the belief in anthropogenic global warming which continues to lack reality-validation.

Thus, while disbelief in technology being harmonious with the environment (articles 1-15) supports the reality-refuted belief in species-extinction/ecological-disaster which in turn prevents cargo/bunker transfer and dispersant use, and promotes 'recycling' of removed pollutants to the detriment of release-response, and while the belief in anthropogenic global warming (as yet neither reality-validated nor reality-refuted), supports all so-called renewable sources of energy, it ought to be widely known that the ensuing belief/counter-belief debates can be resolved only by accepting the earlier reality-refutation of the belief in species-extinction/ecological-disaster and by accepting the need to reality-validate or reality-refute specific hypotheses derivable from the belief in anthropogenic global warming (Preface and articles 116-129).

Article 147.

Further to article 146, I now contrast the so-called renewable sources of energy with the fossil fuel and nuclear options, further to proclaim that definitive knowledge must replace definitive belief if any progress is to be made in reality. Thus, I recall that no electricity is generated in high or low winds; that wind can be absent for long periods, particularly in anti-cyclonic winter conditions when electricity is most needed; that wind farms must thus be supported by fossil fuel, nuclear or hydro-electric power stations; that fossil fuel stations must maintain continuous steam pressure for their turbines, and that wind farms cannot thus remove the need for continuous fossil fuel combustion unless replaced by the other two options, the former of those being no more acceptable to environmentalist belief than is knowledge acceptance in relation to releases/discharges of oils/HNS to seawater (articles 116-120).

Nonetheless, with belief controlling the political agenda, the UK accepted the belief-driven task of generating 38% of its energy from 'renewable' options by 2020 despite 41.8% of our current requirement of 55GW being lost by 2015 with nuclear power stations (10GW) having been age-decommissioned and coal/oil fired stations (13GW) having become non-viable by their failure to comply with the arbitrary directive of the EEC on large combustion plant. Thus, the UK will have lost ~ 42% of its generating capacity while Westinghouse, sold out of UK influence in 2006, had orders by 2010 for 19 new nuclear stations. Thus, while others were placing orders, the UK was constrained by EU belief-only 'state aid' rules, while facing doubtfully reliable imports of natural gas, and belief-driven worries over its internal production causing earthquakes no more significant than those of coalmining. Thus, with only five MPs having voted against acceptance of a 38% deficit in electricity-generating capacity while relying on alternate wind farms, we see that reality is politically dismissible at least until the lights go out, computers crash, and all electricity-consuming work is disrupted.

In this looming reality, there are those who believe hydrogen will replace fossil fuels for motor vehicles, the emissions being water vapour instead of carbon dioxide. However, it ought to be widely known that the electricity required to produce the hydrogen from water in the first place, would result in further calls on our already doubtful electricity-generating capacity; that the transformation from one energy form to another is never 100% efficient because of heat losses; that there is a chain of such losses in converting chemical and nuclear energy to electrical energy, in its cable-transmission; and in its conversion to kinetic energy in individual electric motors; that it is thus more cost-effective to burn fossil fuel directly in the internal combustion engines of motor vehicles than in generating electricity for transmission to electrolysis plant to produce hydrogen for combustion in internal combustion engines, this being an even longer chain of energy conversion and transfer losses, as indeed would be the chain from nuclear power station to hydrogen-production for internal combustion in motor vehicles. Meanwhile, the States which refuse to believe in AGW know that coal combustion remains the cheapest means of electricity-generation.

As to the intermittent production of electricity from wind and other so-called renewable options we know that hydrogen intermittently produced by electrolysis of water could be stored at roadside filling stations for use irrespective of wind-intermittency in a manner comparable to the early intermittency of wind driven flour milling for storage and sale irrespective of wind. However, with hydrogen storage capacity being difficult to predict transitionally, the associated uncertainties are likely to be greater than for flour and petroleum products, while the capital losses of an imposed changeover from petroleum products to hydrogen would be as unnecessary as are those imposed by erection of intermittent wind farms while the belief in anthropogenic global warming continues to await reality-validation.

To conclude this review of the current preference for belief over knowledge, I include the geothermal and nuclear fusion options. Thus, with hot springs being a source of direct heating in Reykjavik, with natural super-heated steam (> 100°C) having generated electricity at Larderello (Italy) since 1905, and with volcanic heat being much in evidence in the north island of New Zealand, it was believed that the ubiquitous temperature- increase observed with depth in coal mines could be a source of geological energy irrespective of geography. However, injection and return of water through permeable rock to depths of 3,000-4,000m has shown that not all rock is sufficiently permeable, that permeability diminishes with depth, and that the rate of heat extraction is limited by the thermal conductivity of rock. Again, as to nuclear fusion, we know that the Joint European Torus (JET) at Culham, UK, has sustained such fusion for 2 seconds in a plasma at 220 million degrees K with an energy release of 2 megawatts for an energy input of 15 megawatts; that investigations continue; but that a practical system is not an immediate prospect.

Thus, with the current preference for belief over knowledge impeding the harmonisation of technology and environment as in articles 1-15, and with articles 145-147 showing that knowledge has difficulty in displacing belief to achieve this harmonisation, the only means by which the supremacy of knowledge over belief can be unavoidably presented to, and accepted by policy-makers and the general public, is through my newly definitive knowledge/belief differentiation (Preface and articles 116-129). Thus, having reached this undeniable conclusion, I turn to initiatives intended to secure knowledge-acceptance/belief-rejection in future policy-making.

Campaign Initiatives for Knowledge Supremacy in Ecological/AGW Policy-Making

Article 148

With articles 143 - 147 having shown the supremacy of belief over knowledge in environmental policy-making thus far, I now return to the previous difficulty of replacing the belief in species-extinction/ ecological-disaster with the knowledge acquired by the R&D programme of the UK's Warren Spring Laboratory into the fate and effects of oil//HNS releases and the responses appropriate to them, and to the initiatives previously taken towards achieving this replacement (Preface: first stage of campaign).

This first initiative of the mid 1970s was intended to dispel the belief in species-extinction/ecological-disaster by the direct measurement which showed that fully spread layers of oil/HNS are too thin and their natural or dispersant-induced dispersion too slow to produce concentrations of more than a few parts per million in the top metre of the water-column; that these concentrations decrease to zero by dilution and biodegradation within the column as a whole; that this concentration/biodegradation profile explains the absence of any such extinction/disaster at the *Torrey Canyon* and at all subsequent incidents; that this profile was consistent with increase in the populations of heterotrophic bacteria when released oils extend their food sources beyond the biodegradation-products which continuously arise from the deaths of more complex organisms within the carbon-cycle which is the marine ecosystem. This initiative was also intended to encourage believers in species-extinction/ecological-disaster to compare the number of deaths arising from the oil-coating of organisms with the numbers dying and birthing annually in the maintenance of species populations, and to encourage them to accept that re-colonisation rates are such as to require continual clearance from slipways, immersed surfaces of ships *etc*; and that no incident has thus far produced species extinction/ecological-disaster.

Nonetheless, this initiative had no such acceptance by believers, while the belief itself continued to prevent other coastal States from releasing oils/HNS for R&D purposes, thus preventing their direct acquisition of knowledge and thus restricting their ability to learn even from their own mistakes at their own incidents. Indeed, as previously recalled, this belief paradoxically inhibits the safe-haven cargo/ bunker transfer which would prevent further releases from more intensely/extensively coating shorelines and organisms, while preventing dispersants from increasing the natural dispersion/biodegradation which itself does more to prevent such coating than does localised dispersant-treatment or mechanical-removal. Again, this belief continues to prolong response not only by preventing dispersant-use, but also by preventing *in situ* decanting of co-collected and demulsified water in the processing of collected emulsions, thus decreasing the rate of clearance and increasing the likelihood of species-extinction/ ecological-disaster, were these effects other than mere belief.

Thus, we see that the inconsistency of the collective intentions and consequences of this belief are disregarded by all who thus irrationally prefer belief to the knowledge which refutes it. Indeed, this irrational preference for belief over knowledge as to the fates/effects of, and responses to releases/ discharges of oils/HNS, greatly decreases the cost-effectiveness of marine-casualty response, despite the earlier initiative (Preface and Acknowledgements) taken by WSL staff to reverse this preference through R&D reports, books and conference papers, and the submission of documents to successive meetings of IMO and the Bonn Agreement and to their respective working groups from the mid-1970s onwards to the mid 1990s.

However, with my second initiative being founded on my newly definitive knowledge/belief differentiation, and with this website being my third (Preface), I now expect to achieve the objective of all three initiatives i.e. the acceptance of knowledge by rejection of its counter-beliefs. To this end this third initiative identifies the physicochemical parameters of oils/HNS which explain the absence of species-extinction/ecological-disaster at all incidents to date; which predict the quantities remaining for dispersant treatment, mechanical removal and residual stranding as functions of incident-specific values of the incident-relevant physicochemical parameters and wind/tide vectors; which characterise shorelines by their pollutant adhesion, penetration, dispersion and bioremediation; and which determine the relative cost-effectiveness of dispersant-use, mechanical-removal, and downstream-processing, 'recycling' or final disposal. Again, I expect this third initiative to commend itself by facilitating the incident-specific record-keeping which will facilitate the settlement of compensation claims and enhance the knowledge repository which itself will preserve and institutionalise the thus growing knowledge which would otherwise wither and be lost through staff change frequency and incident infrequency, even if it were no longer actively suppressed by counter-believers.

Thus my overall expectation of this third initiative is that its knowledge-accepting/belief/rejecting approach will commend itself to the IMO member States wishing to benefit from it; to response-contractors wishing to be accredited in its use by the International Spill Accreditation Association (ISAA) and wishing to be thus publicised; to the IOPCF and P&I Club secretariats; and to global society as the only cost-effective alternative to the resource-wasting beliefs which have thus far controlled the incident response agenda to the detriment of commercial welfare and compensation-fund conservation.

Thus, the intention of this third initiative is for the knowledge of science and technology to wrest the environment from belief-consensual pseudoscience. Indeed, success in this particular overthrow of belief by knowledge will reveal the scope for more such overthrows wherever the knowledge needed for progress is being suppressed, thwarted or ignored by those who debate belief/counter-belief by reference to partially selected facts/counter-facts for party-political advantage despite the said beliefs/ counter-beliefs being unsustainable in reality whether of the majority or of the minority.

Article 149

Further to the need for this third initiative for knowledge-acceptance/belief-rejection in marine casualty response as outlined in article 148, we know that self-styled interested parties debate adjustments to the consensual belief in species-extinction/ecological-disaster in respect of removal/non-removal of cargo, in respect of sheltered/exposed locations for such removal, in respect of dispersant use/non-use at sea, inshore or onshore, in respect of discharge/non-discharge of process-water at sea, inshore, onshore or at approved sites, and in respect of 'recycling'/disposal of removed materials; that coastal-State administrations go along with whatever belief-consensual adjustment is thus reached from incident-to-incident and from day-to-day within incidents; that all participants are obliged to accept whatever belief-consensus is thus reached unless further modified by a belief that it might be judged unreasonable or disproportionate in retrospect, and thus be prejudicial to claim-settlement, while neither claimants nor assessors have as yet definitively differentiated 'reasonable' from 'unreasonable', and while refusal to compensate is thus attributed to 'unreasonableness' as may be adjudicated by lawyers.

As to the likelihood of my newly definitive knowledge/belief differentiation being universally accepted as the sole solution to the general dissention of belief/counter-belief, I know already that those to whom it is presented never fail to understand its benefits, never argue against it, nor ever flatly deny it; that instead they describe it as politically unacceptable; that in thus admitting politics to be knowledge- rejecting/belief-accepting, they are also admitting apolitical craftsmanship science and technology to be knowledge-accepting/belief-rejecting; and that if belief-accepting politics is the only obstacle to my latest knowledge-accepting initiative, then it cannot be other than ultimately successful across the board: reality trumps unreality as co-defined by my knowledge/belief differentiation (Preface and articles 1 and 121 - 124).

As to marine pollution prevention and response in particular, this third initiative shows that the only alternative to knowledge-implementation is to calm belief-driven administrative panic with the prospect of compensation for every belief-driven response action and every belief-driven prohibition whether or not reality-refuted; and to excuse claims retrospectively judged pointless and excessive by reference to this belief-driven panic. In contrast, this third initiative recognises that knowledge is the only antidote to panic; that the costs of belief-driven actions and costs arising from belief-driven prohibitions ought not to be compensated; but that costs of all knowledge-accepting actions which give rise to quantifiable benefits ought to be compensated within Fund limits. As to objections to retrospective assessment of claims, this third initiative recognises that assessments of the success or non-success of prior actions/ inactions are definitively retrospective, even when they are knowledge-only prioritisations.

As to assessment of commercial loss, this third initiative takes such claims to be a straight-forward matter of retrospective comparison of documented pre- and post-incident seasonal profit levels according to pre-set guidelines, these losses having arisen through no fault of the claimant. As to claims made by member States for costs incurred in their responses, this initiative takes admissible costs to be those incurred in respect of the new knowledge-only approach as implemented incident-specifically and as reported in submission of the claim which itself arises from no fault of the claimant; but it also takes costs incurred by the claimant's acceptance of beliefs counter to knowledge to be self-inflicted, and as such to be ineligible for compensation, such claims having arisen from belief-driven prohibitions of safe-haven cargo/bunker transfer, of dispersant-use, of *in situ* decanting of free and demulsified water, and from insistence on all such processing being at approved sites.

Thus, acceptance of this third initiative avoids belief-only panic by acceptance of the new knowledge-only approach which limits the release of oils/HNS to sea and shore by cargo/bunker transfer; which predicts incident-specific fates and effects of releases and the outcomes of responses thereto; which facilitates the reporting of results and the submission of claims for their cost-compensation; and which thus conserves the compensation Funds. This initiative also encourages acquisition of further knowledge from response to successive incidents, thus enhancing the existing knowledge repository, and perpetuating its updated use despite staff-change frequency and incident infrequency. In addition, it commends itself directly to response contractors in their cost-effective interaction with State customers, to State customers through the IMO secretariat, and to the IOPCF and IGP&I secretariats in their direct interaction with State customers.

Article 150

Having brought my newly definitive knowledge-only approach to the attention of IMO at MEPC 59 (Preface: second stage of campaign), I was authorised to inform its OPRC-HNS Technical Group through ISCO as to my development of this approach, the basal knowledge having already been acquired *inter alia* by Warren Spring Laboratory (WSL) of the UK Department of Trade and Industry (DTI) and collated for easy access in my books of 1983 and 1999.

Accordingly, I began to submit articles to the Newsletter of the International Spill Control Organisation (ISCO) together with parallel documents through ISCO to MEPC Technical Group meetings 10 - 16 and subsequently to MEPC 67 and 68 and to IOPCF in 2014 and 2015 to show collectively that this knowledge had been acquired by laboratory, sea, and shore investigations of the physicochemical properties of oils/HNS which determine their slick thicknesses; their rates and extents of evaporation to the atmosphere and their rates of dispersion or solution in seawater as emulsified oil or non-emulsified HNS; their resulting concentrations in atmosphere and sea; the amenability of residual slicks to the viscosity-dependent embodiments of the various design principles for mechanical removal and the viscosity-dependence of their dispersion by kerosene- or water-carried dispersants, whether deployed onshore, from ships, inshore boats or aircraft; and the amenity of stranded slicks to mechanical removal and dispersant applications as functions of shoreline type.

These articles and documents recalled that WSL had extended its laboratory-investigations to the real world by discharging oils/HNS to the sea from its specifically converted and thus dedicated ship, *Seaspring*; that it had confirmed the natural fates and effects of such discharges in terms of their resulting atmospheric and seawater concentrations; that it had quantified the rates of natural dispersion; that it had evaluated the comparative effectiveness of the full range of commercially available mechanical removal options in terms of their design principles; that it had evaluated the comparative capacities of dispersant applications from ships and aircraft; and that it had compared the seawater concentrations arising from natural and dispersant-induced dispersion. Again, these documents recalled that WSL had designed its own viscosity-tolerant single-ship mechanical removal system; that it had optimised droplet size for dispersant delivery from aircraft by spraying-trials over airfields and confirmed spraying-effectiveness in sea trials with oil; that it had related airborne remote-sensing imagery to directly measured slick thicknesses and ultimate sheens at sea. Yet again, these documents recalled that WSL had also discharged oil to UK shoreline types to optimise the effectiveness of its own approaches to shoreline mechanical removal and dispersant treatment and had optimised the latter by direct and modified use of commercial equipment intended for these and/or related purposes.

Again, these articles and documents recalled that WSL had contributed to the means of compliance with IMO regulation of operational oil discharges from ships by providing knowledge of the oil concentrations in bilge and fuel tank ballast water discharges by measurements during normal operations; that it had measured the efficiency of gravitational oil-water separators, coalescers and filters by having built to the IMO test specification a circulatory evaluation system capable of operating at flow-rates up to 100 m^3h^{-1}; that it had quantified the post-discharge cargo residues onboard ocean-going and coastal HNS tankers and their subsequent wash-water concentrations; and that it had modified wash/discharge procedures, thus enabling IMO to finalise its oil/HNS discharge regulations on knowledge of means rather than on belief as to means, though the regulations themselves continued to be belief-only instead of knowledge-only.

As to the relationship between concentration and toxicity, these articles and documents recalled that the concentrations of oil and dispersants needed to kill 50% of test organisms (the LC_{50} values) in the approvals tests of the UK Ministry of Agriculture, Fisheries and Food were 2 - 3 orders of magnitude greater than those arising at sea from the layer thickness of naturally dispersing slicks or at the moderately increased rates induced by kerosene based dispersant-use; that the concentrations of concentrate dispersants as operationally applied were another order of magnitude lower (diluted 10:1); and that their toxicities were so low as to provide LC_{50} values only when mixed with the test oil *i*.e. so low as to provide an LC_{50} value for the test oil only; that neither the oils nor the dispersants were thus toxic at the concentrations arising in the marine environment; and that LC_{50} values thus overstate these concentrations by some three orders of magnitude for oil and up to two more for dispersants.

Thus, these articles and documents recalled that with surface-proximate concentrations being initially too low to be toxic, their subsequent dilutions in the water column as a whole cannot be toxic; that their subsequent biodegradation is thus uninterrupted by toxicity; that inorganic compounds diluted and neutralised by the buffered pH system which is seawater are similarly incapable of producing species-extinction/ecological-disaster; and that with the release of entire cargoes being incapable of such extinction/disaster, the current regulation limits for operational discharges of oil/HNS might already be considered a good deal more than adequate.

Article 151

With articles 148 -150 having shown how the documents submitted to OPRC-HNS Technical Group meetings 10 - 16 progressively increased its awareness of my new knowledge-only approach to marine casualty response, this article now shows how the TG was also made aware of the extent to which counter-belief prevents realisation of the benefits of this new approach.

Thus, the documents of this second initiative made the Technical Group aware that despite these benefits having been available from WSL reports from the mid-1970s onwards and from the books of 1983 and 1999 which were repositories of this knowledge, environmentalist NGOs have continued to suppress/thwart/ignore all of it in propagating their belief in species/extinction/ecological-disaster arising from the water column concentrations of released or discharged oil/HNS, despite such releases being merely the physical cause of short-term commercial losses for which compensation is available, and despite operational discharges having even less effect. Again, these documents recalled that these NGOs believe the physical coating of organisms to be yet another cause of such extinction/disaster, despite none of them ever having measured these concentrations nor compared the numbers killed by coating with the annual deaths and births of species populations, and despite no such species-extinction/ecological-disaster ever having arisen from ship release or oil well blow-out, however large or prolonged. In addition, these documents referred to my newly definitive knowledge/belief differentiation which makes rhetorical conflation/elision of belief with knowledge impossible for the first time ever.

Thus the documents of this second initiative made the Technical Group aware that environmentalist NGOs cannot continue to present belief as though it were knowledge, and that this impossibility extends beyond the belief in extinction/disaster to the belief in carbon dioxide emissions from ‘fossil’ fuels being the cause of anthropogenic global warming. Thus, the TG has been made aware that all organic releases are either biodegraded *in situ* or combusted on removal to carbon dioxide and water; that the entire biomass of land and sea is being continuously recycled from and to the atmosphere as carbon dioxide and water by photosynthesis and biodegradation; that carbonate rock is being continuously recycled tectonically from and to the atmosphere as carbon dioxide and water by the Urey synthesis and its volcanic decomposition; that the Urey synthesis would terminate all life by sequestering all carbon dioxide as carbonate rock were volcanism to cease; and that ‘fossil’ fuels are formed from intermediate biodegradation products only when oxygen depletion causes their biodegradation to cease until re-exposure to aerobic conditions or until deliberate combustion (Preface and articles 116 - 129).

Thus, the documents of this second initiative have made the Technical Group aware that despite reality-refutation of the belief in a toxic permanence of non-biodegraded concentrations of oils/HNS being the cause of species-extinction/ecological-disaster, this belief is cited to refuse entry of impact-damaged ships to safe havens for the cargo/bunker transfer which would avoid further weather-related release;. to limit dispersant-use to arbitrary water depth or distance from shore, despite dispersants putting no more of the release into the sea than would have gone in had the release been far enough from shore for all of it to have dispersed naturally before any of it could strand; to prohibit the *in situ* decanting of co-collected and demulsified water which would conserve storage and transport capacity for oil removed from sea and shore; and to require all such processing to be undertaken at approved locations such as oil refineries, despite the additional costs of transport and storage, and despite the overall restoration rate being thus limited by refinery processing capacities scaled to internal requirements only.

As to the stage now reached in this second initiative, the Technical Group was made aware that belief-promulgating NGOs were invited by ISCO on 15 November 2012 to answer the following questions. Why should we believe in species-extinction/ecological-disaster when we know that the exposure concentrations are low enough to account for their absence thus far, and that no believer has yet reality-validated any such hypothesis by comparing incident deaths with the annual births and deaths in species populations? Again, why should we believe in anthropogenic global warming when we know that we combust only part of a ‘fossilisation’ but for which all of its carbon dioxide equivalent would already be recycling through the atmosphere and biomass just as initially photosynthesised and now ‘fossilised’ oils and their organic HNS derivatives biodegrade and recycle after release? Yet again, why should we believe in combustive global warming when no believer has yet reality-evaluated any hypothesis as to the rate at which increased release of carbon dioxide in one of the above cycles would cause increased abstraction in the other or both, and when investigation of vegetative-mass variation with carbon dioxide concentrations in controlled atmospheres would be an obvious place to start the reality-evaluation of such hypotheses?

Article 152

With environmentalist NGOs having been invited on 15 November 2012 to answer the questions cited in article 151, and having as yet received no acknowledgement, this second initiative may conclude as expected, that believers prefer not to have their beliefs so openly exposed to knowledge or so openly exposed to the likelihood of their reality-refutation as specific hypotheses; that, as ought to be clear by now, they hope their belief-only assertion of any particular need will quickly lead to a displacement debate as to the means of its satisfaction and thence to a further displacement debate as to the visual impact/non-impact of such belief-only means as the construction of wind farms, tidal barrages, or whatever. Thus, while the hypothesis that wind farms produce electricity without wind can easily be reality-refuted thus obviating all debate as to their offering an on-demand supply, a debate as to their visual impact/non-impact may be winnable in around 50% of proposed locations, this being the coin-toss ratio. However, prior to my first, let alone my second initiative on spill-response and operational discharge/emission control, I had already reality-refuted the belief in species-extinction/ecological-disaster and I have since shown that belief in anthropogenic global warming ought to be suspended until hypotheses derived from it are either reality-validated or reality-refuted. Either way, the Technical Group was made aware (through its meetings 10 - 16) of the ubiquitous need for knowledge-only policy (Preface and articles 116 -129).

With the above Technical Group documents having been presented in two summary documents to meetings 67 and 68 of the Marine Environment Protection Committee (MEPC),the IMO member States are themselves now aware that my knowledge-only approach to marine incident response comprises a referential knowledge repository, a contingency plan which relates the relevant physicochemical parameters of released substances to their fates and effects and to the range of possible responses, and which is made incident-specific by the values of these physicochemical parameters which are relevant to specific incidents; that with seawater concentrations of releases/discharges being non-toxic for all such values and being biodegraded to carbon dioxide and water as is the entire biomass of land and sea, belief in species-extinction/ecological-disaster is thus reality-refuted; and that with the biomass being cyclically replaced by photosynthesis from carbon dioxide and with ‘fossil’ fuels arising only when its cyclic biodegradation is interrupted, the belief/disbelief in its combustive resumption being the cause of global warming is only resolvable by reality-evaluation of specific hypotheses to positive/negative knowledge and is un-resolvable to knowledge by merely debating partially selected facts/counter-facts.

Within this second initiative, the weekly articles of Cormack’s Column were intended to test readership reaction to their review of knowledge and its counter-beliefs; to their intention to culminate in a knowledge-only contingency plan from which all future knowledge-only incident-specific plans could be derived for all aspects of oils/HNS response onboard casualties, at sea and onshore. Again, the documents presented to Technical Group meetings 10 - 16 and to the MEPC 67 - 68 were intended to test delegate reaction and to assess the extent to which Member States would retain their preference for belief over knowledge now that knowledge had been definitively differentiated from belief.

Thus, with the invitation to environmentalist NGOs remaining open, the documents presented to TG meetings 10 - 16 and to MEPC 67 and 68 invited individual member States to accept the advantages of my knowledge-only approach to casualty-response planning and to operational discharge and emission regulation and to reject/suspend their corresponding counter-beliefs; to accept the non-existence of species-extinction/ecological-disaster (article 150); to review their discharge/emission regulations; and to suspend their belief in anthropogenic global warming until it is reality-validated to positive knowledge or reality-refuted to negative knowledge (articles 145 and 151). As to the ultimate success of this second stage of my initiative, this third stage website reports a complete absence of overt dissent from any TG or MEPC delegation (Preface).

Knowledge-Only Response Training for Contractors and Customers

Article 153

In the expectation of achieving overt and ubiquitous knowledge-acceptance/belief rejection by means of this third stage website, I am now considering how best to train and accredit response contractors as to their competence to execute my new knowledge-only contingency and incident-specific plans in association with similarly competent coastal States; how best to use each and every successive incident-specific plan as the framework for reporting assessments made, actions taken, results achieved and costs incurred for preparation of their incident-specific compensation claims in a format uniformly assessable by IOPCF and P&I Club secretariats. Only by such means will each and every marine incident cease to be treated as the first one ever, despite the first one having been nearly fifty years ago.

The knowledge previously suppressed/thwarted/ignored by counter-beliefs or lost by staff-change frequency and incident infrequency, must be retrieved, as in this website, before it can be used for knowledge-only training. The training courses run at home and abroad by the WSL marine pollution division from 1975 progressively explained the fate and effects of releases and discharges of oil/HNS in terms of volatility and viscosity, and identified the means by which polluted localities could be restored to their pre-release conditions as quickly and cost-effectively as possible for resumption of the commercial activities interrupted by such releases, while those who believed *a priori* in species-extinction/ecological-disaster did nothing to restore polluted localities to their pre-incident conditions or to avoid or limit the extinction/disaster in which they continue to believe. In contrast to these believers, the division's training courses explained how the natural rates of slick dispersion, dilution and biodegradation were enhanced by dispersant-use prior to and after arrival onshore; how pollutants were removed by mechanical means from the sea-surface and shorelines when and where natural or induced dispersion was reduced for pollutants of higher viscosity; and how the effectiveness of mechanical means depended on the design-principles of differing equipment. Again, in contrast to these believers, the training courses explained how the slick thickness of 0.1mm which ensures the non-toxicity of dispersed oil at seawater concentrations, also limits response-unit encounter-rates to $0.18m^3h^{-1}$ per metre swath width, per knot of advance.

Thus, the training courses recognised that while the belief in species-extinction/ecological-disaster limited/prohibited dispersant use in many countries, all beliefs in the toxicity of oils/HNS and of dispersants at their seawater concentrations were refuted by the absence of such extinction/disaster at all incidents thus far and by the concentrations required for the 'toxicity-testing' of dispersants and oil. Accordingly, the WSL training courses from October 1974 to March 1979 were reflecting the knowledge acquired and the beliefs rejected to a sufficient extent to support a knowledge-only national contingency plan when DTI headquarters established its Marine Pollution Control Unit (MPCU) in March 1979 with this author as 'chief scientist'. However, by then, the politically correct belief in technology being disharmonious with the environment in contrast to articles 1-15, had already ensured that policy-makers would write the Unit's contingency plan as a call for so-called interested parties to debate belief/counter-belief as to what to do or not to do in response to every incident as it might arise. Accordingly, the MPCU contingency plan fell well short of the WSL intention to create the knowledge-only approach now advocated by this third stage website.

Thus, while the MPCU did establish stockpiles of incident response equipment based on the knowledge previously acquired by WSL and transmitted through its training courses, the use of this stockpiled equipment remained subject to politically correct beliefs/disbeliefs which could be debated to one or other belief-consensus on a more or less daily basis. Nonetheless, these knowledge-only stockpiles contained emergency cargo/bunker transfer equipment for oils/HNS; seagoing mechanical recovery equipment for use on *Seaspring* and coastal tankers of opportunity; one oil mop system for use on an offshore supply ship of opportunity; dispersants and spraying equipment for use from ships of opportunity and from contracted standby aircraft, two of which were equipped for remote-sensing; onshore equipment for dispersant and surface-film application; and onshore and inshore mechanical removal equipment and protective booms (articles 39 - 115).

However, knowledge-countering beliefs were meanwhile attempting to ensure that no other country would permit the discharge of oils/HNS for investigative purposes thus ensuring that no laboratory other than WSL would be in a position to challenge the politically-correct environmentalist belief-consensus while normal civil service staff-changes ensured the loss of any UK ability to challenge it by reference to previously acquired knowledge. Indeed, this internal loss was completed by the absence of significant incidents in UK waters from 1979 to 1996 and by the 1994 closure/merger of WSL with UKAEA, which coincided with its atmospheric monitoring and abatement being overtaken by UNCCC belief in anthropogenic global warming, and with its value-recycling and contaminated land remediation being lost in evermore belief-only regulations (Acknowledgements and articles 116 - 129).

Nonetheless, with the advent of definitive knowledge/belief differentiation, there is now no rational reason why knowledge-only incident-response training of customers and contractors cannot be based on the knowledge repository and knowledge-only contingency/incident-specific planning approach of this third stage website.

The Predictive and Quantitative Capacity of Knowledge

Article 154

Article 153 recalled, with respect to the foregoing articles, that knowledge-acceptance/belief-rejection is essential to progress in general. It cannot be over-emphasised, however, that knowledge has the capacity to predict outcomes in specific circumstances while belief has no such capacity. Thus, when the knowledge acquired by the WSL R&D programme was suppressed by political correctness and failed to be implemented in the UK national contingency plan for which it had been ostensibly acquired by government funding, its predictive capacity was also lost. Again, when the said political correctness prevented other countries from acquiring such knowledge for themselves, they never acquired the capacity to predict fates and effects of, and optimal responses to releases of oil/HNS.

However, this and subsequent articles show that this suppressed/lost/ignored knowledge together with its predictive capacity is retrieved by the new knowledge repository and knowledge-only contingency/ incident-specific planning approach of this website; that the deficiencies of all current contingency plans (articles 103-106) as exemplified by the response to the *Sea Empress Incident* (articles 107-115) are caused by knowledge-rejecting/belief-accepting regulations (articles 116-129); that these deficiencies can be corrected only by knowledge-accepting/belief-rejecting contingency and incident-specific planning (articles 130 - 142); that the benefits to be derived from such planning have never yet been fully recognised (articles 143- 147); and that a third initiative towards acceptance of knowledge-only environmental policy and its predictive capacity has already been taken (articles 148-152) which includes the provision of knowledge-only response training for contractors and customers (article 153).

However, while this retrieval of reality-validated knowledge and rejection of reality-refuted beliefs permitted the creation of the new knowledge-only contingency plan, and while this plan in turn permits the creation of knowledge-only incident-specific response plans, no operational improvements will be realised without their acceptance by coastal States. Thus, at this point, it is necessary to emphasise that this general-contingency/incident-specific planning will quantitatively predict the fate and effects of any release and the comparative usefulness of response options thereto; and thus enable quantified results to be reported in the preparation of compensation claims readily assessable by the IOPCF and P&I secretariats; and that it will continually enhance the knowledge repository and the planning itself with knowledge acquired at individual incidents by direct reality-evaluation of predictions against outcomes and that these incident-specific quantitative knowledge-refinements can be shared through the auspices of IMO, and thus be secured against staff-changes in the IMO member States and in the secretariats of the IMO, the IOPCF and the P&I Clubs.

Further to the benefits derivable from the new knowledge-only contingency plan, it is necessary to emphasise to all parties that its purpose is to return localities to their pre-incident conditions as quickly and cost-effectively as possible by preventing or removing the physical coating which negatively affects commercial activities; that prevention of or removal from shorelines, man-made structures and sedentary shellfish is best achieved by assisting natural dispersion, dilution and biodegradation of floating slicks by dispersant-use and by mechanical removal from sea and inshore waters when viscosity precludes dispersant-use; and that removal from differing shoreline types is best achieved by suitable combinations of these viscosity-dependent means. Again, it is necessary to emphasise that dispersant-use at sea, inshore, and onshore, disperses no more oil into seawater than would have dispersed had the release been far enough from shore for natural dispersion to have prevented any of it stranding; and that despite the ineffectiveness of all previous belief-only responses no species-extinction/ecological-disaster has arisen however large or prolonged the release (articles 31 - 33 and 39 - 42).

Thus, the retrieved knowledge (articles 1 - 115) which underpins the new contingency plan, emphasises that the only significant effect of oil releases is their physical coating of commercialised resources; that the belief in species-extinction/ecological-disaster can be rejected together with its prevention of access to safe havens for cargo/bunker transfer; its prevention of dispersant-use onshore and within arbitrary distances/water-depths from shore; and its prevention of *in situ* decanting of co-collected and demulsified water in the downstream processing of removed emulsions; and its insistence on all such processing being conducted at approved sites such as oil refineries, none of which have capacities beyond their own internal requirements. Again, having rejected the needless costs arising from these needless preventions and insistences, we know that the new knowledge-only contingency plan would never have caused the *Sea Empress* to release 67,000-69,000 tonnes of oil beyond the 5000 or 3000 tonnes of initial impact by failing to discharge it as the remaining 58,000 tonnes were later discharged (articles 107-115); and that the negotiation of compensation for response costs might well have opened with an offer of 3/69^{ths} and closed at 5/67^{ths} of the actual claim.

Article 155

As to prediction of the fates and effects of released oils/HNS in general, the new knowledge-only contingency plan relies on articles 22 - 25, 31 - 33 and 39 - 42, in identifying the physicochemical properties of oils/HNS which predict whether they float, sink, evaporate, dissolve or disperse as immiscible droplets; whether they emulsify or not; their half-life dispersion rates from their non-emulsified viscosities; their viscosity-dependent amenity to dispersants and mechanical removal, and their two-phase break-down by heat or demulsifying agents as indicated in articles 56 - 59, 86 - 89 and 92 - 102.

Thus, the new contingency plan records for general reference that whether a substance floats or sinks is predictable from its density with respect to that of local seawater; that its evaporation is predictable from the individual distillation profiles of specific oils or from the boiling point of individual HNS; that specific values are readily available; that all oil components and individual HNS with boiling points < 250°C are predicted to evaporate totally to the atmosphere in < 5 hours unless in confined-spaces such as onboard ship where evaporation is predicted to cease on attainment of the saturated vapour pressure of oil components or individual HNS; that solution is predictable from individual solubility; that dispersion is predictable from viscosity; that specific values are readily available or measurable for emulsions; that the overall rate of solution or of dispersion is predictable from the ratio of interface area to layer thickness, sunken layers restrained by hollows of the seabed being thicker than floating layers; that the half-life for floating-layer dispersion is predictable from viscosity; that HNS do not emulsify, their solution rates from floating layers being predictably comparable to dispersion from floating oil layers with viscosities < 5cSt, this range accounting for almost all floating HNS; that dispersion half-lives are predictable from interpolation within four tabulated viscosity bands for product and crude oils together with their densities, distillation profiles and whether solid or liquid at ambient temperatures, and within three viscosity bands for heavy fuel oils; and that the half-life for viscosities < 5cSt is four hours or less, while almost all other HNS evaporate with only a very few being readily identifiable as solid at ambient temperatures (articles 31-33).

Further to this general prediction of the fates and effects of releases of oils/HNS as determined by their physicochemical properties, the new contingency plan records for general reference that the thickness of spreading layers is determined by gravity constrained by viscosity and subsequently by surface tension as expressed in the Fay equation; that Phase I gravity spreading is over in minutes, while the predominant Phase II ensures a layer thickness of only about 0.1mm which corresponds to a coverage of 100 m^3 per km^2, beyond which the periphery spreads in Phase III through the micron range to zero; that Phases II and III form water-in-oil emulsions of up to 80% water-content before thinning to zero by natural half-life dispersion to diluting and biodegrading droplets within the entire water column (articles 31 - 33 and 39 - 42).

Again, given this fate and effect predictability from the physicochemical properties of released oils/ HNS, the new knowledge-only contingency plan records for general reference that response-unit encounter-rate for a 1m swath-width travelling at 1 knot in 0.1mm layer thicknesses is only 0.18 m^3h^{-1}; that while this quantity increases by a up to a factor of four by formation of emulsions of up to 80% water-content, the quantity of oil removed or actively dispersed per hour remains unchanged; that while encounter rate can be increased by towing booms at 1 knot, the encounter rate for oil with a 15m boom mouth is only $3m^3h^{-1}$, while for an 80% emulsion it would be $12m^3h^{-1}$ of which $9m^3$ would be emulsified water to which must be added the unavoidable co-collected free water; that dispersant application from a ship at 5-10 knots and effective swath width of 15m would treat $15\text{-}30m^3h^{-1}$ of oil or $60\text{-}120m^3h^{-1}$ of emulsion while an aircraft at 100 knots with the same swath width can treat $1200m^3$ of emulsion per operational hour, subject to reloading transit-times (articles 47-61 and 70-91), while layer thickness and potential encounter rates are higher for shorelines (articles 92 - 98).

Thus, the new knowledge-only contingency plan recognises that the provision of equipment for dispersant spraying and mechanical removal should be scaled to the 3,000-5,000 m^3 (tonnes) expected from damage to a single cargo tank; that the greater the release the lower the percentage dispersible or removable; that to avoid greater releases from subsequent weather damage in exposed locations cargo/ bunker transfer in safe havens is unavoidably required; that seawater concentrations arising from natural or dispersant-induced dispersion are too low to be toxic; that the entire slick produces these non-toxic concentrations and that those produced by localised dispersant-spraying or terminated by localised mechanical removal are increasingly insignificant the greater the release, its natural half-life dispersion applying to all of it; and that the latter will prevent any of it stranding if the release is far enough from shore in the first place (articles 103 -106, 107 - 115 and 130 - 137).

NEW KNOWLEDGE-ONLY APPROACH TO INCIDENT RESPONSE PLANNING

Knowledge-Only Contingency and Incident-Specific Plans

Article 156

This section may be read without prior reference to the knowledge preserved for its support in articles 1- 115; without reference to the need for knowledge to dispel belief as set out in articles 116 - 129; to the benefits of implementing knowledge as set out in articles 130 - 147, to the initiatives already taken towards this implementation as set out in articles 148-152; or to knowledge-only training and predictive capacity of knowledge as set out in articles 153 - 155. However, with articles 153-155 constituting a comprehensive victory for knowledge over belief, articles 156 - 162 may now be read as a summary of the new knowledge-only contingency/incident-specific plans and of the conversion of the former to the latter for response to each and every incident. However, on the basis of the foregoing articles, I recognise that coastal States will now be able to create their own plans which may vary in respect of their shoreline types and their temperate/tropical natures whether tidal or non-tidal; that some may nonetheless seek contractual assistance; but that in every case knowledge-only plans will need to comply with articles 1 - 162 and with any further knowledge acquired through reality-validating observations arising from implementation of incident-specific plans as indicated in articles 156 - 162.

Thus, as to release-prevention, any knowledge-only contingency plan must accept that normal practice is for the ship's crew to conduct a damage survey and to undertake damage-limitation action to the best of its ability after grounding or collision; that beyond this stage, the public interest is best served when the marine survey service of the coastal State collects as much knowledge as possible as to the condition of the casualty before salvors arrive on-scene; and that such knowledge together with that later acquired by salvors is the only means of enabling States to assume joint ownership/endorsement of all elements of any ensuing incident-specific salvage plan (articles 161 - 162); and thus to invoke the Powers of Intervention to overcome any belief-only objections to any element thereof. Thus, such contingency plans will acknowledge that whether the incident-specific plan derived from it, is for *in situ* ship-to-ship transfer of cargo/bunkers and wreck removal; for movement to a safe haven for such transfer; or for movement to an oil port for discharge to shore, the above collaborative knowledge-acquisition is the only means of avoiding the uncertain outcome of the belief/counter-belief debates of the adversarial legal processes which discourage the use of Intervention Powers in the first place.

Again, such contingency plans must acknowledge that such collaboration of the salvor in possession with the marine survey service of the coastal State, is best able to secure the good offices of the International Salvage Union (ISU) or the American Salvage Association (ASA); that such overall collaboration is best able to reach a knowledge-only assessment of damage and of the means of release-limitation prior to and during re-flotation by pressurisation of tank water-bottoms; that such preparation facilitates safe-haven entry for ship-to-ship transfer of cargo/bunkers by onboard or emergency pumping, or port entry for ship-to-shore discharge by either means. Yet again, such contingency plans must accept that intervention-induced releases are insignificant in comparison with total loss of cargo/ bunkers which may arise were the casualty to remain at the weather-exposed location of its initial impact-damage; that the cost of responding to the former is insignificant compared to the cost of responding to total release or to anything approaching it; that intervention-releases are preferable to damage-releases; and that with shipping casualty-response, blow-out prevention and oil-well capping being technological, they have not benefited from the panic induced by the reality-refuted belief in species-extinction/ecological-disaster.

Again, such contingency plans will overcome the reluctance of coastal States to use their Powers of Intervention, and enable them to see that this reluctance was born of the belief-driven fear of liability-transfer from owners to themselves; that this fear has been decidedly unhelpful thus far; that they now have no alternative but to accept the lead-role supported by providers of professionally relevant knowledge; that despite the calamitous response to *Sea Empress Incident* of 1996, the usual dilemma of belief/counter-belief made the Donaldson Enquiry reluctant to recommend safe-haven use despite the Enquiry having been referred to my knowledge-only advocacy for it, as presented in my book of 1983 and as further supported by my knowledge-only assessment of the incident in the format I had previously developed for salvage-claim arbitrations (articles 107 - 120).

As to activities onboard casualties, such contingency plans must accept the physicochemical properties of oils/HNS which determine saturated vapour pressures in confined spaces and the atmospheric concentrations attainable in open spaces adjacent to them, and the flammability/non-flammability and human toxicity/non-toxicity associated with them, all of which are readily identifiable for evaluation. Thus, while atmospheric analysis, breathing apparatus and protective clothing are recommended onboard, the new contingency plans must accept that, for example, the single compound, nonane, evaporates entirely from a 0.1 mm layer in 3 minutes and from a 1.0mm layer in 30 minutes; that while slicks burn in the open air when vapours are ignited, explosions are possible only in confined spaces where layer thicknesses may be sufficient to create saturated vapour pressures and dilutions to within specific explosive envelops; that casualties may be approached through floating slicks without any such explosive risk; that reliance on the toxicity and explosion icons of guidebooks which ignore known concentration-toxicity and concentration-explosion relationships are no substitute for measurement and constant availability of safety equipment for all such onboard activities (articles 105 - 106).

Article 157

As to potential response to releases at sea, the new contingency plans must accept that the volatile components of oils and volatile HNS simply evaporate to the atmosphere from insoluble surface slicks thus eliminating any need to disperse them or any possibility of collecting them; that the concentrations are initially no more than a few ppm in the bottom metre of the atmosphere; that they dilute in the upper reaches and degrade by aerial photolysis or biodegrade after rainout to sea or land; that gaseous HNS are emitted from pressurised tanks as jets which dilute with entrained air to plumes of increasing vertical and horizontal cross-sections with distance from source; that they cannot be collected; that gases transported in pressurised bottles/cylinders are of localised effect if released; that natural gas is transported in specialised-ships' tanks, none of which are likely to be damaged; that flammable gases may be flared at source under knowledge-only professional direction; that plume dilution to safe concentrations could be modelled for the new plans and confirmed by direct measurement at subsequent incidents; and that while downwind evacuations may be necessary, plume dilution may make window-closure adequate (articles 31 - 46).

Further to releases of non-volatile-insoluble liquid oils/HNS, the new contingency plans must accept that HNS disperse naturally at rates comparable to the lightest product oils such as gasoline and diesel, in having viscosities ≤5cSt at 15°C; that in not forming emulsions with water, they disperse at greater rates than crude oils of viscosities ≥5cSt at 15°C which form emulsions of yet higher viscosities; that while the former group (of HNS) disperses rapidly without dispersant treatment, the resulting concentrations are too low to be toxic and thus do not need removal even if it were possible; that the latter group (of oils) are amenable to dispersants below temperature-dependent viscosity limits (articles 47 - 61); that above these limits mechanical removal from water surfaces becomes similarly limited and is ultimately limited to scraping from shorelines; that some removal-equipment designs have been identified as successful only at viscosities amenable to dispersants; and that at viscosity ranges common to both, there is no need to remove that which could be dispersed or would disperse naturally at rates and distances from shore which would avoid stranding (articles 47 - 61 and 70 - 91).

Further to releases of soluble HNS, the new contingency plans must accept that these dissolve at rates determined by solubility and mass transfer coefficient; that dissolving continues to completion, the lower surface of the layer tending to produce its saturated solution concentration in a very thin surface-proximate layer of seawater while diffusion dilutes it by progressive transport to greater depths; that as with dispersion of insoluble droplets, the concentration of dissolved molecules in the top metre of the water column cannot be > 100ppm even if solution/dispersion were instantaneous; that they must be less in reality, given the competing rates of solution/dispersion and of dilution/biodegradation to greater depths if organic and of dilution/neutralisation if inorganic; that the layer thickness of sunken oils/HNS may depend on seabed configuration, with the surface : volume ratio in a hollow being less than for a floating slick; that seawater concentrations are the same whether arising from the upper surface of a sunken pool or from the lower surface of a floating slick; that the time taken for such a pool to dissolve/ disperse totally would be greater than for a surface slick, the source-area being smaller; and that the pumped recovery rate from a point of maximum pool thickness would be higher than from a slick, were either necessary in reality with respect to quantity/location.

Further to the possible requirement to respond to non-volatile/insoluble surface slicks of oils/HNS at sea, the new contingency plans must accept that their natural dispersion rates can be expressed as half-life values and value-ranges of 4, 12, 24 - 48 and > 48 hours by reference to Groups I - IV of their relevant physicochemical property values; that those of heavy fuel oils are grouped in three viscosity ranges of 2-4, 4-6 and 6-8 days; that these half-lives indicate the increasing likelihood of requiring response at sea to prevent arrival on shore; and that equipment encounter-rates with the inverse thinness and areas of slicks, make cargo/bunker transfer the more imperative the more resistant the cargo and bunkers are to natural dispersion; that HNS packages are smaller than HNS cargo tanks which are smaller than oil cargo tanks, that only about 3000-5000 tonnes of oil can be released from one damaged oil tank; and that the half-lives of non-volatile/soluble surface slicks of HNS are likely to be less than the 4 hours of the fastest naturally dispersing insoluble oils (articles 31 - 42, 47 - 61 and 70 - 91).

Article 158

As to potential response to releases onshore, the new contingency plans must accept that any response is determined by the shoreline type and its interaction with the viscosity of the stranded substance; that equipment and techniques have been designed or modified to cope with this variety of response tasks; and that the former should be paired with the latter for all usage (articles 92 - 102).

As to onshore arrivals, the new contingency plans must accept that these are only the floating residues of incomplete evaporation, solution or dispersion; that none would have arrived had these processes been completed between release and potential arrival; and that consequently the options on arrival are to permit or assist completion of these non-toxic/anti-coating processes or to remove arrivals for which these processes, whether assisted or not, are ineffective for timely cleaning of the shorelines thus affected; that while dispersants are unnecessary for natural evaporators and dissolvers, they increase the natural dispersion rate of immiscible substances without putting more of them into the sea than would have gone in naturally had more time been available prior to stranding; and that with non-dispersible removals requiring downstream processing, it is preferable to avoid such processing whenever and wherever dispersants are effective (articles 31 - 33, 39 - 42, 47 - 61 and 92 - 95).

As to monitoring slick movement between source and shore to estimate the geographical extent of their likely stranding, and to direct response units to areas of maximum slick-thickness and hence encounter- rate, the new contingency plans must accept that slicks must be differentiated from all natural phenomena; that the slicks themselves must be differentiated as to windrows and phase II and III layers *i.e.* as to layer thicknesses ~ 1.0mm (windrows), 0.1mm (slicks), 0.4mm (emulsified slicks) and microns (sheens); and that IR/UV line-scanning combined with side-looking airborne radar (SLAR) meets this need when the instrumentation has been calibrated against measured thicknesses (articles 62 - 69).

However, the new contingency plans must also accept that layer thicknesses at sea and hence equipment encounter-rates, can increase by a factor of 10 or more when these are pressed against shorelines by onshore winds while stranding on the ebb-tide; that consequently the shore is more effective than any deployable boom or adsorbent; that emulsion layers of up to say 5mm thickness can thus be collected from wet (poorly drained) sand beaches by water flushing into contour-trenches dug for removal by viscosity-tolerant pumps; that stranded emulsion is otherwise difficult to separate from underlying beach materials without co-collection and subsequent separation by equipment designed for this purpose; that heavy rubber strips attached to the edge of mechanised scraper-blades can be effective even on well-drained sand in pushing the emulsion layer into contour-trenches where water intended for flushing would simply drain into the beach; that non-separated mixtures of emulsion and sand have been stabilised by addition of lime to form concrete when suitable building projects are concurrent; that pollutant/particulate mixtures can be separated by modified mineral-processing equipment; and that otherwise the options are *in situ* bioremediation or land-farming at oil refineries, where earlier acceptance of landfill is now prohibited by belief (articles 96 - 98 and 100 - 102).

Again, the new contingency plans must accept that emulsions removed from water-surfaces at sea, inshore or from beaches, must be separated from co-collected free-water or from co-collected beach materials and the oil subsequently separated from de-emulsified water, if the oil is to be used as fuel by those who will accept it as such (article 102); that the value of such oil is far below the cost of its collection and processing; that these costs are further increased by the reality-refuted belief which currently prohibits *in situ* decanting of all such processed water; that such 'recycling' does not justify its costs; but that where viscosity/solidification necessitates physical removal, and where bioremediation by land-farming would be overwhelmed, 'recycling' as fuel could be acceptable were its net costs per tonne to be less than landfill costs per tonne (articles 116 -129 and 145), though these latter costs have been increased by belief-only regulation to make 'recycling' costs look more attractive in general.

Again, the new contingency plans must accept that gel-formation causes dispersants to cling to and act on emulsions coating sloping and vertical surfaces prior to water-jet washing; that while surface film chemicals were developed to thicken small areas of floating oil, their application onshore prior to stranding avoids adhesion and thus facilitates removal by water washing on ebb tide and offshore wind, thus preventing the admixture of pollutants with particulate beach materials and avoiding any need for their subsequent separation (articles 92 - 102).

Thus, the new contingency plans must accept that inshore waters and shorelines are the ultimate arena of response to release residues which arrive there as physical coatings; that natural processes which may reduce these residues to zero do so without toxic-cessation of their biodegradation; that the optimal response is thus to disperse stranded residues to resume this biodegradation and to remove only that which is resistant to dispersants; and that this non-toxicity permits *in situ* decanting of the water arising from downstream processing thus making the process itself quicker and more cost-effective.

Article 159

Articles 153-158 summarise my new knowledge-accepting/belief-rejecting approach to contingency planning, the knowledge thus accepted having been reviewed in articles 1-147 and the beliefs thus rejected having been reviewed in articles 116-129. Accordingly, this article now shows how incident-specific values of the physicochemical parameters identified in the new contingency plan can determine whether or not incident-specific releases of oils/HNS will float, sink, evaporate, dissolve or disperse, and the responses/non-responses appropriate thereto at sea, in inshore waters (articles 50 - 91) and on the shoreline types with which they may potentially interact (articles 92-102).

Thus, when a liquid or solidifying release arises from an impact-damaged casualty, the new incident-specific plan must accept that the first step is to avoid subsequent weather-damaged releases by cargo/bunker transfer; that the second is to ascertain the values of the physicochemical parameters identified by the contingency plan and the specific incident as being relevant to its cargo and bunkers; that the third is to note the fates and effects of any releases in terms of floating or sinking, fractional or total evaporation, total solution, or progressive dispersion according to the half-life/viscosity relationship previously tabulated for crude oils and bunkers (articles 31-33 and 39 - 42); that the fourth is to calculate the fractional evaporative loss from any incident-specific crude oil cargo from its fractional distillation profile as co-tabulated, this being usually 25-30% in < 5 hours or 100% for volatile HNS in < 5 hours; that the fifth is to calculate the time for non-volatiles to reach shore from the vector sum of 100% of the tidal vector and 3% of wind vector and to apply the respective dispersion half-lives of the non-volatile fractions of cargo/bunker oils and of non-volatile insoluble HNS to the quantified releases and to the predicted time to reach shore, in order to predict the quantities likely to arrive onshore and to identify the shoreline types at this location; and that the sixth is to consider, on the basis of known viscosities and half-life dispersion rates, whether dispersants or removal, both or neither, should be applied at sea, there being no need to enhance or prevent dispersion which of itself will prevent stranding (articles 31-33, 39 - 42 and 130 - 147).

Again, when a soluble HNS is released from an impact-damaged casualty, the new contingency plans must accept that this will dilute and biodegrade or neutralise and dilute; that the viscosity of insoluble liquid HNS will be < 5cSt with very few readily identifiable exceptions; that dispersion half-life will thus be < 4 hours; that there is no need to enhance these natural rates; that there is no possibility of collection; but that with respect to known toxicity-concentration relationships their decreasing concentrations in seawater may be monitored by progressive measurement down-tide of the source; and that avoidance warnings as appropriate should constitute the sole incident-specific response in such cases. Yet again, when a gas is released from an impact-damaged casualty, the new contingency plans must accept that it will naturally disperse and dilute downwind of the source in an expanding diluting plume; that there is no need for assisted dispersion; and that there is no possibility of collection, but that with respect to its known toxicity-concentration relationship its decreasing atmospheric concentrations may be monitored by progressive measurement downwind of the source; and that avoidance guidance as appropriate may be issued to downwind populations.

As to the banning of net- and line-fishing, the new contingency plans must accept that fish never contact floating slicks unless they break the surface; that the water column in which they swim never contains dispersed oil droplets equivalent to molecular concentrations > 10-20ppm in the top metre; that these decrease rapidly with depth throughout the life of the slick; that these concentrations are consistent with the absence of taint reported by taste panels served with fish caught for this purpose at the Ekofisk blow-out for example; and that in respect of releases of dispersing or soluble oils/HNS such measurements of concentration, with or without panel-tasting, ought to decide the need for and duration of fishing bans. As to banning the sale of shellfish, the new contingency plans must accept that oil-coated shellfish on shores and on tidal cultivation stakes are as un-sellable as would be fish drawn in nets through floating slicks; but that these must be differentiated from depurated shellfish previously in contact with oil at concentrations in the ppm-ppb ranges, as many are even in the absence of an incident (articles 1-15); and that such differentiation would reduce compensation claims which arise more from bans *per se* than from actual contamination.

Article 160

As to onshore response the new contingency plans must accept that stranding is reduced by the cargo/ bunker transfer which limits releases from casualties to those of initial tank damage at most; by subsequent natural evaporation, dispersion or solution of such releases of oils/HNS as occur prior to stranding; by the residues having been reduced by dispersant application and/or mechanical removal prior to stranding; and by these residual quantities having been further reduced by natural post-stranding dispersion; and by all HNS having been reduced to zero by 100% evaporation, solution or dispersion, pre- or post-stranding, except for the readily identifiable few which solidify at ambient seawater temperatures.

Thus, with respect to onshore arrivals, the new contingency plans must accept that the first step is to identify the shoreline types likely to be impacted and the lengths and widths of such impaction from the predicted/monitored movement of slicks at sea and their time-dependent quantities and surface coverage (article 159); that the second step is to identify the techniques and equipment applicable to each shoreline type and to its contiguous inshore waters, all such equipment being stocked-piled either nationally or locally (articles 92-102); that the third is to activate transportation of the associated equipment in quantity and sequence appropriate to predicted need; that the fourth is to identify and alert those who might wish to receive emulsions processed towards heat-generating combustion or reluctantly to accept emulsions for biodegradation by land-farming or for ultimate disposal to landfill, all such potential recipients having already been identified in the national or regional/local contingency plans at appropriate levels of detail (articles 96 - 102).

However, oils/HNS off-loaded from casualties by cargo/bunker transfer will also arrive onshore. Thus the new contingency plans must accept that crude oils must eventually go to refineries and bunkers to bunkering stations; and that HNS from parcel tankers, specialised containment, or individual packages within standard containers must go to their intended or alternate customers; and that while released oils recovered from water surfaces or from shorelines may be processed for heat-generating combustion in a variety of industrial processes, HNS arriving onshore as release-residues or in leaking packages must be treated, collected, over-contained, 'recycled' or disposed of as in industrial waste-chemical practice.

Thus, with these new contingency plans having been implemented and their procedures followed to create incident-specific plans as need arises (articles 161 -162), the recording of assessments made, actions taken, results obtained and costs incurred according to the format of the latter would facilitate the preparation of admissible compensation claims and their assessment by the IOPC Funds and P&I Club secretariats. Again, this recording would enhance the knowledge repository and the contingency plan with any new knowledge acquired at any incident and thus facilitate its dissemination through IMO for enhancement of the knowledge repository. Yet again it is the intention of the International Spill-Response Accreditation Association (ISAA) to accredit spill response contractors as to their familiarity with this new contingency/incident-specific planning approach while recognising contractor-obligation to comply with any un-rejected belief-only regulations as may perversely remain (article 153). It is also the author's intention to make the administrations of coastal States and the secretariats of the IOPCF and the P&I Clubs aware of progress towards acceptance of these initiatives by member States collectively and/or individually through Next Steps at Annex III of this website.

However, while this new contingency/incident-specific planning approach is ubiquitously applicable to cargo/bunker transfer and to dispersant-treatment/mechanical-removal of releases at sea and on inshore waters, its onshore aspects may be made location-specific with respect to geographical variation in shoreline type and tidal range. Thus, while UK shoreline type includes mudflat, salt-marsh, poorly and well-drained sand, shingle, pebble/cobble, rock and cliff, together with manmade coastal structures, all of which are exposed to substantial tidal ranges, shorelines elsewhere may be predominantly sand, mangrove or coral and may be non-tidal or of low tidal-range. Thus, for example, Mediterranean, Baltic, and Black Sea shorelines, whatever their type, cannot have the widths of shoreline-coating experienced elsewhere. Accordingly, non-tidal low tidal-range countries have little call for the full range of shoreline response equipment identified and evaluated in articles 92 - 102, and little or no tidal-dependence on the use of whatever dispersant or mechanical removal equipment may best facilitate natural re-colonisation and/or re-growth as identified and evaluated in articles 92 - 99. Again, floating and land-fast ice may present few if any response needs or options.

Thus, while stockpiles of equipment for dispersant-spraying and mechanical-removal at sea, are intended to prevent stranding, the new contingency plans for non-tidal countries must recognise a reduced need for shoreline cleaning-equipment while accepting the usual need for at-sea and inshore equipment. Again, for countries with limited ranges of shoreline type, the new contingency plans must recognise a need to stockpile only a correspondingly limited range of equipment types. Yet again, with seawater concentrations being non-toxic whether natural or dispersant-induced, and with the physical coating of organisms being likewise incapable of producing species-extinction/ecological disaster, the new contingency plans must accept that the only choice with respect to dispersant-use and mechanical-removal is for the most viscosity-tolerant options to be available, this being even more so, the lower the ambient temperature and thus the higher the pollutant viscosity.

Knowledge-Only Incident-Specific Planning and Implementation

Article 161

Having summarised the content of the new knowledge-only contingency/incident-specific response plans in articles 156 - 160, articles 161 - 162 now exemplify their implementation by consideration of the following scenarios. Thus, were a casualty to release 5000 tonnes of crude oil from initial damage to a single tank or *pro rata*, the first step would be to identify the physicochemical properties of the named oil as from Groups I - IV of articles 31- 42 and thus to note whether it is solid or liquid at the sea temperature of the incident, the weight percentage of evaporative loss to be expected from its distillation profile, and its emulsion dispersion half-life as 4 or 12 hours or as interpolated within the ranges 24 - 48 or > 48 hours.

The second step is to calculate the evaporative loss which at 25% in our example would leave 3,750 tonnes, which at a layer thickness of 0.1mm would cover 37.5km^2. The third step is to tabulate the quantities remaining after successive half-lives by halving the previous amount. Thus, for a half-life of 12 hours for example, the successive amounts remaining in tonnes at 12 hour intervals are 1,875, 938, 469, 235, 117, 59, 30. . . After 7 half-lives the residue is always < 1% of the original. Again, for any 5000 tonne release with a 25% evaporative loss, the above quantity sequence would result at intervals of the appropriate half-life. Similarly, for bunker releases, the first step is to use the incident-specific viscosity to interpolate the half-life from the ranges of 2-4, 4-6 and 6-8 days, while the second is to tabulate the residual quantities after sequential lapses of the appropriate half-life. Thus for a 50 tonne fuel oil release with no evaporative loss, the residue sequence for any half-life interval is 25, 12, 6 . . . tonnes as in articles 107 - 120.

However, in order to know the actual pollutant tonnage after any number of half-lives, the fourth step is to include the emulsified water which at 80% would increase the above half-life tonnages by up to a factor of four for crude oils and by two for heavy fuel oils, in the absence of analytically determined *pro rata* water-contents. Again, to emphasise the need for cargo/bunker transfer, we know that the sequence in tonnes of crude oil residuals from a total loss of 100,000 tonnes less 25% evaporative loss, are 75,000, 37,500, 18,750, 9,875 4,987, 2,495, 1247, 628 . . . , while the sequence for release of 500 tonnes of heavy fuel oil is 250, 125. . . tonnes, before multiplying by up to four or by two respectively for their emulsion quantities. This comparison between release from single damaged-tank and greater releases from further damage reinforces the need for cargo/bunker transfer to be an integral part of all contingency/ incident-specific planning.

As to predicting the quantities likely to reach shore, the fifth step is to use the local tidal stream atlas and actual wind direction and speed towards shore as locally measured to calculate the time interval from release to onshore arrival, while the sixth is to compare this time interval with those of the half-life/residual-quantity tabulation specific to the incident, which by direct or interpolated read-off, gives the residual quantity which will reach shore unless the wind changes. Clearly, it is necessary to monitor wind direction and speed, and accordingly to update the vector sum of 100% of the tide vector and 3% of the wind vector until the slick strands. Meanwhile, the seventh step is to decide on the basis of pollutant viscosity whether the response is to be dispersant-treatment, mechanical-removal, or both. These steps are summarised and extended to twelve in article 162, to cover the overall mass-balancing of quantities evaporated, dispersed/removed at sea, and stranded as residuals.

Again, the new contingency/incident-specific plans must accept that the encounter-rate for both dispersant use and mechanical removal is 0.18 tonnes per hour per metre swath per knot of advance at the layer thickness of 0.1mm which corresponds to a surface coverage of 100 tonnes per km^2; that it is thus realistic to scale seagoing response capacity to about 3,750 tonnes per day *i.e.* to a treatment area of 37.5 km^2; that it is thus best to treat the edge of the slick closest to shore in successive paths, to treat it other than locally being impossible in any case; and that treatment should not start or should cease when natural half-life dispersion is seen to be sufficient to prevent residual stranding. Again, the plans must accept the futility of equipment-provision to deal with a total cargo release, spraying- or removal-units being limited to operational speeds and swath widths completely out of scale with surface areas of 1000km^2 per 100,000 tonnes of oil, and must thus accept the imperative need for cargo/bunker transfer.

Further to treating the edge of the slick closest to shore, the new plans must accept that to treat it anywhere else is to permit the untreated slick already closer to shore to strand untreated if it fails to disperse naturally; that treatment of the shore-proximate edge, as the slick moves ever closer to shore, can *mutatis mutandis* be continued onshore when natural dispersion coupled with dispersant treatment and mechanical removal has failed to prevent stranding. As to the quantity stranded, the plans must recognise that this can be estimated from the length, width and thickness of shoreline coverage and from the quantities removed or dispersed from the shores; and that the quantity stranded equates to the quantity released less the sum of the quantities evaporated, dispersed naturally, actively dispersed (estimated from the dispersant used) and removed prior to stranding. Again, adopters of this new planning approach can make more precise the quantitative relationships of viscosity to half-life, to dispersant-effectiveness and to removal-effectiveness by such mass balancing as exemplified by articles 107 - 120 and as will become routine when applied as in article 162.

In adjudication of salvage claims arising under Lloyds Chapter XIV for the *Aegean Sea*, *Carina*, *Nikitas Roussos*, *Patraikos II and Sea Empress* incidents, I implemented my above mass balancing procedure to compare the quantity actually stranded from initial damage-release with that which would have stranded had the salvor not removed the remaining cargo and bunkers. Indeed, for the *Sea Empress*, I compared the quantity which would have stranded from the initial release of 3000-5000 tonnes with that of the actual release of 72,000 tonnes and with that which would have stranded from the total release of 130,000 tonnes had 58,000 tonnes not been removed by belated decision to allow salvors to move the casualty to its discharge berth (articles 107-120). Again, I brought this mass-balance analysis together with the relevant chapters of my 1983 book to the attention of the Donaldson Enquiry in presenting my general case for cargo/bunker transfer in safe havens before a post was created and filled by an individual uniquely designated as responsible for all safe haven use. Nonetheless, this designation left room for doubt as to whether such use would be definitely permitted or left to the judgement of the first and any subsequent post-holders (article 120).

Article 162

In addition to release-response, the knowledge-only contingency/incident-specific plans must accept the primacy of release-prevention. Thus, full implementation of this approach as outlined in articles 156 - 161 would require coastal States to accept that while the Powers of Intervention were intended to prevent release, this is actually increased by their use to prevent safe haven access for cargo/bunker transfer; that collaboration of marine-survey staff with the salvor in possession best acquires the incident-specific knowledge needed for casualty-stabilisation and cargo/bunker transfer whether at sea or in a safe haven; that with respect to the latter, such a jointly owned knowledge-only plan best avoids the uncertainties of the belief/counter-belief debates of the adversarial legal processes which currently discourage applications for access; that oil-well blow-outs also need such collaborations of administrations and contractors; and that such knowledge-only collaboration would eliminate politics and convert administrations from self-styled victims of others' mistakes, to the protectors of the public interest they are intended and expected to be.

Thus, with acceptance of the this new knowledge-approach, global society will see that its maritime administrations are collaborating with professional prevention/response contractors to execute an incident-specific plan derived from their knowledge-only coastal-specific contingency plan which is derived from a universally accepted knowledge-repository; that releases in excess of initial damage are being prevented; that sea-going, inshore and onshore response to residual releases are in hand; that these are supported by natural evaporation, dispersion and biodegradation; that predictions made, decisions taken, accredited contractors employed, results obtained, and costs incurred will be routinely reported to the IOPC Fund and P&I Club secretariats in fully documented form, and to the IMO secretariat for enhancement of the thus UN shared repository of knowledge to the benefit of all future incident responses.

Thus, when a non-solidifying release arises from an impact-damaged casualty, the format of the incident -specific plan must accept that the first step is to avoid subsequent weather-damage releases by cargo/bunker transfer; that the second is to ascertain the values of the physicochemical parameters relevant to its cargo and bunkers; that the third is to note the fates and effects of any releases in terms of floating or sinking, of fractional or total evaporation, total solution, or progressive dispersion according to the half-life/viscosity relationships previously tabulated for crude oils and bunkers; that the fourth is to calculate the fractional evaporative loss from any crude oil cargo from its fractional distillation profile as co-tabulated, this being usually 25 - 30% for oils or 100% for volatile HNS in < 5 hours; that the fifth is to calculate the time for the non-volatile oil components to reach shore from the vector sum of 100% of the tidal vector and 3% of the wind vector, that the sixth is to apply the respective viscosity-dependent dispersion half-lives of the non-volatile fractions of the cargo/bunker oils and of the non-volatile insoluble HNS to the quantified releases and to the time to reach shore, in order to estimate the quantities likely to arrive on the shoreline types identified at these locations; that the seventh is to consider, on the bases of known viscosities and half-life dispersion rates, whether dispersant or removal techniques, both or neither, should be applied at sea, there being no need to enhance or prevent natural dispersion which of itself would prevent any onshore arrival. Thus, we know that were this sequence to be followed, it would not only give structure to the response, it would also provide a format for claim submission and settlement.

Again, when a solidifying release arises, the format of the incident-specific plan must accept that all such oils/HNS have been identified; that with removal being the only option, it will best be achieved onshore; that when a soluble HNS is released, it will dilute and biodegrade or dilute and neutralise; that the half-lives of floating soluble HNS will be shorter or comparable with the half-lives of floating insoluble oils of viscosity < 5cSt at 15°C, as most HNS are; that there is no need to enhance these natural rates, no possibility of recovering evaporators, dispersers or dissolvers, and no need to remove rapid dispersers; but that known toxicity-concentration relationships may require down-tide HNS dilution to be monitored by sample analysis with respect to commercial fishing.

In continuance of the above step-sequence, the incident-specific plan must accept that the eighth step is to repeat the sixth to estimate the quantity likely to strand just prior to its arrival, having further reduced it by the quantities already removed, and/or dispersed at sea by the quantity of dispersant applied to it; that the ninth is to revise the identification of the shoreline types to be impacted and the lengths, widths and thicknesses of these impactions; that the tenth is to identify the techniques applicable to each shoreline type and to its contiguous inshore waters; that the eleventh is to activate transportation of the associated equipment in quantity and sequence appropriate to these various locations; and that the twelfth is to identify and alert all who might receive oils for heat-generating combustion ‘land-farming’ or landfill. Again, we know that this sequence would not only give structure to the response, it would also provide a format for claim submission and settlement; and that it would enable more precise knowledge to be acquired from successive incidents as to the relationship of viscosity values to half-lives, to dispersant effectiveness, and to the effectiveness of differing mechanical design-principles .

WIDER BENEFITS OF KNOWLEDGE/BELIEF DIFFERENTIATION

Benefits for Incident-Response in General

Article 163

The reluctance to discard belief-consensual policy has long prevented realisation of the benefits of knowledge-only policy in all fields of belief/counter-belief. Thus, before extending my newly definitive knowledge/belief differentiation to the regulation of operational discharges and emissions from ships, policy-makers ought to be aware of the extent to which knowledge was previously suppressed by belief in marine casualty-response. Thus, while I took Elsevier’s invitation to write my first book as an opportunity to make the knowledge acquired by WSL more widely available, and while I took Kluwer’s invitation to write my second book as an opportunity to record the failure of the MPCU contingency plan to retain this knowledge, I subsequently had to admit that neither book had achieved any impact on belief-only regulation of shipping nor on the cost-ineffectiveness of casualty-response as confirmed by the *Sea Empress* incident of 1996 and all incidents before and since.

Again, while the Donaldson Enquiry had subsequently taken some note of my first book’s case for cargo/bunker transfer in safe havens, it did nothing to dispel the beliefs which thwarted the application of all other aspects of WSL-acquired knowledge. Yet again, there was no governmental encouragement when I as Chairman of the British Oil Spill Control Association (BOSCA) and John Dawes as a member, introduced a scheme for accrediting inland response contractors as to their familiarity with WSL-acquired knowledge of inshore and shoreline response, and when we subsequently morphed into the International Spill Accreditation Association (ISAA) we found that the continuing supremacy of belief-driven policy deprived government of all enthusiasm for knowledge-only casualty-response.

Thus, having made the mistake of assuming that my first two books on knowledge-acquisition would of themselves dispel all counter-belief, I had to admit that counter-belief would suppress all knowledge as long as its believers were numerous enough and/or influential enough; and that this would continue as long as knowledge remained undifferentiated from belief in everyday speech. Thus, having been made an Honorary Fellow of ISCO, invited to be a member of the ISCO delegation to IMO, and to write Cormack’s Column in the ISCO Newsletter by David Usher, President of ISCO, I decided to apply my third book’s definitive differentiation of the knowledge/belief dichotomy to the task of definitively differentiating knowledge for acceptance and belief for rejection in respect of all aspects of marine casualty response (Foreword, Preface and articles 1 - 129).

Again, by reference to this differentiation, I ensured that my contemporaneous documents for the OPRC-HNS Technical Group of the IMO Marine Environment Protection Committee (MEPC) retrospectively differentiated the knowledge presented in my first two books from the beliefs which had been suppressing it. Later, I summarised these documents for the MEPC in respect of casualty response and discharge/emission regulation and for the International Oil Pollution Compensation Fund (IOPCF) in respect of claim submission and settlement. The documents for MEPC also differentiated knowledge from the knowledge-suppressing beliefs which have long been reality-refuted, and from those which have yet to be reality-validated or reality refuted, these being respectively the belief in species-extinction/ecological-disaster and the belief in anthropogenic global warming, while those for IOPCF were restricted to avoidance of the consequences of the former belief. Thus, these documents were intended to show that while knowledge has been suppressed/thwarted/ignored by counter-belief promulgation, my newly definitive knowledge/belief differentiation would enable knowledge to suppress its counter-beliefs, and while the suppression was not immediately reversed, none of these documents provoked even the mildest overt dissent. Indeed, it is this absence of overt dissent which now permits me to conclude that knowledge will ultimately and universally dispel belied in casualty-response (articles 130 - 147); that this will be extended to discharge and emission regulation either in the short or the longer term; and that ultimately it will be extended to all fields of policy-making.

As of now, this website offers my re-presented Newsletter articles on casualty-response to IMO member States as a repository of the knowledge to be universally accepted as security against staff-change frequency and incident infrequency (articles 1 - 115); as a repository of the beliefs to be universally rejected as security against their resurrection by fresh staff (articles 116 - 129); and as the knowledge to be accepted and the beliefs to be rejected in creating the first-ever knowledge-only contingency plans from which even fresh staff can construct incident-specific plans for any and every future incident and from which they will be able to report assessments made, actions taken, accredited contractors used, results obtained and costs incurred to the IOPC Funds and P&I Club secretariats for expeditious settlement of claims and to IMO for continual enhancement of the thus collective knowledge repository. As to hints of early progress, I have been gratified to note (article 177) that an IMO Correspondence Group on Guidance for Dispersant Use has recently reported what looks like a movement towards knowledge-acceptance/belief-rejection when articles 14 -15 and 47 - 49 are compared with articles 50 - 61).

Benefits for Operational Discharge and Emission Regulation

Article 164

Further to article 163, my newly definitive knowledge/belief differentiation in documents MEPC 67 and 68 (Annex I) were intended to dispel the growing dissention of the developing world from the so-called developed world's belief-consensus on anthropogenic global warming, and to dispel the growing dissention of industrial NGOs from actual and potential regulation on ballast water management and on exhaust gas emissions in general. These inter-delegate dissentions arise from the perception that actual and potential regulation may be beyond known need and/or beyond known means of compliance. Of course, this is not the first time IMO regulation has been in this situation. Thus, my submitted documents had recalled that the limit of 100ppm of oil in water discharges was beyond the known performance of onboard gravity-separation as was shown by WSL in the 1960s; and that it was the demonstration of downstream coalesce/filtration efficiency by WSL in the 1970s which saved this regulation and enabled it to be tightened beyond known need to 15ppm, to 5ppm, and to zero in so-called Special Areas, without raising any dissent from Member States or industrial NGOs sufficient to disturb the prevailing though reality-refuted belief-consensus in species-extinction/ecological-disaster (articles 16 - 21).

Again, these submitted documents recalled that the regulated limits for the discharge of tank washings from HNS parcel tankers were beyond known achievement until the 1970s when WSL demonstrated the means by which tank residues could be reduced to less than the regulated 1 tonne per tank, and the means by which the regulated concentrations in wash-water discharge could be met, thus once more saving belief-only regulation from embarrassment by reality. Yet again, whether or not regulation is beyond known need, no dissent arose sufficient to disturb the belief-consensus (articles 116 - 129), presumably because compliance costs for oil/HNS are not considered unacceptable by those thus regulated.

In contrast, however, the cost of compliance with the regulations in respect of ballast water management will be high, thus explaining current reluctance to ratify the Convention while industry reports that three of the ballast water systems approved by the self-styled group of experts on the scientific aspects of marine pollution (GESAMP) and installed by some ship owners in advance of enforcement, have been found non-compliant under operating conditions. Thus, in contrast to the aforementioned oil/HNS discharges, the prospect of high initial expenditure is now coupled with the additional costs of replacement when the regulations are in force, and with the problem of deciding which if any of the other 39 systems approved by GESAMP will be in compliance if installed initially or as replacements.

Again, in addition to growing levels of dissent among IMO member States over the belief-consensus on anthropogenic global warming (AGW), industry representatives are also showing increasing levels of dissent over the means of compliance with proposed regulations on sulphur dioxide and nitrogen oxide emissions, the concentrations of which have not been reality-evaluated as to their actual effects. As to carbon dioxide, we know that anthropogenic global warming is merely a belief-consensus as confirmed by its believers denoting dissenters as non-believers, this being the language of belief/counter-belief: not of knowledge let alone scientific knowledge (articles 121 - 127). In contrast to this on-going belief/counter-belief debate, it is now known that the parallel debate respecting species-extinction/ ecological-disaster was resolved by WSL in the 1970s by reality-refuting this belief as specific hypotheses by releasing oil to the sea, by measuring its resulting concentrations, and by confirming them at the scale of the Ekofisk blow-out as being three orders of magnitude less in the top metre of the water column than were needed in test-tank measurement of oil LC_{50} values; that these concentrations were reduced effectively to zero by dilution with increasing water-column depth and by biodegradation; and that these concentrations were very significantly localised for operational-discharges in contrast to the slick areas arising from casualty-releases: while, again in contrast, no-one has as yet reality-validated the belief in AGW nor the belief in oil-coating being the cause of species-extinction/ ecological-disaster. Thus, we must conclude that the belief/counter-belief debate respecting AGW and sulphur and nitrogen oxides will only be resolved when these beliefs are reality-evaluated as hypotheses (Preface and articles 14 -.15 and 116 - 129).

Accordingly, my documents presented through ISCO to MEPC meetings 67 and 68 (Annex I) invited member States to accept my knowledge-only approach to casualty-response in principle, to reject reality-refuted counter-beliefs, to suspend beliefs not yet reality-evaluated, and thus to remove all needless inter-delegate dissention, these documents recognising that belief/counter-belief dissention is resolvable only by knowledge-acquisition whether positive or negative. Thus, while my first objective is to realise the benefits of accepting my knowledge-only approach to casualty-response, my second is to realise the benefits of its acceptance in operational discharge/emission regulation.

Article 165

Further to articles 163 and 164, my documents for MEPC meetings 67 and 68 were/are intended to initiate knowledge-acceptance/belief-rejection in general, by showing that knowledge works in reality while belief/counter-belief is debated to one or other belief-consensus without regard to reality; that belief-consensus never dispels covert nor overt minority-dissention, this being resolvable only by reality-evaluation of the belief-consensus to positive or negative knowledge; but that knowledge and even recognition of its absence have been suppressed by majority-belief since time immemorial, except in knowledge-only craftsmanship, science and technology all of which work in reality. Thus, having definitively differentiated the knowledge/belief dichotomy and having thus differentiated the knowledge-only approach to release-response which would cost-effectively work in reality, from the belief-only approach which does not, these MEPC 67 - 68 documents also apply this knowledge/belief differentiation to current regulation respecting operational oil/HNS discharges, ballast water management and emission control to differentiate need from non-need and success from failure in order to harmonise technology with currently suppressed environmental knowledge (articles 1-15).

As to further promotion of this initiative, these documents not only represent the general social interest, but also the specific interests of member States, shippers, manufacturers and customers; that this mutuality of interest requires harmonious progress within the MEPC; that this mutuality requires the continuity and commonality of knowledge without which we have actual or potential inter-delegate belief/counter-belief dissention; and that debate itself indicates the absence of the knowledge which would terminate it. As to differentiating knowledge from beliefs for their respective acceptance and rejection, these documents recall that this is the simple matter of recognising the respective presence or absence of prior reality-evaluation; and that beliefs which cannot or have not been thus reality-evaluated remain beliefs which can only be accepted, rejected or suspended as matters of personal choice, but which cannot be accepted as the knowledge without which there is no rational basis for action.

Thus, the documents for MEPC 67 and 68 were intended to initiate recognition that debate of opinion/ counter-opinion is debate of belief-counter-belief supported by partially selected facts/counter-facts, neither set of which is debate-terminating knowledge, facts per se, having no causal relationship to the cited effects; that the outcome is merely a transient belief-consensus which can vary from debate to debate and even flip to the counter belief-consensus, and as such is no basis for progress in reality; and that the very existence of debate shows the absence of the knowledge which would terminate it. Thus, these documents recall that while the reality-evaluation of belief as specific hypothesis has harmoniously produced the entire body of knowledge which is craftsmanship, science and technology, political belief-consensus has been harmonious only until open dissent has become disharmony, violence, revolution or war; that dissention can be dispelled peaceably only by knowledge acquisition and acceptance; that dissention is now overt in respect of the belief-contents of MEPC regulations for ballast water discharge and exhaust-gas emissions; and that the benefits of dissent-resolution are deliverable only by my newly definitive knowledge/belief differentiation and by its co-definitive reality-evaluation of belief to positive or negative knowledge.

Further to dispel dissent with already available knowledge, MEPC 67/19/INF.13 recalls in particular that the consensus of belief in oil/HNS discharges and releases being the cause of species-extinction/ ecological-disaster was reality-refuted in the mid 1970s by knowledge of their water column concentrations being at least three orders of magnitude less than those of their LC_{50} values, and by the repeated absence of such extinction/disaster at all previous or subsequent incidents; but that this reality-refuted belief-consensus nonetheless continues to oppose emergency use of safe havens for cargo/bunker transfer despite its avoidance of the weather-damage which increases the third-party commercial losses which are the only significant consequences of such incidents; that it continues to prohibit dispersant-use in inshore waters and on shorelines despite the dispersed droplets being biodegradable and thus non-toxic, and despite individual deaths by oil-coating being replaced by natural regeneration rates; and that it continues to prohibit the *in situ* decanting of process water in mechanical removal operations, despite its acceptance of removal and its rejection of dispersants.

Thus, by identifying the reality-refuted belief which has suppressed knowledge of release response, document MEPC 67/19/INF.13 was intended to show that this same reality-refuted belief in extinction/ disaster is the continuous driver of all regulation respecting oil/HNS discharges and emission control; and that the only means of dispelling all related MEPC delegate-dissention is for member States to accept that this belief was reality-refuted in the mid 1970s; that in any case no species-extinction/ ecological-disaster has arisen from any incident thus far however large or prolonged; and that current dissention over ballast water management arises from belief/counter-belief as to whether or not the approved systems work in reality.

Further to dispelling dissent, document MEPC 67/19/INF.13 recalls that on 15 November 2012, environmentalist

NGOs were invited to reality-evaluate for themselves their beliefs in species-extinction/ecological-disaster and in anthropogenic global warming as specific hypotheses; and that as yet there has been no reply. Thus, while inviting member States to accept in principle, the new knowledge-accepting/belief-rejecting approach to contingency and incident-specific response planning, this INF.13 document also invited them to consider interim arrangements for ballast water management and exhaust gas emission control while awaiting the acquisition of definitive knowledge; and to give the UNCCC the opportunity, thus far ignored by environmentalist NGOs, to reality-evaluate their belief in anthropogenic global warming as hypotheses respecting the natural recycling of carbon and other life-essential elements which this belief continues to ignore (Preface and articles 43 - 46 and 116 - 129).

Article 166

Again to dispel inter-delegate dissent, document MEPC 68/20/INF.6 reinforced the document MEPC 67/19/INF.13 respecting marine casualty response in particular, by reviewing the benefits of replacing belief with knowledge, and the extent to which belief has nonetheless suppressed knowledge despite its acquisition by the dedicated R&D programme of WSL, by expressing the expectation that my newly definitive knowledge/belief differentiation would at last result in knowledge-acceptance/belief-rejection, and by describing the progress already made towards my then proposed knowledge repository and my then proposed knowledge-only approach to contingency and incident-specific planning. As to the differentiation itself, there has been a total absence of delegate dissent whether in the Technical Group, the MEPC or the IOPCF while the first report of the Correspondence Group on Guidance for Dispersant Use shows part-acceptance of the consequences of this absence of dissent (article 177). Again, by describing the new step-wise approach to incident-specific planning (articles 130 - 147 and 156 - 162) document 68/20/INF.6 showed how the new approach would facilitate assessment of claims by the secretariats of the IOPCF and of the Protection and Indemnity (P&I) Clubs were it to be adopted, and how reportage of further knowledge-acquisition to the IMO secretariat would thus continually enhance the new knowledge repository. In addition, document MEPC 68/20/INF.13 reinforces MEPC 67/19/INF.13 by re-emphasising the need to liberate knowledge from belief in the regulatory field.

Both of these documents recall that knowledge is suppressed by belief only when it is undifferentiated from belief and is thus mistaken for counter-belief. Nonetheless, document MEPC 68/20/INF.6 notes that belief in species-extinction/ecological-disaster probably did more to establish the MEPC than did knowledge of third-party commercial losses; and that without this belief, no government would have funded the work by which WSL acquired the knowledge collated in the repository which is this website. On the other hand, the absence of this belief would have prevented the MEPC member States from going beyond known need as far as they have in regulating operational discharges from ships, which even close to shore cause insignificant third party commercial losses in comparison with total casualty- releases; and that this over-regulation imposes needless costs on ship-owners and society in general; but that with these costs not being unacceptable and in any case passed to customers, these belief-consensual regulations have remained unchallenged despite extinction/disaster never having arisen even from total casualty-releases.

Again, both of these documents recognise that MEPC member States have devoted less attention to their own responses to casualty releases than to their regulation of the operational discharges of others, despite being the designated agents for all aspects of release-response as recognised by the Powers of Intervention conferred upon them by the Convention as *quid pro quo* for the associated costs and third-party compensations being borne by the releaser; that while the belief in species-extinction/ecological-disaster is the stated motivation of release-response, no member State has yet conducted a response capable of preventing such extinction/disaster had it been other than mere belief; and that this belief itself opposes all of the known elements of response despite its being long since reality-refuted. Thus, both of these documents have made MEPC Member States aware that this reality-refuted belief opposes dispersant-use; that despite its support for removal, it prevents the decanting of co-collected and demulsified water; that despite the viscosity and encounter-rate limitations of dispersants and mechanical removal, it prevents the movement of casualties to safe havens for the cargo/bunker transfer which is the only means of limiting the releases which increase third-party commercial losses and which would cause the species-extinction/ecological-disaster which such believers are ostensibly seeking to prevent, despite its absence. With such a train of internalised inconsistencies arising from knowledge suppression by belief, incident-response cannot be expected to be other than incomprehensibly inept to the general public.

However, this belief-driven ineptitude, as exhibited by all incident responses to date, does collectively confirm the absence of species-extinction/ecological-disaster, however large or prolonged such releases have been. Thus, both of these documents have directed Member States to the commercial losses which can be limited only by the knowledge which limits releases and responds to them when they occur by the knowledge-only response planning advocated by this website, this being the only means of returning localities to their pre-incident conditions quickly and cost-effectively, thus minimising third-party commercial losses, these being the only significant consequences of incident-release, as explained in the parallel documents presented to the IOPCF meetings of October 2014 and April 2015.

As to the knowledge required to tackle the real problems posed by real casualty releases, these documents made the MEPC and IOPCF Assembly aware that my new knowledge-only approach to casualty response planning comprises a knowledge repository and a knowledge-only contingency plan secure against staff changes in member States; that the latter is based on the physicochemical parameters of oils/HNS which control fates, effects and response; that insertion of incident-specific values for the relevant incident-specific parameters would enable even fresh staff to create and execute cost-effective incident-specific plans which would enable predictions made, decisions taken, accredited contractors used, results obtained, and costs incurred to be reported to the IOPCF and P&I Club secretariats for expeditious settlement of claims and to the IMO secretariat for enhancement of the shared knowledge repository, were Member States to accept this knowledge-only approach.

As to control of discharges and emissions, the documents for MEPC and IOPC respectively invite member States to recognise that all regulations and casualty response plans ought to express knowledge instead of belief; that regulations ought not to be pushed beyond known need and capability; that all of the chemical elements essential to life, recycle through the biomass, atmosphere, soil and water in their various molecular arrangements and non-toxic concentrations; and that believers in AGW and in species-extinction/ecological-disaster denote non-believers as sceptics in the language of belief/counter-belief dissention: not of science, but of pseudoscience.

Thus, it is now plain for all to see, that the wider benefits of knowledge/belief differentiation can only be realised by actively using this differentiation to achieve knowledge-acceptance/belief-rejection whenever and wherever the current practice is belief-acceptance/knowledge-rejection.

Benefits from Differentiating Science from Pseudoscience

Article 167

Further to the differentiation of science from pseudoscience (article 166), this article records that the MEPC and IOPCF documents of Annex I, respectively note that science is reality-evaluation of belief to positive or negative knowledge by the observation which describes and classifies, and by the experimentation which elucidates cause-effect relationships by the reality-evaluation of beliefs in the form of specific hypotheses; that science varies the cause and observes the variation of effect in isolation from all other causal-interference; that having thus established a quantified cause-effect relationship, science can predict quantified effects from quantified causes and *vice versa*; that its knowledge-acquisition is continual because each hypothesis (belief) for reality-evaluation has been derived from the knowledge acquired by reality-validation or reality-refutation of a previous hypothesis.

In contrast, these documents of Annex I, also note that pseudoscience is neither descriptive nor classifying, nor does it establish cause-effect relationships; that it arbitrarily selects one parameter as causing an effect on another and 'justifies' this arbitrary correlation by spurious statistical analysis or mathematical modelling; that in doing so it ignores all of the other parameters which could have had just such statistical/modelled correlation with either or both; and that the belief which chose the arbitrarily correlated pair remains belief no matter how valid the statistics or the modelling may have been *per se.* Indeed, statistics is incapable of deciding which is cause and which is effect, even when such a relationship has been fortuitously chosen at the outset (articles 43 - 46)..

Another way of differentiating science from pseudoscience is to recognise that the quantified cause-effect relationships of the former can be given mathematical expression in equations which enable predictions to be made which can be reality-validated by observation, while the latter is incapable of prediction because its correlated parameters are not cause and effect, having been arbitrarily correlated on the basis of arbitrary belief. Again, while the former creates internally consistent knowledge, the latter does not. Indeed, the latter does nothing other than announce the dire effects of its believed causes while collecting what it calls evidence supportive of its belief, while its disbelievers do nothing other than collect counter-evidence supportive of their disbelief. Thus, the documents for MEPC 67/68 note that pseudoscience is always engaged in debate of facts/counter-facts; that such can only be terminated by science (knowledge); and that pseudoscience is thus self-defined as belief-consensus.

As to the regulation of technology by the belief-consensus which is pseudoscience, the MEPC 67/68 documents of Annex I, recognise that belief in species-extinction/ecological-disaster has erroneously obstructed knowledge-only response to shipping casualties and oil-well blowouts; and that it has pushed regulation of operational oil/HNS discharges from ships beyond known need; but that, with respect to regulation, it has not raised any MEPC dissention from my knowledge/belief differentiation, while the belief-only regulation of ballast-water management and exhaust-gas emissions has provoked actual and potential inter-delegate dissention (article 164). Thus, with respect to ballast water management, the industry is exhibiting more concerted dissent than it did in respect of operational discharges of oil/HNS, while the industry and the developing Member States are dissenting from differing aspects of exhaust-gas emission regulations, in particular from the proposed sulphur-limits for heavy fuel oil and from the imposition of charges for emissions of carbon dioxide.

As to the current levels of inter-delegate dissent with respect to ballast water management, the documents for MEPC 67/68 note that while my knowledge-only approach to problem solving eschews opinion other than to identify it for replacement with knowledge, the industry has reported the known failure of three ballast water management systems despite their having been approved by MEPC on the advice (opinion) of GESAMP; and that the resulting uncertainty is delaying Convention ratification. Again, these MEPC 67/68 documents recall that the early failure to meet arbitrary limits for the oil/ HNS content of operational discharges from ships would have conflicted with MARPOL regulations had Warren Spring Laboratory not saved these regulations by showing how knowledge-only technology could meet them (Annex I); that this might yet be done for ballast water; but that this will again require knowledge-only improvements to existing management-systems, or even new systems.

As to inter-delegate dissent over exhaust-gas emissions, the documents for MEPC 67/68 recommend that regulation should not go beyond known need and capability as it initially did with operational oil/ HNS discharges from ships where arbitrary regulations were eventually met by technological solutions and where the costs were insufficient to re-open inter-delegate dissension. However, these documents also note that the regulation of exhaust-gas emission regulations is again going beyond known need and known capability; and is again involving costs for arbitrary reductions in the sulphur-content of fuel oils, arbitrary reductions in nitrogen oxide emissions, and arbitrary charges for emissions of carbon dioxide, while the low-sulphur fuel oils which would meet the latest sulphur dioxide emission limits, might not be available in sufficient quantity whatever the cost (article 170).

The Current Position Respecting the MEPC

Article 168

Previous articles relating to the documents for MEPC 67/68 (Annex I) have noted that the minority in any belief-consensus may be acquiescent and compliant or dissenting and non-compliant; and that when the regulating majority is not among those thus regulated, it may tend to absolutism. Thus, in respect of the current environmentalist belief-consensus, we know that member States do not regulate themselves as to common standards for casualty-response, while they regulate the shipping industry as to common standards for safety and operational discharge/emission avoidance; that their intention is absolute, though progressive to avoid open dissention to the maximum extent possible; but that while inter-delegate dissention has been covert thus far, in respect of operational-discharges of oil/HNS, it is now overt in respect of ballast water and emission regulation as expressed by all shipping NGOs and by a significant number of high population member States.

The cited MEPC 67/68 documents thus identify the source of this covert/overt dissention as the tendency of some member States to drive regulation of industry beyond known need and known capability merely on arbitrary belief. Thus, these documents identify knowledge as that which resolves all belief/counter-belief dissention, and as that which will resolve all inter-delegate belief/counter-belief dissention respecting casualty-release response when previously suppressed knowledge is activated. In support of this contention these documents recall that earlier belief-only regulation of operational oil/ HNS discharge was saved only by the knowledge acquired by WSL for compliance. Thus, these documents contend that current inter-delegate belief-only dissention over ballast-water and emission regulation will be resolved only through acquisition of the knowledge needed for compliance or the knowledge which refutes the need.

As to casualty-release, these documents for MEPC 67/68 were intended to summarise the content of this website of which articles 1 - 106 constitute the knowledge which will resolve all current dissent over contingency and incident-specific planning for casualty-response, while articles 107 -120 identify the need for acceptance of this knowledge as exemplified by the *Sea Empress* incident, while articles 116-129 review the counter-beliefs which need to be rejected by acceptance of this knowledge, and while the benefits derivable from this knowledge-acceptance/belief-rejection are reviewed in articles 130 - 162. Again, as to ballast water and emission regulation, these documents were intended to show that the knowledge-acceptance/belief-rejection which silenced overt dissent respecting casualty-response might be equally successful respecting dissent over ballast water and emission regulation; and that this success might be the first step to an overall preference for knowledge over belief in policy-making in general (articles 163 - 167).

Thus, to further encourage this outcome respecting casualty-response and operational discharge/ emission regulations, the documents presented to MEPC 67/68 recall the knowledge that seawater concentrations arising from natural and dispersant-induced dispersions of surface slicks are too low to be toxic to the micro-organisms which biodegrade them as they dilute; that this non-toxicity is revealed by the higher concentrations and longer exposure times needed to measure their LC_{50} values; that the continued measurement of such values maintains belief in the toxicity of such releases, despite the belief itself having been reality-refuted; that nonetheless, this belief continues to be cited for regulations which continue to be based on LC_{50} values for oil/HNS, despite non-toxic discharge concentrations being further diluted and indeed biodegraded in the receiving water column; and that the above reality-refutation of the belief in species-extinction/ecological-disaster is confirmed at all incidents thus far whether operational or accidental, despite its continuing absence at the latter, let alone the former (articles 14 - 15 and 128 - 129).

As to ballast water, these MEPC documents respond to the reported failure of already approved systems by noting that those who express opinions on toxicity (LC_{50} values) for regulatory purposes regardless of seawater exposure concentrations are now expressing opinions as to ballast-water management techniques, without having reality-evaluated the nature of the problem in relation to possible solutions; that WSL protected its HNS tank-washing samples from *in transit* biodegradation, by killing the causative organisms in these wash-water samples by addition of the biocide, hibitane just as oil samples for analysis are protected from biodegradation by acidification (article 69); that it is thus possible to kill ballast-water organisms, though apparently not at the HNS concentrations in cargo tanks of wash water or at oil concentrations discharged oil in analytical sample jars; and that the successful killing of organisms in ballast water is probably being prevented by belief in the treated ballast discharge being toxic to the marine environment despite its post-discharge concentration diluting effectively to zero, and despite agricultural pesticides having already been developed to kill weeds and to degrade before damaging the subsequent crop. Indeed, it may be possible for ballast water to be rendered anaerobic and thus inimical to life by flushing out its dissolved oxygen with inert gas during the ballast voyage. Once again, we have an example of the internal contradictions inherent to belief-only systems as previously exemplified for incident-response (articles 14 -15 and 116 - 129).

Article 169

As to emission regulation, document MEPC 67/19/INF.13 (Annex I) specifically refers to the already available knowledge that life-essential elements, such as sulphur, nitrogen, phosphorus, iron etc are incorporated from the environment in the carbon dioxide photosynthesis which continuously produces/ maintains the entire biomass of land and sea; that these biomasses are continuously degraded directly by micro-organisms or indirectly by combustion of their 'fossilised' residues; that consequently the entire biomass continuously recycles all of its carbon, sulphur, nitrogen, *etc*, through the atmosphere, soil and water as carbon dioxide, sulphur dioxide, nitrogen oxides e*tc*; that prior to their photosynthetic combination with carbon dioxide, the nitrogen and oxygen are directly 'fixed' from the atmosphere as nitrogen oxides and hence to nitrates by micro-organisms directly in the natural fertilisation of the soil, and symbiotically in the root nodules of the leguminous plants which fertilise the soil in crop rotation or by the Haber process in the manufacture of nitrate fertilisers.

In the Haber process a large alternating current is flashed between water cooled copper poles and spread by an intense magnetic field into a disc of 'flame' about 2 metres in diameter through which air (nitrogen and oxygen) is passed to form nitrogen dioxide (NO_2) which in the presence of water is 'fixed' to HNO_3 (nitric acid) in the manufacture of nitrate fertilisers. Previously, Nernst investigated the equilibrium concentrations of $N_2 + 2O_2 \leftrightarrow 2NO_2$ in air as a function of temperature and had shown that the equilibrium concentration of NO_2 is only 5% at 3000°C. Thus, while heat-engine emissions contain concentrations of sulphur and nitrogen oxides according to the presence of biosynthetic sulphur and nitrogen in the fuels, any additional NO_2 is due to the Nernst equilibrium in air at the internal cylinder-temperature before dissociating back to the Nernst equilibrium ($N_2 + 2O_2$) at atmospheric temperatures on emission, unless it is 'fixed' to HNO_3 by water and hence to fertiliser. Nitrogen was however being oxidised to nitrogen dioxide by micro-organisms in soil fertilisation long before our seasonal cropping of the land required supplementary nitrate additions in the form of Chile Nitre and/or guano imports, the blockade of which in the 1914-18 war resulted in the Haber process. Thus with nitrogen oxides and sulphur dioxide etc being life-essential they cannot be toxic *per se*. Indeed, the nitrates in nitre and guano had themselves arisen from the 'fixation' of atmospheric nitrogen and oxygen in the photosynthetic biomass.

Again document MEPC 67/19/INF.13 notes that the atmosphere above 1 acre of global surface is estimated to contain 35,000 tons of N_2: yet prior to Haber, not a molecule could enter the biological cycle as protein, for example, without bacterial nitrogen-fixation to NO_2. Thus, while lightening combines nitrogen with hydrogen from water to form NH_3 (ammonia), this is oxidised to the nitrite ion NO_2^{-1} after rain-out, by the genus *Nitrosomonas*; while the *Nitrobacter* oxidises this to the nitrate ion NO_3^{-1} which is essential for higher plants, while the *Azotobacter* transforms atmospheric N_2 to nitrate directly while utilising other bio-generated nitrites and nitrates; while the *Nitrobacterieae* transform NH_3 to nitrate directly; and while the *Rhizobium* symbiotically transforms atmospheric N_2 and O_2 directly to nitrates.

As to the cycling of other life-essential elements, the cited document notes that the genus *Nitrosomonas* will grow by photosynthesis from atmospheric carbon dioxide in a buffered solution containing only inorganic ammonium sulphate (2.0 gm), potassium hydrogen sulphate (1.0gm), magnesium sulphate (0.5gm), iron sulphate (0.4gm), sodium chloride (0.4gm) and water (1.0 litre); that nitrogen, sulphur, phosphorus, magnesium and iron thus recycle through the biomass, atmosphere, rain, soil and sea; and that we cannot know that their anthropogenic emissions are damaging without reality-evaluation of their molecular forms with respect to their exposure concentrations to plants, animals and humans. Again, as to nitrogen in the form of nitrates, the cited document notes that its contribution to food production ensures a significant percentage of the human population now owes its existence to the Haber process; and that any contribution from engine emissions is likely to be insignificant in comparison to the quantity produced by micro-organisms and recycled through the entire global biomass, and which in any case, is deficient for current human purposes to the extent of requiring the Haber top-up.

Again, as to sulphur, the cited document notes that this is cycled through the atmosphere as hydrogen sulphide and sulphur dioxide by tectonically driven volcanism and through the biomass by photosynthesis to such as the essential oils and proteins of onions, garlic, mustard, horseradish, eggs, hair *etc*; and that its belief-instigated removal from heavy fuel oil to avoid its exhaust-gas emission, raises questions as to oceanic and agricultural need for fertilising sulphate, and as to our need and cost-effective capability to remove sulphur from all residual fuels. As to the belief in our emissions of carbon dioxide being the source of so-called anthropogenic global warming, the cited document recalls that believers in AGW were invited on 15 November 2012 to reality-evaluate this belief; and that no response has yet been received, though none was expected of those who prefer retention of belief to the acquisition of knowledge (Preface and articles 121 - 127, 167 and 170).

Article 170

In parallel with the absence of response to the invitation referenced in article 169, the documents presented to MEPC 67/68 recall that the belief in species-extinction/ecological-disaster rejects available knowledge of the biodegradation which recycles all organic substances back to the carbon dioxide from which they were photosynthesised; that it rejects available knowledge of the re-colonisation/ regeneration which returns sedentary and mobile species to their pre-incident population levels; and that it uses these rejections in obstructing the use of dispersants, the discharge of post-recovery process-water, the emergency-use of safe havens, and the regulation of operational discharges beyond known need and beyond the unavoidable costs of incident response and of shipping operations in general. Again, these documents recall that the belief in anthropogenic global warming also rejects available knowledge of the recycling of carbon dioxide and of all the other life-essential elements (article 169); and that it uses these rejections in justifying its regulation of engine emissions beyond known need and beyond otherwise unavoidable costs.

Thus, these documents recalled that the invitation to NGOs of November 2012 sought to encourage believers to reality-evaluate as specific hypotheses their beliefs in species-extinction/ecological-disaster and in anthropogenic global warming by asking the following questions. Why should we believe in the former when we know that the concentrations of exposure are low enough to account for the absence of species-extinction/ecological-disaster in all incidents thus far; that re-colonisation/regeneration rates are high enough and physical coating extents are low enough to account for their absence in all incidents thus far; and that no believer has yet reality-evaluated any such hypothesis by comparing incident deaths with annual birth/death rates of relevant species populations? Again, why should we believe in the latter when we know that we combust only part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through the atmosphere and biomass just as initially photosynthesised and now 'fossilised' oils and their organic HNS derivatives recycle after release? Yet again, with atmospheric carbon dioxide recycling through the biomass by photosynthesis and biodegradation, and through carbonate rock by the tectonically driven Urey reaction and its volcanic reversal, why should we believe in anthropogenic global warming when no believer has yet reality-evaluated any hypothesis as to the rate at which increased carbon dioxide release in one of these cycles would cause increased abstraction by the other or both, and when experimentation on the variation of vegetative-mass with variation in carbon dioxide concentrations in controlled horticultural atmospheres is an obvious place to start? (articles 121 -127)

Thus, these documents for MEPC 67/68 recognise that problem-solving needs knowledge of the problem and knowledge of how to solve it; that if one believes in the existence of a problem, one has to reality-evaluate this belief to positive knowledge of its reality or to the negative knowledge of its unreality; that the problem of ship-release/ship-discharge causing species-extinction/ecological-disaster is unreal; that the problem of third-party commercial loss is real; that fuel costs are real; that unreal problems need no solutions; and that real problems have knowledge-only solutions if any. Again, these documents recall that while the belief in species-extinction/ecological-disaster was reality-refuted in the mid-1970s, this refutation has been ignored ever since by policy-makers; that the belief in anthropogenic global warming has never been transformed to hypotheses for reality-validation or reality-refutation; that believers collect facts in support, while disbelievers collect non-supportive counter-facts; that believers announce the dire consequences of failure to believe, while disbelievers deny these consequences; that such is merely a specific example of belief/counter-belief debate; that for the present, we have a majority belief-consensus in favour of AGW, while the minority hopes to flip it to the counter-consensus; and that while neither the majority nor the minority chooses to terminate this belief/counter-belief debate with debate-terminating positive or negative knowledge, we continue to have suppression of knowledge-only science by belief-only pseudoscience (article 167).

In the meantime, these documents recognise that belief-consensual decisions are maintainable only when dissent is suppressed by the *pro tem* majority-voting which does nothing to eliminate it; that nonetheless, everyone must assent to definitive knowledge, dissent from it being rationally impossible; that knowledge-only policy is definitively differentiated from belief-consensual policy by the respectively noting the prior presence or prior absence of my co-defined reality-evaluation; that this definitive knowledge/belief differentiation will, late or soon, terminate all dissent respecting regulation of ballast water discharge and engine emissions, all current dissent respecting marine casualty response, all dissent respecting operational discharge regulation, and indeed all socio-political belief/counter-belief dissent by belief suspension pending reality-evaluation to positive or negative knowledge.

Thus, while these documents invited IMO member States to accept in principle this new knowledge-only approach to contingency and incident-specific response planning, they are now invited to practice it with reference to this website. In order to facilitate its ultimate adoption, member States are thus invited to divest themselves of the already reality-refuted belief in species-extinction/ecological-disaster, and to accept commercial loss as the only significant consequence of casualty-release. Similarly, in light of available knowledge, IMO member States are invited to reconsider their earlier belief in the need for operational discharges to be zero in so-called Special Areas, to consider interim arrangements for ballast water management pending development of knowledge-only solutions, to reconsider engine emission regulations in general and to suspend arbitrary charges for carbon dioxide emissions pending reality-evaluation of specific hypotheses derived from the belief in anthropogenic global warming, and to notify the UNCCC of their individual suspensions of this particular belief while continuing to pursue the fuel-efficiencies which simultaneously reduce emissions and operating costs.

The Current Position Respecting the IOPCF

Article 171

While the documents presented to MEPC 67/68 showed that the current inter-delegate dissention of belief/counter-belief would be eliminated by the reality-evaluation which would transform all such belief/counter-belief to positive knowledge for acceptance or to negative knowledge for rejection, parallel documents submitted to IOPCF/Oct/2014 and April/2015 (Annex I) showed how belief/ counter-belief dissension over the drafting of claim-submission guidelines would be eliminated by adoption of the knowledge-only approach to contingency/incident-specific response planning now advocated by this website.

Attendees at the IOPCF/May 2014 meeting may recall that my intervention following the discussion on Guidelines for Submission of Claims was as follows: 'Staff changes have been mentioned in relation to the difficulty in presenting claims. There is also the question of 'reasonableness' and 'proportionality' (as these terms are used in the Convention). In this connection, ISCO is now offering a new approach to incident response. This new approach comprises a repository of knowledge supportive of a knowledge-only contingency plan based on the physicochemical parameters which control the fates and effects of releases, which determine prevention and response, and which by their incident-specific values predict incident-specific fates and effects, thus enabling incident-specific prevention and response to be cost-effective. Thus, on completion of this approach, coastal states will have access to a repository of knowledge secure against staff changes and a contingency plan from which even fresh staff will be able to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors employed, results obtained and costs incurred, to be reported to the IOPC Fund secretariat in fully documented form and to the IMO secretariat for enhancement of the thus shared repository of knowledge.'

This intervention was intended to suggest that dissention as to what is 'reasonable and proportionate' will not be resolved by speaking of administrative belief rather than of incident-response knowledge, by speaking of settlement for whatever was done in the heat of the moment regardless of outcome, or by seeking to define 'reasonable and proportionate' by reference to differing national laws and administrative procedures rather than by reference to incident-response knowledge, while failing to recognise that the drafters of the Convention selected these valueless terms because they themselves lacked the incident-response knowledge which would have defined them; that this continuing absence of knowledge, results in incidents being approached as though they were the first ever to have occurred; that this know-nothing/first-ever approach is reflected in the (fundamental) inadequacy of claim-submissions; that this inadequacy is perpetuated by the frequency of staff-turnover and the infrequency of incidents; that this perpetuation will continue until a knowledge-repository is made available to all; and that my new knowledge-only approach eliminates the knowledge-countering beliefs which have been suppressing the means to cost-effective minimisation of the commercial losses which are the only significant effects of oil releases from ships, oil thus far being the only concern of the IOPCF as its name makes clear.

As an unexceptional example of the need for such a repository, it is a matter of public record that while the UK Marine Pollution Control Unit (MPCU) had been established in March 1979 (ostensibly) on the incident-response knowledge acquired by the Warren Spring Laboratory between October 1974 and March 1979, no releases requiring any significant UK response arose until the *Sea Empress* grounded in the entrance to Milford Haven in February 1996; that the inability of the MPCU to institutionalise the knowledge available to it through frequent use despite staff-changes, had resulted in the initial release of 3,000-5,000 tonnes being increased to 72,000 tonnes by successive ebb-tide groundings from 15 to 22 February, before she was moved to a terminal for discharge of the residual 58,000 tonnes.

As to claim-settlement, Fund managers could now ask themselves whether it was 'reasonable and proportionate' to settle *Sea Empress* claims for the whole release of 72,000 tonnes or only for five sixty-sevenths or even three sixty-ninths of it, the balance having been caused/permitted by the failure of casualty-response managers to acquaint themselves with the available preventive-knowledge, while their release-response itself further demonstrated the need for a referential knowledge-repository covering all aspects of casualty-response to be available to all coastal States, the current absence of which increases rather than decreases all such interruptions of commercial coastal activities .

Thus, Fund Managers were informed that the ISCO Newsletter articles, re-collated in this website, were initially intended to retrieve earlier-acquired casualty-response knowledge and to familiarise coastal States with it by submitting sequential summaries of these articles to meetings 10-16 of the OPRC-HNS Technical Group, to the IOPCF meetings of October 2014 and April 2015, and to MEPC meetings 67 and 68; that these summaries were collectively intended to prepare coastal States for acceptance of the casualty-response knowledge earlier acquired and subsequently suppressed/thwarted/ignored or lost by the frequency of staff changes and the infrequency of incidents which in turn have everywhere prevented institutionalisation of this knowledge; and that the countering beliefs of environmentalists have long suppressed the knowledge which long since would have eliminated dissention over casualty response, claim submission and assessment and operational discharge and emission regulations.

The Current Position Respecting MEPC and IOPCF

Article 172

As a consequence of submitting the cited documents to the MEPC and the IOPCF Assembly (Annex I), both bodies are now aware that in the creation of a knowledge repository on oil/HNS release-response between October 1974 and March 1979, WSL had reality-evaluated the belief in species-extinction/ ecological-disaster to the knowledge that oils disperse from layer thicknesses of ~0.1mm; that instantaneous dispersion from such thicknesses would cause concentrations in the top metre of the water column of no more than 100ppm even if permanently retained there; that oils with high rates of natural dispersion such as Ekofisk crude, disperse completely over time while producing top metre concentrations of no more than 1 - 2ppm; that these dilute further with diffusion and turbulent mixing throughout the entire water column in which they are biodegraded by the micro-organisms involved in the ultimate biodegradation of the entire marine biomass; that such natural dispersion proceeds to completion at slick half-lives dependent on pollutant viscosities unless interrupted by stranding; that diluting/biodegrading concentrations at depths of 10 - 15metres are ~ 0.05ppm while top metre concentrations beneath naturally dispersing micron thickness sheens surrounding the main slick are in the range 0.1 - 0.01ppm prior to further water column dilution; that were oil to be the cause of species-extinction/ecological-disaster, it would have to be sufficiently toxic at these concentrations; and that the standing hydrocarbon concentrations in coastal waters average around 0.1 - 0.01ppb without attracting any attention at all (articles 14 - 15).

Again, both bodies are now aware that in creating its intended knowledge repository, WSL reality-evaluated the belief in dispersant-induced concentrations being the cause of species-extinction/ ecological-disaster to the knowledge that 5 minutes after dispersant-application, those in the top metre of the water column average 10 - 20ppm, while after 10 minutes and within an hour they average 5ppm and 2ppm respectively; and that volatile oil components and volatile HNS cannot reach saturated vapour pressure because they dilute into the atmosphere and degrade by photolysis or return to the sea by rainout for biodegradation to carbon dioxide and water.

Yet again, both bodies are now aware that WSL already knew, as a matter of public record, that believers in species-extinction/ecological-disaster measured LC_{50} values for oils and dispersants without reference to concentration, dilution and biodegradation in the sea; that to measure LC_{50} values for the early hydrocarbon-based dispersants, the UK Ministry of Agriculture Fisheries and Food simply exposed the test organism *Crangon crangon* to concentrations high enough for long enough; that when the toxicity of the subsequent water-based concentrates became too low to be thus measurable in any practicable timescales, the test organisms were exposed to 1000ppm of oil (fresh Kuwait crude) dispersed in seawater with 1000ppm of the dispersant or with 100ppm of the later concentrates; that while the earlier test ensured acceptance of only the least toxic dispersants, the later testing revealed a reluctance to recognise the non-toxicity of the new concentrates and a desire to continue measuring the ‘toxicity’ of dispersed oil despite the risk of thus accepting only the least effective dispersants; and that neither test took any account of the concentrations in the sea as directly measured, nor indeed of the total absence of extinction/disaster at all incidents to-date whether dispersed naturally or by dispersant-inducement (articles 14 - 15).

Thus, both bodies are now aware that WSL knew that this test regime was sustained merely by the belief which its results reality-refuted; that the thinness of floating layers of oil, their rates of natural dispersion and the increases induced by dispersant-use were such as to ensure the concentrations in the top metre, let alone at deeper levels, are too low to produce toxicity in the water column; that oil released to the sea is not a biocide in respect of the micro-organisms which biodegrade it; that consequently the banning or restriction of dispersant-use; the banning of process-water discharge in recovery operations, and the prohibition of safe haven cargo/bunker transfer, all arise from belief and not from knowledge; and that the duration of net-fishing bans owes more to belief than to knowledge while filter-feeding shellfish are freed of oil droplets by routine pre-sale depuration.

As to the future possibility of there being an HNS compensation fund, both bodies are now aware that the belief in HNS discharges and releases being the cause of species-extinction/ecological-disaster was treated by WSL as a hypothesis for reality-evaluation in light of the knowledge that some disperse, dilute and biodegrade as do oils; that others dissolve, dilute and biodegrade; that some evaporate as do the volatile components of oils; that others are neutralised by the inorganic-content of seawater; that very few are non-dispersing/non-soluble solids; that their respective behaviours are all predictable from the known values of their relevant physicochemical properties as are those of all the oils; that whether they are the components of oils or individual HNS, all with boiling points < 250°C evaporate in < 5 hours to the extent of 25 - 30% or 100% respectively; that atmospheric concentrations with respect to altitude are similar to those of dispersers/dissolvers in the sea with respect to depth; that evaporators simply evaporate; that while water-in-oil emulsions naturally disperse at half-life rates dependent on their measurable viscosities, floating non-volatile HNS have slick thicknesses no more than 0.1mm, do not form emulsions and disperse at half-life rates dependent on their known viscosities as do the oils; that these are generally in the gasoline-diesel range (< 5cst at 15°C) which disperse naturally without dispersant-inducement; and that no evaporating, dispersing or dissolving HNS needs dispersant treatment or removal, these operations being either impossible or pointless; and that only an identifiable few are solids, best recovered onshore.

Article 173

Again, documents presented to MEPC and IOPCF (Annex I) recalled that between 1974 - 79 WSL reality-evaluated hypotheses to the knowledge that the effectiveness of both dispersants and mechanical removal decrease with increase in pollutant viscosity, the former more quickly than the latter; that the latter varies with individual design principles; that for both, the encounter rates for response units are limited by layer thickness, the swath width of the system, and its travel speed during the encounter; that for a system of 1 metre swath width travelling at 1knot the encounter rate is $0.18m^3h^{-1}$ per 0.1mm of slick thickness and *pro rata*; that for ship-mounted spray sets the effective swath width can be up to 20metres and travel speed 5 - 10 knots; that aerial spraying can have swath widths of 10-15 metres and much higher speeds than ships but require frequent re-loading; that for mechanical removal swath widths can be 100metres or more but the speed is limited to 1 knot; that such large boom-mouths need two ships to tow them and one to remove the pollutant; that the recovery of each ship is thus 1/3 of the total; that the efficiency of skimmers decreases rapidly with increasing wave height; and that removal involves downstream processing to separate the co-collected water, to break the emulsions and to separate the demulsified water from the demulsified oil (articles 50 - 55, 70 and 100 - 102).

Thus, these documents for the MEPC and the IOPCF Assembly concluded as a matter of definitive knowledge that planning to respond to casualty releases of more than the 3000-5000 tonnes expected from impact damage to a single cargo tank is unrealistic; that to plan to respond to the release of total cargoes and bunkers is even more so; and that consequently there is an unavoidable need for emergency cargo/bunker transfer and for the means by which casualties can be secured for safe-haven entry to avoid the possibility of total loss at the exposed location of initial impact (articles 106 - 106). Again, as a matter of definitive knowledge, these documents concluded that the belief in species-extinction/ ecological-disaster can be rejected not only by the concentrations measured in the water column beneath slicks but also by its reality-refutation by all casualty-releases to-date; that this rejection would remove current objections to safe haven use, to dispersant use and to *in situ* discharge of recovery-process water; that this rejection of belief would reduce the quantities otherwise released, conserve the storage capacities of recovery vessels and eliminate the cost of transporting un-processed removals to authorised locations such as oil refineries, the controlled-waste status of process water having thus been abandoned by acceptance of the reality-refutation of its initiating belief. Thus, with rejection of the belief in species-extinction/ecological-disaster, the current drafters of claim-settlement guidance could look forward to release prevention and response becoming increasingly cost-effective and to these costs and those of commercial interruptions being greatly reduced for all future incidents.

Again, as to the potential arrival of releases onshore, these documents included the knowledge that arrivals are only the floating residues of incomplete evaporation, solution or dispersion; that none would have arrived onshore had these processes been completed between release and potential arrival; that the options on arrival are thus to permit or assist completion of these non-toxic non-coating processes by continuing dispersant application and/or physical removal of that which is non-amenable to dispersant treatment; that dispersant-use is unnecessary for natural evaporators or dissolvers but assists natural dispersion without putting more of the release into the sea than would have gone in had more time been available prior to stranding, no further action then being needed; that mechanical removal of non-dispersible pollutants requires downstream processing; and that dispersants, when effective, are thus preferable to removal in their avoidance of such downstream processing.

As to shoreline cleaning, these documents recalled that between 1974-79, WSL reality-evaluated specific hypotheses to the knowledge that encounter-rates may increase by up to a factor of 10 when emulsified layers are pressed against shorelines by onshore winds while stranding on ebb tides; that consequently the shore is more effective than any deployable boom or absorbent; that inshore removal from water surfaces is to this extent more effective than removal at sea; that emulsion layers up to say 5mm thickness can thus be collected from wet (poorly drained) sand beaches by water-flushing into contour trenches dug for removal by viscosity-tolerant pumps; that on dry sand where flushing-water would simply drain away, heavy rubber strips attached to the lower edge of mechanised scraper blades can be effective in pushing the emulsion into contour trenches; but that otherwise specialised equipment is needed to separate collected pollutant from co-collected beach material (articles 92 - 102).

Thus, with a wider and more detailed coverage than the above summary, the MEPC/IOPCF secretariats and member States have been informed as to the nature of the new knowledge repository, and the benefits of replacing belief with knowledge in contingency and incident-specific planning and in the preparation and assessment of claims for compensation (Annex I)

Tendency Towards the New Knowledge-Only Approach

Article 174

With the summarising documents for MEPC and IOPCF having outlined the need for and the content of my knowledge repository and the contingency/incident-specific plans derived/derivable from it, Member States' policy-makers may have begun to relate the physicochemical properties of oils/HNS to the full range of fates and effects of their releases, to the effects which require and which do not require response in any specific incident, and to the equipment and techniques best suited to whatever response is required. Again, Member States' policy-makers may have begun to recognise that cargo/bunker transfer and well-capping are the primary aspects of casualty-response; that natural evaporation, dispersion, solution, dilution and biodegradation are the ultimate protectors of the environment; that human response is needed only insofar as it limits commercial loss by preventing releases beyond those of initial tank damage, by dispersant treatment to enhance natural biodegradation rates or by mechanical removal of dispersant-resistant releases; and that incurred-costs can be justified only insofar as they are commensurate with commercial loss-minimisation, the belief in species-extinction/ecological-disaster having been reality-refuted some forty years ago.

Furthermore, Member States' policy-makers may have begun to recognise that the means of minimising commercial losses by cargo/bunker transfer and by dispersant-use and mechanical-removal at sea and in inshore waters are ubiquitously applicable, while dispersant-use and mechanical removal on shorelines, have to be matched with individual types and tidal ranges. Thus, while UK shoreline types include mudflats, salt-marshes, poorly- and well-drained sand, shingle, pebble/cobble, rock and cliff, all of which are exposed to substantial tidal ranges, shorelines elsewhere may be predominantly sand, mangrove or coral and may be non-tidal or of low tidal range, and as such unable to expose wide inter-tidal shoreline widths to contiguous pollutants. Again, Member States' policy-makers may have begun to recognise that the more limited the types of tidal shorelines the more limited the range of equipment needed for response; that non-tidal shorelines have no need for inter-tidal cleaning equipment; that non-tidal shorelines are more effective than floating booms in containing contiguous slicks for mechanical removal; and that with respect to dispersant-application/mechanical-removal, the only choice is for their most viscosity-tolerant manifestations.

However, Member States' policy-makers may also have begun to recognise that oils/HNS off-loaded from casualties by cargo/bunker transfer must also arrive onshore; that crude oils must go to refineries; that bunkers and fuel cargoes must go to bunkering stations; that HNS from parcel tankers, specialised containers or individual packages within standard containers must go to intended or alternate customers; and that while released oils removed from water surfaces or from shorelines may be 'recycled' as low grade fuel for a variety of identifiable receivers, HNS arriving onshore as release-residues, or in leaking packages, are to be treated, collected, over-contained and ultimately disposed of by the standard procedures of the chemical industries which produce them.

As to the details of slick treatment, Member States' policy-makers may have begun to recognise that dispersants should be applied to the slick-edge closest to shore, wind permitting; that to apply them elsewhere is to permit the untreated slick already closer to shore to strand untreated if it fails to disperse naturally; that treatment of the shore-proximate edge as the slick moves closer to shore can be continued onshore when natural dispersion at sea coupled with dispersant treatment and mechanical removal fails to prevent stranding; and that at-sea mechanical removal should be applied longitudinally with the windrows which permit single-ship systems to benefit from their increased thickness. Again, Member States' policy-makers may have begun to recognise that the quantity eventually stranded can be estimated from the length, width and thickness of the coverage, and/or from the quantities subsequently removed and/or dispersed, the latter being estimated from the quantity of dispersant used; that the quantity stranded also equates to the quantity released less the quantities evaporated, dispersed naturally, dispersed by dispersants (estimated from the quantity used) and mechanically removed prior to stranding; and that such mass-balancing at future incidents will enhance our current knowledge of the relationships of pollutant-viscosity/half-life, pollutant-viscosity/dispersant-efficiency per dispersant-formulation, and pollutant-viscosity/removal-efficiency per remover design-principle.

Again, Member States' policy-makers may have begun to recognise that this mass-balance approach has already been used to compare the quantity stranded with the quantity released and with the quantity which would have stranded had the salvor not removed the cargo and bunkers; that this approach was successfully applied by this author in salvage claim adjudications in respect of the *Aegean Sea*, *Nikitas Rousos*, *Paraikos II*, and *Sea Empress Incidents*; and that it would similarly help in assessing incident-response claims submitted to the IOPCF and P&I secretariats while submission of the supporting reports to the IMO secretariat would enable the repository to be enhanced with knowledge acquired at specific incidents in respect of viscosity-related fates and viscosity-related technique/equipment performance.

Article 175

In addition to release-response, the cited MEPC/IOPCF documents showed that the new knowledge-only contingency plan also included release-prevention. Thus, Member States' policy-makers may have begun to recognise that while the Powers of Intervention were intended to prevent release, their use to prevent access to safe-havens for cargo/bunker transfer actually increases release; that collaboration of marine-survey staff with the salvor-in-possession best acquires the knowledge needed for casualty-stabilisation and cargo/bunker transfer whether at sea or in a safe haven; that with respect to the latter, such a jointly owned knowledge-only plan best avoids the uncertainties of the belief/counter-belief debates of the adversarial legal processes which currently discourage applications for access in the first place; that oil-well blowouts also need such collaboration of administrations and contractors; and that such collaboration would eliminate politics, and convert administrations from self-styled victims of others' mistakes, to the protectors of the public interest they are intended and expected to be.

Again, Member States' policy-makers may have begun to consider how best to collaborate with response contractors in creating and executing knowledge-only incident-specific response plans derived from the foregoing knowledge-repository and its knowledge-only contingency plan; how best to ensure the integration of the thus derived incident-specific plans for sea-going, inshore and onshore response; and how best to report the predictions made, decisions taken, accredited contractors employed, results obtained and costs incurred to the IOPC Fund and P&I Club secretariats in fully documented form and to the IMO secretariat for enhancement of the thus shared repository of knowledge.

Thus, when faced with liquid non-solidifying release from an impact damaged casualty, Member States' policy-makers may have begun to recognise that the first step is to avoid subsequent weather-damage releases by cargo/bunker transfer; that the second is to ascertain the values of the physicochemical parameters relevant to its cargo and bunkers; that the third is thus to note the fates and effects of any releases in terms of floating or sinking, of fractional or total evaporation, total solution, or progressive dispersion according to the half-life/viscosity relationship previously tabulated for crude oils and bunkers; that the fourth is to calculate the fractional evaporative loss from any crude oil cargo from its fractional distillation profile as co-tabulated, this being usually 25 - 30% for oils or 100% for volatile HNS in < 5 hours; that the fifth is to calculate the time to reach shore from the vector sum of 100% of the tidal vector and 3% of the wind vector; that the sixth is to apply the respective viscosity-dependent dispersion half-lives of the non-volatile fractions of the cargo/bunker oils and of the non-volatile insoluble HNS to the quantified releases and to the time to reach shore, in order to estimate the quantities likely to arrive on the shoreline-types identified at these locations; that the seventh is to consider, on the bases of known viscosities and half-life dispersion rates, whether dispersants or recovery, both or neither, should be applied at sea, there being no need to enhance or prevent natural dispersion which of itself would prevent any onshore arrival. Thus, Member States' policy-makers may have begun to see that were this sequence to be followed, it would not only give structure to the response, it would also provide a format for claim submission and settlement.

Again, when faced with a solidifying release, Member States' policy-makers may have begun to recognise that all such oils/HNS have been identified; that with recovery being the only option, it will best be achieved onshore; that when a soluble HNS is released it will dilute and biodegrade or neutralise; that the half-life of floating soluble HNS will be shorter than or comparable with the half-lives of floating insoluble oils of viscosity < 5cSt at 15°C as most HNS are; that there is no need to assist these natural processes, no possibility of collecting evaporators, dispersers and dissolvers and no need to remove rapid dispersers; but that known toxicity-concentration relationships may require down-tide HNS dilution to be monitored with respect to commercial fishing.

In continuance of the above step-sequence Member States' policy-makers may have begun to recognise that the eighth step is to repeat the sixth to estimate the quantity likely to strand just prior to its arrival, having further reduced it by the quantities already removed mechanically, and/or dispersed at sea by the quantity of dispersant applied to it; that the ninth step is to revise the identification of shoreline types to be impacted and the lengths, widths and thicknesses of these impactions; that the tenth is to identify the techniques applicable to each shoreline type and to its contiguous inshore waters; that the eleventh is to activate transportation of the associated equipment in quantity and sequence appropriate to these various locations; and that the twelfth is to identify and alert all who might receive oils for heat-generating combustion, 'land-farming' or land-fill. Again, Member States' policy-makers may have begun to recognise that were this sequence to be followed, it would not only give structure to the response, it would also provide a format for claim submission and settlement.

Article 176

With the new knowledge-only approach to policy-making having raised no dissention when exposed to meetings 10-16 of the OPRC-HNS Technical Group, to MEPC 67/68 and to IOPCF OCT/2014 and May/2015, Member States' delegates themselves may have begun to recognise that no dissent is possible from my newly definitive differentiation of the knowledge/belief dichotomy; that beliefs are transformed to positive or negative knowledge by evaluating their compatibility or incompatibility with reality; that belief remains belief in the absence of this reality-evaluation; that craftsmanship, science and technology are knowledge-only; that belief-consensus is belief-only pseudoscience, reality-evaluation of cause-effect having been ignored or the need for it having been unrecognised; that belief/ counter-belief dissent is resolvable only by the reality-evaluation which coverts belief to positive or negative knowledge; and that beliefs beyond reality-evaluation in *pro tem* practice must await this practice, while those beyond reality in principle can only be accepted, rejected or suspended as beliefs beyond reality-evaluation and thus incapable of acceptance as positive or as negative knowledge.

Indeed, in light of the above documents, Member States' delegates themselves may have begun to recognise that there is no rational alternative other than to accept that the reality-evaluation which thus differentiates the dichotomies of knowledge/belief, truth/falsehood, wisdom/folly, right/wrong and good/bad is the sole means by which specific beliefs (hypotheses) were transformed to the positive craft- and self-knowledge which secured the socially cohesive survival of our group-species from time immemorial, and to the science and technology which enhanced our physical welfare from the seventeenth century onwards; and that the social cohesion which depends on self-knowledge has been continually interrupted by religious beliefs/counter-beliefs beyond reality-evaluation in principle, by reality-rejecting secular beliefs or by the reactions of ignored-reality in ways which belief *per se* is unable to anticipate or avert. Thus, Member States' delegates may have begun to recognise that there is no rational alternative to accepting that the absence of this reality-evaluation produces dissent, disharmony, violence, revolution and war, and that its lax application corrupts socio-economic and environmental science to the pseudoscience which diminishes social cohesion, causes economic crises, and diverts resources from real to unreal problems with needless increases in material and energy costs.

In consequence, Member States' policy-makers and delegates may have begun to recognise that previously acquired knowledge of casualty-response has been lost in not having been institutionalised in practice because of staff-change frequency and incident infrequency and because of the absence of a centrally accessible knowledge repository; that belief in species-extinction/ecological-disaster has been institutionalised instead to the detriment of knowledge retention; that successive impasses in regulation-compliance have been removed only by subsequent knowledge-acquisition; and that only acquisition and acceptance of further knowledge can resolve current dissention over the regulation of ballast water discharge, while the beliefs in anthropogenic global warming and in the negative effects of sulphur and nitrogen oxide emissions ought to be suspended until they are reality-validated or reality-refuted.

Thus, Member States' policy-makers and delegates may have begun to accept the need for this repository of knowledge and for adoption of its knowledge-only contingency/incident-specific planning approach, to which ends I make them available to all Member States through this website, my further intention being to accredit response contractors as to competence in their use; and to liaise with IMO, IOPCF and P&I Club secretariats and Member States towards facilitation of claim-settlement through mutual acceptance of casualty-response knowledge, and towards enhancement of the knowledge repository itself through knowledge-only incident-reportage by Member States to the IMO secretariat.

1 Response to Oil and Chemical Pollution, D. Cormack, Elsevier Applied Science, 1983.
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack, Kluwer Academic, 1999.
3 The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack, Bright Pen, 2010, from www.authorsonline.co.uk
4 ISCO Documents for MEPC/TG Meetings 10 - 16.
5 Cormack's Column in the ISCO Newsletter, weekly articles from November 2010 - August 2014.
6 ISCO Documents for MEPC 67 and 68 (Annex I).
7 ISCO documents for IOPCF/Oct 14 and May15 (Annex I).
8 Website www.knowledgeonlypolicy.weebly.com from March 2014.

ADOPTION OF THE KNOWLEDGE-ONLY APPROACH THUS FAR

The Latest IMO Guidance on Dispersant Use

Article 177

Having observed in article 176 that IMO Member States may have begun to accept my knowledge-only approach to casualty-response and discharge/emission regulation, I now record that a Correspondence Group on Guidelines for Dispersant Use has been operative while I was sequentially presenting my documents to the Technical Group, to the MEPC and to the IOPCF; that the TG has been subsumed in the Pollution Prevention and Response Sub-Committee (PPR) of the MEPC; that the Correspondence Group has reported to PPR2 (19-23 January 2015) for onward transmission to MEPC 70; and that I am thus now able to evaluate the extent to which the Guidelines accept knowledge and reject the beliefs refuted by it, as already advocated by my own presentations to the MEPC and to the IOPCF Assembly.

I took no part in this Correspondence Group, having had no wish to associate myself with what could have been yet another round of knowledge suppression by belief, a suppression of which I am painfully aware, having since the mid 1970s been head of the oil/HNS division at Warren Spring Laboratory (WSL), a founding member of the UK marine pollution control unit (MPCU), chairman of the oil response manual working group of the MEPC and of the parallel working group of the Bonn Agreement, and ultimately director of the WSL Environmental Science and Technology Agency (Acknowledgements) in which interval I had experienced the extent to which belief was suppressing the knowledge which refutes it, not only in respect of marine releases and discharges, but also respecting national air-quality monitoring, industrial/automotive emissions abatement, waste recycling/disposal, and contaminated land remediation (Acknowledgements), all of which had caused me to seek liberation through my newly definitive knowledge/belief differentiation.

Nonetheless, I can now report that while dispersant use has been banned/restricted since the mid 1970s by the reality-refuted belief in species-extinction/ecological-disaster, the Correspondence Group now accepts that the concentrations of oil in seawater arising from release/discharge are insufficient to cause such effects; that dispersants are much less toxic than oil at seawater concentrations; that the oil slick thickness which is the only source of such seawater concentrations is 0.1mm; that dispersed oil dilutes and biodegrades in the water column; and that dispersant-use prevents the physical coating of organisms and shorelines and eliminates the need to process recovered pollutants: all of which is in compliance with my knowledge repository as sequentially presented to the previous OPRC/HNS Technical Group, to its parent MEPC and to the IOPCF Assembly, though no reference was made to these prior presentations by the Correspondence Group.

However, the Correspondence Group has yet to accept overtly that the belief in extinction/disaster which still prohibits dispersant use in shallow waters and within prohibited distances from shore has been refuted by the absence of any such effects at all incidents thus far; and that the maximum concentration to be expected from instantaneous dispersion of a 0.1mm thick slick would be 100ppm, even if all of it were permanently retained in the top metre of the water column. Again, while the Group accepts that dispersants prevent the physical coating of birds, animals and shorelines, it still cites the belief that the concentrations resulting from their use are disadvantageous to the organisms of the water column despite being biodegraded by them. Yet again, the Group claims that the advantages and disadvantages of dispersant use are such as to require Net Environmental Benefit to be evaluated by (belief/counter-belief) discussion despite the seawater concentrations which reality-refute all belief in these disadvantages, despite the absence of any quantified permanent effects at any and every oil release thus far whatever the response or non-response might have been, and despite the management-ineffectiveness of all incidents thus far having been fully capable of causing species-extinction/ ecological-disaster, had these effects been other than mere belief.

Nonetheless, I gladly report that this latest Guidance on Dispersant Use has made progress towards ultimate acceptance of my knowledge-only approach to marine casualty response in general; and that full acceptance cannot now be long delayed, given that rejection is now unavoidably shown to require an irrational preference for definitive belief over the definitive knowledge which refutes it.

However, to avoid any misunderstanding, readers must recall that releases from marine casualties cause sufficient interruption of commercial activities to justify response by all available cost-effective means; and that this is the main if not the only reason for such response. Further to such response, policy-makers must also recall that the slick encounter rates of all such means are limited by the slick thickness which limits the seawater concentrations arising from natural and induced dispersion; that while response units are encountering only very localised areas of slicks, natural evaporation and/or dispersion is occurring over the entire slick area; that the quantities thus naturally evaporated and/or dispersed, greatly outweigh the amounts attributable to any mountable response; and that these known limitations of all release-response techniques make imperative the need to limit all releases by cargo/ bunker transfer in the nearest safe haven or by expeditious well-capping to limit releases, and thus to limit the commercial losses arising from physical-coating.

Again, to avoid any misunderstanding, policy-makers must now recall that whereas regulations for the operation of ships by ship-owners are intended to be mandatory under Conventions currently in force, only guidance is offered by MEPC to otherwise regulating States as to how to deal with accidental releases from ships, individual States being free to accept or reject such guidance; but that individual States are also free to accept definitive knowledge and to reject definitive beliefs already refuted by such knowledge, without need of prior endorsement by any IMO committee or indeed by any authority other than reality itself. Thus, at this point, all may conclude that knowledge-acceptance and belief-rejection is now achievable for, and by policy-makers who have here been shown that their former knowledge-rejection and belief-acceptance would now require the irrationality of definitive madness.

ANNEX I
Documents Submitted to MEPC and IOPCF

The documents reproduced in this Annex were submitted to the Marine Environment Protection Committee (MEPC) of the IMO and to the International Oil Pollution Fund (IOPCF) Assembly after completion of the series of submissions to meetings 10 - 16 the OPRC/oil/HNS Technical Group of the MEPC and in parallel with the article-sequence in the ISCO Newsletter, but before re-editing and representing these articles for this website. Those for the MEPC itself were summaries of the foregoing respecting release-response and operational discharges and emissions, while those for the IOPCF Assembly and Executive Committee summarise their impact on cost-compensation, the differences and repetitions of these documents reflecting the respective involvements of these Organisations.

Thus, these documents have shown Member States how adoption of my newly definitive knowledge/ belief differentiation would enable them to accept knowledge, to reject beliefs which knowledge refutes, and to recognise beliefs which have not as yet been validated or refuted. Thus, with this new ability to accept knowledge and to reject belief, Member States are now aware that adoption of the knowledge repository and the knowledge-only contingency and incident-specific plans of this website would dispel all belief/counter-belief dissention over release-response and claim settlement and by extension would dispel all inter-delegate belief/counter-belief dissention over operational discharges and emissions from ships, having recalled that earlier belief-driven oil/HNS discharge regulation was saved from self-destruction only by subsequent knowledge-acquisition.

The Document IOPCF/OCT14/4/6 which expands on the above is reproduced below for ease of reference to the knowledge repository of this website.

COMPENSATION FOR CASUALTY-RESPONSE
Submitted by the International Spill Control Organisation (ISCO)

1 Introduction

1.1 This document is offered in response to Document IOPCF/May14/4/1, *Information for claimants - Guidelines for presenting claims for clean up and preventive measures*, submitted by the Secretariat; and to Document IOPCF/May14/4/2, *Assessment of the claim of a State in case of a disaster- Document IOPCF/MAY14/1/2*, submitted by France, Spain and the United Kingdom. It is also offered in expansion of the statement made by ISCO at the end of the discussion, as reported in Document IOPCF/May14/10/WP.1.

1.2 The ISCO statement was: "Staff-changes have been mentioned in relation to the difficulty in presenting claims. There is also the question of reasonableness/proportionality. In this connection, ISCO is now offering a new approach to incident response. This new approach comprises a repository of knowledge supportive of a knowledge-only contingency plan based on the physicochemical parameters which control the fate and effects of releases, which determine prevention and response, and which by their incident-specific values predict incident-specific fates and effects, thus enabling incident-specific prevention and response to be cost-effective. Thus, on completion of this approach, coastal states will have access to a repository of knowledge secure against staff changes and a contingency plan from which even fresh staff will be able to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors employed, results obtained, and costs incurred to be reported to the IOPC Funds in fully documented form and to IMO for enhancement of the thus shared repository of knowledge.'

1.3 To this statement, ISCO added that a document justifying this approach would be available for MEPC 67, and that a shorter version in relation to claims-settlement would be available for the October 2014 meeting of the IOPCF.

1.4 As to this document, the above statement was intended to suggest that current dissention as to what is 'reasonable and proportionate' will not be resolved by speaking of administrative belief rather than of incident-response knowledge, by speaking of settlement for whatever was done in the heat of the moment regardless of outcome, by seeking to define 'reasonable' and 'proportionate' by reference to differing laws and administrative procedures rather than to incident-response knowledge, or by failing to recognise that the drafters of the Convention selected these valueless terms because they themselves lacked the necessary incident-response knowledge. Again, this statement was intended to suggest that this continuing absence of knowledge causes incidents to be approached as though no knowledge had ever been previously acquired; that this absence of knowledge is reflected in the inadequacy of claim submissions; and that staff turnover-frequency and incident-infrequency will perpetuate this absence and inadequacy until a repository of all relevant knowledge is made accessible to all who need it.

1.5 As an unexceptional example of the need for such a knowledge-repository, the public record shows that while the UK's Marine Pollution Control Unit (MPCU) had been established in March 1979 on the incident-response knowledge acquired by the UK's Warren Spring Laboratory between October 1974 and March 1979, no significant incidents arose thereafter until the *Sea Empress* grounded in the entrance to Milford Haven in February 1996; that the MPCU was thus unable to institutionalise this knowledge through frequent use; and that the consequent knowledge loss resulted in the initial grounding-release of 3,000-5,000 tonnes being increased to 72,000 tonnes by successive ebb-tide groundings before the casualty was moved to a terminal within the Haven for discharge of the residual 58,000 tonnes. Thus, this unexceptional example confirms the need for a repository of casualty-response knowledge to avoid its otherwise inevitable and irrecoverable loss.

1.6 As to claim submission, it may be asked whether it was 'reasonable and proportionate' to settle claims for the whole release of 72,000 tonnes or for only five sixty-sevenths or three sixty-ninths of it,, the rest having been caused/permitted by failure to retain otherwise available release-prevention knowledge, while the release-response itself confirmed the need for a repository of knowledge of all aspects of casualty-response to be available to all who need it [1,2].

2 Knowledge-Belief Differentiation

2.1 To reclaim and preserve the incident-response knowledge acquired prior to and since 1979, and to reject all knowledge-countering beliefs perpetrated since the *Torrey Canyon Incident* of 1967, ISCO has been progressively submitting documents on its knowledge-only approach to contingency and incident-specific planning to OPRC-HNS Technical Group meetings 10 - 16[4-6]. However, to avoid these documents being dismissed as the self-interested beliefs of casualty-response contractors, ISCO adopted the definitive knowledge/belief differentiation which was first enunciated in 2010[3]. This differentiation arose from observing that reality stimulates our imaginations to beliefs transformable to positive or negative knowledge by evaluation of their compatibility or incompatibility with reality or to those which can only be accepted, rejected or suspended as beliefs beyond this co-defined reality-evaluation in principle or *pro tem* practice, but which cannot be accepted as knowledge[3,7].

2.2 Thus, this newly defined differentiation of the knowledge/belief dichotomy and with it those of truth/falsehood, wisdom/folly, right/wrong and good/bad has shown that reality-evaluation of specific beliefs (hypotheses) produced the craft- and self-knowledge which secured our group-species survival from time immemorial and the science and technology which enhanced our physical welfare from the seventeenth century onwards, while our knowledge-only social cohesion has been intermittently disrupted by religious beliefs/counter-beliefs beyond reality-evaluation, by reality-rejecting secular beliefs or by the reactions of ignored-reality in ways which belief is unable to anticipate or avert[3,7].

2.3 Thus, this new differentiation has shown that beliefs ought to be reality-validated to positive knowledge prior to implementation; that beliefs reality-refuted to negative knowledge ought not to be implemented; that the absence of this reality-evaluation leads to belief-counter-belief disharmony, violence, revolution and war; and that its lax application corrupts what would otherwise be the socio-economic and environmental sciences to the pseudoscience responsible for deteriorating inter-personal behaviour, diminishing social cohesion, and recurring economic crises; and for diversion of resources from real to unreal problems with needless increases in the costs of materials and energy supply[3, 6, 7].

2.4 Thus, this definitive differentiation now enables humanity to conclude that its dissentions are those of belief/counter-belief; that these can be resolved by mutual acceptance of definitive knowledge; that this requires knowledge-only policies conducive to our species survival and physical welfare to be ubiquitously recognised as definitively true, wise, right or good while beliefs counter to knowledge are recognised as untrue, foolish, wrong or bad; that political manifestos ought to offer knowledge-only policy options for electoral prioritisation within known resource limits, while recognising belief-only policies as arising from *pro tem* ignorance pending knowledge-acquisition; that this first-ever definition of beneficial political-change will render continuous our otherwise intermittent progress; and that harmonisation of technology and environment is as good a field as any in which to make a start[3, 6, 7].

3 Definition of Opinion/Counter-Opinion

3.1 The above knowledge/belief differentiation shows that debate of opinion/counter-opinion is merely debate of belief/counter-belief supported by partially selected facts/counter-facts or evidence/ counter-evidence, no set of which is debate-terminating knowledge; that the outcome is merely a belief-consensus which may flip peaceably to the counter-consensus or may be overthrown by overt-dissention, disharmony, violence, revolution, war or ignored reality; that belief-consensus is thus no basis for progress in reality; that the minority in any belief-consensus may be acquiescent and compliant though covertly dissenting, or overtly dissenting and non-compliant; and that when a belief consensus regulates beyond its co-believers, it aspires to absolutism[3,6,7].

3.2 Thus, in respect of the present environmentalist belief-consensus, we see that believers do not regulate themselves to any consensual standard of release prevention or response while they regulate others to the current consensual standard of discharge-avoidance; that while this regulation tends to absolutism its gradualism has thus far avoided the open dissent now exhibited by ship-owners in respect of ballast water management and by developing member states in respect of combustion-emissions; and that this dissent arises from belief-only regulation being pushed beyond knowledge of need and capability[6] (paragraphs 4.1 - 4.3); and that it is this same dissention of opinion/counter-opinion which is thwarting progress on the drafting of guidelines for claim submission and settlement[3,6].

3.3 Again, we see that member states have devoted much less attention to their response to casualty-releases than to their regulation of operational discharges, despite being the designated agents of response to such releases as is recognised by the Powers of Intervention conferred upon them by the Convention as the *quid pro quo* for the associated costs and third-party commercial losses being borne by the releaser; and that while the belief in species-extinction/ecological-disaster is the motivation of all discharge-regulation and casualty-release response, no member state has yet conducted a response capable of preventing such extinction/disaster had it been other than mere belief, known seawater concentrations of all releases being too low for such extinction/disaster however inadequate the belief-consensual response may have been (paragraphs 5.3 - 5.7)[6].

3.4 However, while this belief is the cited motivation of all casualty-release response, it nonetheless opposes the knowledge-only dispersant-use which would minimise commercial losses and prevent the *in situ* decanting of co-collected and demulsified water which makes the mechanical- recovery alternative less cost-effective than it would be were such decanting permitted. Again, this belief prevents the safe-haven cargo/bunker transfer which, given the low encounter-rates of dispersant-application and mechanical-recovery, is the only means of avoiding the releases which substantially increase third-party commercial losses, and which would cause species-extinction/ecological-disaster were such to be other than mere belief[4-6] (paragraphs 2.1 - 3.3 and 4.1 - 5.17). Thus, we see that the belief-consensus which currently controls the environmental agenda is the cause of external conflict while its internal inconsistency remains unrecognised; and that progress on the guidelines for claim submission and settlement depends on acceptance of environmental knowledge and on rejection of the environmentalist beliefs of pseudoscience[4-6].

4 The Associated Document Submitted by ISCO to MEPC 67

4.1 This document to IOPCF/OCT/14/4/6 was written in association with that previously submitted to MEPC 67[6] (paragraph 1.3). Thus, the MEPC was invited to recognise previous release-responses as having done little more than collectively confirm the absence of species-extinction/ ecological-disaster however large and prolonged the release; and thus to accept knowledge-only response as the sole means of returning affected environments to their pre-incident states quickly and cost-effectively, thus minimising the third-party commercial losses which are the only real consequences of casualty-releases let alone operational-discharges.

4.2 Again, to encourage acceptance of these recommendations, the document to MEPC 67 attributes all industry/member-state dissent within the MEPC (paragraphs 3.1 - 3.4) to the belief in species-extinction/ecological-disaster which in addition to thwarting casualty release-response as identified in paragraph 3.4, has also been driving operational discharge and combustion emission regulations beyond need and realistic capability while thwarting solution of the ballast-organism problem. Yet again, the document to MEPC 67, attributes the growing dissent of member states from the belief in anthropogenic global warming (AGW) to the failure of its believers to reality-evaluate their belief to positive or negative knowledge, and to the failure of believers and deniers alike to do other than debate belief/counter-belief in respect of cost-impositions for CO_2 emissions. Accordingly the document to MEPC 67 suggests that the UNPCC be invited to suspend these impositions pending reality-evaluation of the AGW belief to the positive or negative knowledge which alone will terminate all such debate; and that current efforts to reduce running-costs by increased fuel-efficiency will reduce CO_2 emissions whether AGW belief is reality-validated or reality-refuted in the longer term[6].

4.3 Thus, having shown that industry/state dissent would be resolved were knowledge to replace belief in respect of release prevention and response and in respect of zero discharge, and that state/state dissent would be resolved were belief in AGW to be reality-evaluated to positive or negative knowledge, this document to IOPCF now shows that state/secretariat dissent in respect of the drafting of guidelines for claim submission and settlement would also be resolved were the new knowledge-only approach to contingency and incident-specific response planning to be accepted and were its countering beliefs to be rejected. Thus, this document for IOPCF now summarises the knowledge repository in paragraphs 5.1 - 5.17, the contingency plan derived from the repository in paragraphs 6.1 - 6.7, and the incident-specific planning format derived from both which will cost-effectively guide all aspects of casualty-response through the sequential steps which will additionally facilitate submission and evaluation of incident-specific compensation claims, as outlined in paragraphs 7.1 - 7.5.

5 The Knowledge Repository

5.1 The knowledge[1, 2] intended for this repository has been referenced in reporting progress on the new ISCO approach to contingency and incident-specific planning to Technical Group meetings 10-16[4], and has been more fully reviewed in Cormack's Column[5] in the ISCO Newsletter where it has also been definitively differentiated from the beliefs which have been regulating it out of use wherever it has not already been lost by the frequency of staff-turnover and the infrequency of incidents (paragraphs 1.2 and 1.6). Thus, this repository will identify the physicochemical parameters which control the fates and effects of oil/HNS releases, and which by insertion of incident-specific values will produce knowledge-only incident-specific response plans for all future incidents involving oils and/or HNS.

5.2 Thus, while readers are referred for more details to the above sources and to the associated MEPC 67 document[6], this IOPCF document now shows how compilation of the new repository will secure reclaimed knowledge against staff changes in member states; how the resulting knowledge-only contingency plan will enable even fresh staff in member states to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors employed, results obtained, and costs incurred to be reported to the IOPC Funds and P&I Club secretariats for expeditious knowledge-only settlement of claims and to the IMO secretariat for enhancement of the collective knowledge repository through which IMO would then be able to maintain a continually enhancing backup for individual member states[6] (paragraphs 1.2 and 1.3).

5.3 As to the knowledge itself, WSL acquired most of it between October 1974 and March 1979 (paragraph 1.5) by reality-evaluation of a series of hypotheses to the positive knowledge[1-6] that oils disperse from floating layer thicknesses of ~ 0.1mm; that while water-in-oil emulsion formation may increase thickness to ~ 0.4mm, the oil quantity per unit area is unchanged; that were these thicknesses to disperse instantaneously with retention in the top metre of the water column, the resulting concentration would be 100ppm; that oils with high rates of natural dispersion such as Ekofisk crude, disperse completely while producing top metre concentrations of no more than 1- 2ppm; that these dilute further by diffusion and turbulent mixing throughout the entire water column in which they are biodegraded by the micro-organisms which biodegrade the entire marine biomass; that slicks disperse completely at viscosity-dependent half-lives unless interrupted by stranding; that diluting/biodegrading concentrations at 10-15 metres depth are ~0.5ppm while top metre concentrations beneath naturally dispersing micron thickness sheens surrounding the main slick are in the range of 0.1 - 0.01ppm; and that were oil to be the cause of species-extinction/ecological disaster it would need to be toxic at these concentrations (paragraph 5.5).

5.4 Again, WSL, reality-evaluated the belief in dispersant-induced concentrations being the cause of species-extinction/ecological-disaster to the knowledge that 5 minutes after dispersant-application those in the top metre average 20ppm, while after 10 minutes and within an hour they average 5ppm and 2ppm respectively. Yet again, belief was reality-evaluated to the knowledge that volatile oil components and volatile HNS cannot reach saturated vapour pressure because they dilute into the atmosphere and degrade by photolysis or biodegrade in the sea after rainout as do non-volatiles directly. However, WSL already knew, as a matter of public record that believers in species-extinction/ ecological-disaster measured LC_{50} values for oils and dispersants without regard to concentration/ degradation; that to measure LC_{50} values for the early hydrocarbon-based dispersants the UK Ministry of Agriculture Fisheries and Food simply exposed the test organism *Crangon crangon* to concentrations high enough for long enough; that when the toxicity of later water-based concentrates became too low to be thus measurable, the test organisms were exposed to 1000ppm of oil (fresh Kuwait crude) dispersed in seawater with 1000ppm of dispersant or with 100ppm of the later concentrates; that while the earlier test ensured acceptance of only the least toxic dispersants, the later testing revealed a reluctance to recognise the non-toxicity of the new concentrates and a desire to continue measuring the ‘toxicity’ of dispersed oil despite the risk of thus accepting only the least effective dispersants; and that neither test took any account of the concentrations in the sea as directly measured nor indeed of the total absence of extinction/disaster at all incidents to-date whether dispersants were used or not.

5.5 Thus, we can confidently conclude as a matter of knowledge that the thinness of floating layers of oil, their rates of natural dispersion and the increases induced by dispersant-use produce concentrations in the top metre which are too low to produce toxicity anywhere in the water column; that the oil released at sea does not act as a biocide in respect of the micro-organisms which biodegrade it; that consequently, the banning or restriction of dispersant-use, the banning of the discharge of recovery-process water, and the prohibition of safe-haven cargo/bunker transfer, arise from belief rather than from knowledge; and that the duration of net-fishing bans owes more to belief than to knowledge while filter-feeding shellfish may be freed of oil droplets by routine pre-sale depuration.

5.6 As to belief in exposure to HNS being the cause of species-extinction/ecological-disaster, this too was reality-evaluated by WSL as a series of hypotheses in the light of the knowledge that some disperse, dilute and biodegrade as do oils; that others dissolve before diluting and biodegrading; that some evaporate including the volatile components of oils; that yet others are neutralised by the inorganic content of seawater; that the behaviours of all of them together with non-soluble/non-dispersing solid exceptions is predictable from the values of their relevant physicochemical properties as are those of all the oils; that whether they are components of oils or individual HNS, all with boiling points < 250°C evaporate in < 5 hours to the extent of 20 - 30% or 100% respectively; that the atmospheric concentrations with respect to altitude are similar to those of dispersers/dissolvers in the sea with respect to depth; that evaporators simply evaporate; that while water-in-oil emulsions naturally disperse at half-life rates dependent on their measurable viscosities, floating non-volatile HNS have slick thicknesses no more than 0.1mm, do not form emulsions and disperse at half-life rates dependent on their known viscosities; and that these are generally in the gasoline-diesel range (< 5cSt at 15°C) which disperse naturally without dispersant-inducement. and that all HNS which thus disperse, dissolve or evaporate, need neither induced-dispersion nor removal, these being pointless/impossible in any case after natural dispersion, solution or evaporation, regardless of their LC_{50} values.

5.7 Again, beliefs as to the effectiveness of dispersants and mechanical-removal were reality-evaluated as hypotheses by WSL to the knowledge that both are limited by pollutant-viscosity, the former more than the latter, though the latter vary with individual design principles; that removal has the further disadvantage of requiring downstream processing to separate water co-collected with the emulsified oil, to break the emulsion and to separate the demulsified water from the demulsified oil, this processing being unavoidable to conserve oil-storage capacity and to recycle the oil. However, we know that the belief in species-extinction/ecological-disaster which was reality-refuted in the mid 1970s as recalled in paragraphs 3.3 - 4.2, restricts or prohibits dispersant-use within arbitrary water depths and/or distances from shore and prohibits *in situ* discharge of all process-water by having classified it as a controlled waste lest any droplets be returned to the sea no matter how high the dilution; that this in turn requires all such processing to be conducted at approved sites such as oil refineries the capacities of which are limited to their own internal requirements; and that consequently, the cost-effectiveness of release-response is greatly reduced for no benefit whatsoever.

5.8 However, further to the real limitations on dispersant and mechanical-recovery effectiveness, WSL reality-evaluated hypotheses to the knowledge that with neither technique being equally applicable across the range of potential viscosities, both should be applied within their known viscosity limits regardless of arbitrary water depths and/or distances from shore, that removal is additionally limited by wave action unless the recovery unit is small enough and light enough to follow the wave-air interface without agitating the floating layer to droplets which pass un-removed beneath the unit. Thus, we see that reality-refuted beliefs in extinction/disaster and in expectations of equipment performance continue to distract responders from the knowledge which would return environments to their pre-incident states more quickly and cost-effectively than beliefs have ever permitted (paragraphs 1.3 & 4.1- 4.3).

5.9 However, in addition to knowing that floating layers of oils/HNS are too thin to produce toxicity in the water column, we also know from the reality-evaluation of hypotheses by WSL that this thinness limits the encounter rate of response units with the floating layer, as does the swath width and travelling speed of the response unit; that for a response unit of 1 metre swath width travelling at 1 knot, the encounter rate with a pollutant layer thickness of 0.1mm is 0.18 m^3h^{-1}; that while a sweeping boom system may increase the effective swath width of a recovery system to 100 metres, its towing speed is limited to 1 knot, if pollutant is not to be lost beneath the unit; that such a system would need two ships to tow the boom and another to recover the collected pollutant; that while encounter rate would thus be $18m^3h^{-1}$, the recovery rate per ship would be viscosity- and/or wave-dependent, and at best would be only $6m^3h^{-1}$ per ship; and that contingency plans based on recovery units nominally rated at $100m^3h^{-1}$ owe more to belief than to knowledge. Again, we know from reality-evaluation of hypotheses by WSL that with an effective swath width of 20 metres, the encounter rate of a ship-mounted spray-set travelling at 5 knots would be $18m^3h^{-1}$ while that of an aircraft at a speed 125 knots with an effective swath width of 16 metres would be $360m^3h^{-1}$ though a spray rate of 18-36m^3h^{-1} would be needed, while, for example, the dispersant payload for a DC 3 is only about $2m^3$ per sortie.

5.10 As to comparison of the foregoing encounter rates with the natural evaporation and dispersion rates of releases, WSL showed that a 5,000 tonne (m^3) release of a crude oil would evaporate to 25-30% in < 5 hours which equates to say, 1,250m^3 being lost at an average rate of ~ 250 m^3h^{-1}, leaving 3,750 m^3 to disperse naturally; that at a thickness of 0.1mm this would cover an area of 37.50km^2, that this would be difficult if not impossible for response-units to encounter entirely at attainable rates; that at a half-life of 12 hours, this 3,750 m^3 would disperse naturally at 12 hour intervals in the sequence of 1,875, 937.5, 468.7, 238, 169, 85, 42 . . .m^3; that this sequence results whatever the half-life interval; that a 50 m^3 release of heavy fuel oil would disperse at intervals of days depending on its specific half-life as 25, 12, 6, 3 . . . m^3, there being no evaporative loss; and that all such sequences diminish to ~ 1% of the initial quantity after the lapse of ~ 7 half-lives. Thus, we see that evaporation and natural dispersion rates greatly exceed any attainable rates of dispersant-induced dispersion or of mechanical removal. Indeed, a release of 100,000 m^3 of crude oil would evaporate to the extent of 25,000m^3 in < 5 hours and disperse naturally in the sequence, 75,000, 37,500, 18,750 . . . m^3 per half-life interval.

5.11 As to the half-lives of surface slicks of non-volatile/insoluble oils/HNS in general, we know that on the above basis, all have been Grouped I - IV within half-life values and ranges of 4, 12, 24 - 48 and > 48 hours by reference to the values and value-ranges of their relevant physicochemical properties; that those of heavy fuel oils are grouped in three viscosity ranges as 2 - 4, 4 - 6 and 6 - 8 days; that these half-lives indicate the increased likelihood of having to respond at sea to reduce arrival onshore; and that known encounter-rates with the inverse thinness and areas of slicks, make imperative the limitation of potential release which cargo/bunker transfer alone provides. Again, we know that HNS packages are smaller than HNS cargo tanks which are smaller than oil cargo tanks; that only about 3,000-5,000 tonnes (m^3) of oil can be released from one damaged cargo tank of the largest oil tankers; and that plans to respond at sea to more than 5,000m^3 prior to arrival onshore is unrealistic (paragraphs

5.9 & 5.10). As to the need to respond to non-volatile/soluble surface slicks of HNS, we know that the half-lives for solution are likely to be less than the 4 hours of the most rapid natural dispersion of insoluble oils/HNS.

5.12 As to the potential arrival of releases onshore, we know that these are only the floating residues of incomplete evaporation, solution or dispersion; that none would have arrived had these processes been completed between release and potential arrival; and that consequently the options on arrival are to permit or assist completion of these non-toxic non-coating processes by dispersant application and/or physical removal of that for which these treatments have been ineffective for timely avoidance of shoreline arrival; that dispersant-use is unnecessary for natural evaporators or dissolvers; but that it assists natural dispersion without putting more of the release into the sea than would have gone in had more time been available prior to stranding, no further action then being needed; that mechanical removal, of that which does not disperse rapidly enough, needs downstream processing; and that when effective, dispersants are thus preferable to removal, even when the quantity released and proximity to shore of the release-point requires both.

5.13 As to monitoring the movement of slicks between source and shore, WSL in collaboration with the Royal Signals and Radar Establishment (RSRE) reality-evaluated a series of hypotheses to the knowledge that a combination of airborne IR/UV line scanning and side looking radar could differentiate slicks from natural surface phenomena; that by relating their respective images to direct measurements of the thicknesses of windrows and of spreading phases II and III, the combination could differentiate thicknesses > 1.00mm, 0.1- 0.4mm and the micron range; and that this was sufficient to direct response-units to areas of greatest encounter rate and to estimate quantities and locations of stranding, but insufficient to determine operational discharge-concentrations in parts per million.

5.14 As to shoreline cleaning, WSL reality-evaluated hypotheses to the knowledge that encounter-rates may increase by up to a factor of 10 when emulsified slicks are pressed against shorelines by onshore winds while stranding on ebb-tides; that consequently the shore is more effective than any deployable boom or adsorbent; that inshore removal from water surfaces is thus more effective than recovery at sea; that emulsion layers up to say 5mm thickness can also be collected from wet (poorly drained) sand beaches by water flushing into contour-trenches dug for recovery by viscosity-tolerant pumping; that stranded emulsion is otherwise difficult to separate from underlying beach materials without co-collection and subsequent separation by equipment designed for this purpose; that on well-drained sand where flushing water would simply drain away, heavy rubber strips attached to the lower-edge of mechanised scraper-blades can be effective in pushing the emulsion into contour-trenches; that non-separated mixtures of emulsion and sand collected by scraping can be stabilised by addition of lime to form concrete when suitable building projects are concurrent; and that otherwise the options are *in situ* bioremediation or ‘land-farming’ at oil refineries.

5.15 However, further to the physicochemical approach, WSL reality-evaluated hypotheses to the knowledge that gelling agents cause dispersants to cling to and act on emulsions coating sloping and vertical surfaces prior to water-jet washing; and that application of surface-film chemicals between shore and shore-proximate slicks can prevent stranding in onshore winds and on flooding tides, or that application onshore prior to stranding can avoid adhesion and thus facilitate removal on ebb-tides and offshore winds. Further to emulsions recovered from water and shoreline surfaces, we know that these have to be processed prior to use as low grade fuel; and that, as with much other ‘recycling’, the actual value is far below the cost of removal and processing, without being further increased by its separated waters being classified as controlled wastes which cannot be discharged *in situ*.

5.16 Thus, we may confidently conclude from the above summary of reality-validated knowledge, acquired largely by WSL, that the maintenance of a response capability for releases of more than the 3,000 - 5,000 m^3 to be expected from damage to one oil cargo tank is unrealistic; that to expect to avoid shoreline cleaning in the event of a total release of cargo and bunkers is even more so; but that those who believe in species-extinction/ecological-disaster will do all they can to prevent the safe-haven cargo/bunker transfer which would prevent the initial impact-release from one or two tanks from becoming the release from all those subsequently weather- or impact-damaged at the location of the initial incident. Thus we see belief in species-extinction/ecological-disaster to be inconsistent in being cited to avoid a low risk of small releases in a haven while accepting the high-risk/inevitability of massive release outside it, while ignoring the third-party commercial losses likely to arise from the latter, despite the belief itself having been reality-refuted in the mid 1970s and despite species-extinction/ecological-disaster never having arisen from any release or operational discharge thus far *i.e.* not even from the *Torrey Canyon Incident* of 1967 which erroneously initiated this belief.

5.17 The intended repository of knowledge, of which the foregoing is a summary, will also describe the equipment and techniques for securing casualties for safe haven entry, for cargo/bunker transfer therein and for all other activities onboard casualties; for aerial remote sensing of floating slicks; for dispersant-treatment and/or mechanical-removal at sea, from inshore waters, and from all types of shorelines and manmade coastal structures as and when possible: all of which knowledge is already available and reality-validated for use[2,4-6] though not here described.

6 Knowledge-Only Contingency Planning

6.1 Having presented the above summary of the intended knowledge-repository, this section now presents an outline of the knowledge-only contingency plan to be derived from it. This plan will relate the physicochemical parameters of oils/HNS to the full range of fates and effects to be expected from their releases; identify the parameters for which response is necessary and unnecessary; and identify the equipment and techniques best suited to whichever response is necessary. Again, this knowledge-only contingency plan will recognise cargo/bunker transfer and well-capping as the primary aspects of shipping and oil-well casualty-response; recognise the natural processes of evaporation, dispersion, solution, dilution and biodegradation as the inherent self-protectors of the environment; recognise human response only in so far as it limits commercial loss by preventing avoidable casualty-releases, by enhancing natural rates of biodegradation/neutralisation and/or by mechanical-recovery; and recognise incurred costs only in so far as they are commensurate with commercial loss-minimisation, belief in species-extinction/ecological-disaster having been reality-refuted some forty years ago.

6.2 Thus, this new knowledge-only contingency plan will be ubiquitously capable of minimising commercial-loss by cargo/bunker transfer and by dispersant-use and mechanical-recovery at sea, and of relating the potential use of shoreline release-response techniques to individual shoreline types and tidal ranges. Thus, for example, it will recognise UK shoreline types as including mudflats, salt-marshes, poorly and well-drained sand, shingle, pebble/cobble, rock and cliffs, all of which are exposed to substantial tidal ranges, while shorelines elsewhere may be predominately sand, mangrove or coral and may be non-tidal and consequently unable to expose inter-tidal shoreline widths for the stranding of released oils/HNS whatever their type, as for example, in the Mediterranean, Baltic, Black Seas. Thus, this new contingency plan for non-tidal shorelines will have no need of response-equipment reality-validated for inter-tidal use, though it will recognise that inter-tidal stranding will not interrupt the use of equipment reality-validated for inshore waters whether tidal or non-tidal.

6.3 Thus, while reality-validated equipment for dispersant-application and mechanical-removal at sea is capable of minimising/preventing stranding on tidal shorelines, the new contingency plan will recognise the lack of need to prevent slicks at sea from becoming contiguous with non-tidal shorelines and the need only to stockpile such inshore equipment as is commensurate with the residual release-quantities arriving there, having already recognised cargo/bunker transfer as the primary aspect of incident-response, and non-tidal shorelines as offering more efficient containment for recovery than do floating booms. Again, for coastal states with limited ranges of shoreline type, the new contingency plan will recognise a need only to stockpile a correspondingly limited range of equipment types. Yet again, with seawater concentrations for natural and dispersant-induced dispersion being effectively non-toxic, the new contingency plan will recognise that the only choice with respect to the dispersant/ mechanical-recovery options is for use of the most viscosity-tolerant variants of either or both.

6.4 However, the new contingency plan will also recognise that oils/HNS off-loaded from casualties by cargo/bunker transfer must also arrive onshore; that the crude oils must go to refineries; that bunkers and fuel cargoes must go to bunkering stations; that HNS from parcel tankers, specialised containers or individual packages within standard containers must go to intended or alternate customers; and that while released oils recovered from water surfaces or from shorelines may be recycled for heat-producing combustion in a variety of identifiable industrial processes, HNS arriving onshore as release-residues or in leaking packages must be treated, collected, over-contained, recycled or ultimately disposed of by the standard procedures of the chemical industries which produce them.

6.5 As to the details of slick treatment, the new contingency plan will recognise that dispersants should be applied to the slick-edge closest to shore, wind permitting; that to apply it elsewhere is to permit the untreated slick already closer to shore to strand untreated if it fails to disperse naturally; that treatment of the shore-proximate edge as the slick moves closer to shore can be continued onshore when natural dispersion coupled with dispersants and mechanical removal fails to prevent stranding; and that longitudinal application of mechanical removal along windrows enables single-vessel recovery systems to maximise their encounter- and hence removal-rates from the increased thickness of windrow layers. Again, it will recognise that the quantity eventually stranded, can be estimated from the length, width and thickness of the coverage and/or from the quantities subsequently removed or dispersed, the latter being estimated from the quantity of dispersant used; that the quantity stranded also equates to the quantity released less the quantities evaporated, dispersed naturally, dispersed by dispersants (estimated from the quantity used) and removed mechanically prior to stranding; and that future mass-balancing will increase the precision of our current knowledge of the viscosity-dependence of half-lives and of induced-dispersion and mechanical-removal efficiencies .

6.6 The new contingency plan will also recognise that salvage claim adjudications under Lloyds 'Chapter XIV' have already used this mass-balance procedure, adjusted for local incident-specific wind and tide conditions, to compare the quantity stranded after release-times at sea with the quantity released, and with the quantity which would have stranded under the prevailing conditions had the remaining cargo and bunkers not been removed; and that this was successful in respect of claims arising from the *Aegean Sea, Carina, Nikitas Roussos, Patraikos II* and *Sea Empress Incidents* (paragraph 7.4 - 8.2). Indeed, the new contingency plan will recognise that for the *Sea Empress Incident*, the quantity stranded from the initial release of 3,000 - 5,000 tonnes was compared with the quantity stranded from the subsequent releases totalling 67,000 - 69,000 tonnes and with those which would have stranded from the total release of 130,000 tonnes had salvors not been permitted to remove the residual 58,000 tonnes (paragraph 1.6); and that when these analyses and previous analysis of the general need for safe haven access[1, 5] were brought to the attention of the Donaldson Enquiry, a unique post was created for an individual uniquely responsible for future UK safe haven access and use.

6.7 Thus, were the summarised knowledge repository (paragraphs 5.2 - 6.1) and the approach to contingency and incident-specific plans (paragraphs 6.2 - 7.2 & 7.4 - 8.3) to be accepted in principle, accepting states could look forward to reporting assessments made, decisions taken, accredited contractors used, results obtained, and costs incurred, to the IOPC Funds and P&I Club secretariats for expeditious settlement of claims, and to reporting the mass-balancing results of successive incidents to the enhancement of the knowledge repository maintained by IMO and disseminated to all member States in respect of the increasing precision of viscosity/half-life and viscosity/response-efficiency relationships. Again, such acceptance would assist the International Spill Accreditation Association (ISAA) in accrediting response-contractors together with IMO member States to this new knowledge-only approach, and would enhance the ability of the IOPCF and P&I Club secretariats to assess and settle the resulting claims.

7 Knowledge-Only Incident-Specific Planning

7.1 Having compiled the knowledge-repository summarised in paragraphs 5.1 - 5.17 and having thus created the knowledge-only contingency plan outlined in paragraphs 6.1 - 6.7), this section shows that substitution of incident-specific values for the physicochemical parameters of the contingency plan creates incident-specific plans; that these substitutions predict whether incident-specific oil/HNS releases will float, sink, evaporate, dissolve or disperse; that these predictions determine which incident-specific responses will be appropriate at sea, which shoreline-interactions might result, and which incident-specific responses will be appropriate in inshore waters and on shorelines; that these determinations themselves determine the knowledge-only response; and that were all such knowledge-only predictions made, decisions (determinations) taken, accredited contractors used, results obtained and costs incurred to be submitted for compensation settlement, all previous dissentions over belief/ counter-beliefs would be avoided.

7.2 Thus, when a liquid non-solidifying release arises from an impact damaged casualty, the incident-specific plan will recognise that the first step is to avoid subsequent weather-damage releases; that the second is to ascertain the values of the physicochemical parameters relevant to its cargo and bunkers; that the third is to note the fates and effects of any releases in terms of floating or sinking, of fractional or total evaporation, and of total solution or progressive dispersion according to the half-life/ viscosity relationship previously tabulated for crude oils and bunkers; that the fourth is to calculate the fractional evaporative loss from any crude oil cargo from its fractional distillation profile as tabulated, this being usually 25 - 30% in < 5 hours; that the fifth is to calculate the time to reach shore from the vector sum of 100% of the tidal vector and 3% of the wind vector; that the sixth is to apply the respective viscosity-dependent dispersion half-lives of the non-volatile fractions of the cargo/bunker oils and of the non-volatile insoluble HNS to the quantified releases and to the time to reach shore in order to estimate the quantities likely to arrive on the shoreline types identified at these locations; that the seventh is to consider, on the basis of known viscosities and half-life dispersion rates, whether dispersants or recovery, both or neither, should be applied at sea, there being no need to enhance or prevent dispersion which of itself would prevent any onshore arrival. Thus, we see that were this sequence to be followed, it would not only give directional structure to the response, it would also provide a format for claim submission and subsequent settlement.

7.3 Again, when a solidifying release arises, the incident-specific plan will recognise that all such oils/HNS have been identified; and that with recovery being the only option, it will be best dealt with onshore; that when a soluble HNS is released, the incident-specific plan will recognise that it will dilute and biodegrade or neutralise; that the half-life of soluble liquid HNS will be shorter or comparable to the dispersion half-life of insoluble HNS of viscosity < 5cSt at 15°C; that there may be no need to assist these natural processes; that there is no possibility of recovering evaporated, dispersed or dissolved substances; but that known toxicity-concentration relationships may require their concentrations in seawater to be monitored by progressive measurement down-tide of the source, warnings as appropriate being the sole release-response in such cases. Yet again, when a gas is released from an impact-damaged casualty, the incident-specific plan will recognise that it will naturally disperse and dilute downwind of the source in an expanding/diluting plume; that there is no need for assisted dispersion and no possibility of recovery; but that its concentration in the atmosphere may need to be monitored, the issuance of guidance to downwind populations being the sole release-response in such cases also, though gas-jets may be ignited as they are from oil-rigs in standard operational practice.

7.4 As to the banning of net- and line-fishing, the incident-specific plan will recognise that fish never contact floating slicks unless they break the surface; that the water in which they swim never contains dispersant-induced oil droplets equivalent to molecular concentrations of more than 10-20ppm in the top metre (paragraphs5.3 - 5.6); that these decrease rapidly with time and depth; that such concentrations are consistent with the absence of taint reported by tasting panels served with fish caught in seawater concentrations exemplified by the Ekofisk blow-out; and that in respect of releases of dispersing or soluble oils/HNS, such measurements of concentration with or without panel tasting ought to decide the need for and the duration of fishing bans. As to banning the sale of shellfish, the incident-specific plan recognises that oil-coated shellfish on shores and on cultivation stakes are un-sellable as are fish drawn in nets through floating slicks; but that these must be differentiated from depurated shellfish previously in contact with oil at ppm-ppb concentrations; and that such differentiation would reduce compensation-claims caused more by bans *per se* than by releases *per se.*

7.5 In continuance of paragraph 7.2, the incident-specific plan will recognise that the eighth step is to repeat the sixth step to estimate the quantity likely to strand just prior to its arrival, having further reduced it by the quantities already recovered or dispersed by the quantity of dispersant already applied at sea; that the ninth is to revise the identification of the shoreline types and extents to be impacted and the lengths, widths and thicknesses of this impaction; that the tenth is to identify the equipment and techniques applicable to each shoreline type and to its contiguous inshore waters, all such being stockpiled locally or nationally; that the eleventh is to activate transportation of associated equipment in quantity and sequence appropriate to predicted need at these various locations; and that the twelfth is to identify and warn those who might wish to receive oils from broken emulsions as low grade fuels or to accept emulsions for such processing or for bioremediation by land-farming, all such potential recipients having been identified in the national/regional/local contingency plans at appropriate levels of detail. Again, we see that this sequence would not only give directional structure to the response, it would also provide a format for claim submission and subsequent assessment.

8 Next Steps

8.1 Further to this document and to that submitted to MEPC 67[6], ISCO will now collate the knowledge-repository supportive of its knowledge-only contingency plan from which all future incident-specific oil/HNS response plans will be derivable, the contingency plan having identified the physicochemical parameters which control the fates, effects and non-effects of oil/HNS releases, which determine prevention and response when and where needed, and which by their incident-specific values predict incident specific fates, effects and non-effects, thus enabling incident-specific prevention and response to be as rapid and as cost-effective as possible. In addition, with the intention being for this contingency/incident-specific approach to cover casualty preparation for safe haven entry, cargo/ bunker transfer and release-clearance at sea, inshore and onshore, the knowledge-repository will also describe all relevant response equipment and techniques with reference to their viscosity-/wave-dependent performance in so far as this has already been reality-validated.

8.2 On completion of this approach, ISCO intends member States to have access to a repository of knowledge secure against staff-turnover and a contingency plan from which even fresh staff will be able to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors used, results obtained and costs incurred to be reported to IOPC Fund and P&I Club secretariats for expeditious settlement of claims and to the IMO secretariat for enhancement of the then shared repository of knowledge.

8.3 At this point, member states are invited to reject the belief in species-extinction/ecological-disaster as reality-refuted; to accept third-party commercial losses as the only real effects of ship and oil-well releases; to accept in principle the knowledge repository, the contingency plan and the incident-specific response planning procedure currently outlined in paragraphs 5.1 - 5.17, 6.1 - 6.7 and 7.1 - 7.4; to accept knowledge as the only means of resolving belief/counter-belief dissention in general[7]; and to accept the foregoing incident-response knowledge in particular, as the only means by which the current belief/counter-belief dissention is to be resolved in respect of the intended guidelines for claims submission and settlement.

9 References

1 Response to Oil and Chemical Marine Pollution, D. Cormack, Elsevier Applied Science, 1983
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack, Kluwer Academic 1999.
3The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack, Bright Pen, 2010, available from www.authorsonline.com
4 Knowledge-Based Response Planning, MEPC/OPRC-HNS/TG Documents for TG 10 - 16
5 Cormack's Column, ISCO Newsletter, weekly articles from 8 November 2010
6 Harmonisation of Technology and Environment, ISCO Document for MEPC 67.
7 www.knowledgeonlypolicy.weebly.com

10 Action to be taken

10.1 IOPCF Assembly is invited to note the information supplied in this document.

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The document MEPC 67/19/INF.13 was subsequently presented to MEPC Delegates as a summary of the documents already presented to meetings 10 - 16 of the Technical Group on the authorisation of MEPC 59, these presentations having been based on the author's newly definitive knowledge/belief differentiation. By comparing the exposure concentrations of oil and dispersant in the regulatory procedure for dispersant approval, with those arising in seawater from natural and dispersant-induced dispersion of slicks, the Introduction to this document concludes that such regulatory testing has no useful relationship to reality, while the document itself recalls that environmentalist NGOs were invited to reality-evaluate their beliefs in species-extinction/ecological-disaster and in anthropogenic global warming, in light of our existing knowledge of the ecosystem and of the global biological/geological mechanisms of carbon dioxide recycling; that suggestions were made as to the hypotheses they might reality-evaluate to this end; and that no response had yet been received. The document then reviews the advantages of the new knowledge/belief differentiation and the disadvantages of mistaking belief for knowledge in its absence.

Following this knowledge/belief differentiation, document notes that belief-driven regulation of oil/ HNS discharges was saved from failure in reality, only by subsequent knowledge-acquisition; that belief-inspired regulation of ballast discharge has apparently failed in reality with as yet no knowledge-acquisition to save it; and that regulation of emissions is based on beliefs which have not been reality-evaluated as to need or means of compliance; and that such knowledge-acquisition requires the differentiation of science/pseudoscience and assent/dissent by recognition of the presence/absence of the reality-evaluation which definitively differentiates knowledge from its counter-beliefs.

As to next steps, the document advises Delegations to accept that the belief in species-extinction/ ecological-disaster has long been reality-refuted to negative knowledge; to adopt the new knowledge-only approach to incident-response; to invite the UNCCC to resolve the belief/counter-belief debate anthropogenic global warming by reality-evaluation of the belief to positive or negative knowledge; to reconsider the regulatory limits on operational discharges of oils/HNS in light of the longstanding reality-refutation of belief in accidental releases being the cause of species-extinction/ecological-disaster; to place a moratorium on ballast water discharges pending development of reality-validated means of compliance; and to suspend regulation on emissions until beliefs as to need and means of compliance have been reality-validated to positive knowledge.

The document MEPC 67/19/INF.13 is reproduced below for ease of reference to the knowledge repository of this website.

HARMONISATION OF TECHNOLOGY AND ENVIRONMENT IN RESPRCT OF Oil/HNS
Submitted by the International Spill Control Organisation (ISCO)

Introduction.

1 Since obtaining authorisation from MEPC 59, ISCO has been submitting progress reports to Technical Group meetings 10-16 on its knowledge-accepting/belief rejecting approach to contingency and incident-specific planning for oil/HNS release-response[1,2,4] for which purpose, knowledge and belief have had to be definitively differentiated.

2 Fortunately, this differentiation had already been achieved[3] by my having shown that reality stimulates our imaginations to beliefs transformable to positive or negative knowledge by evaluating their compliance or non-compliance with reality, or to those which can only be accepted, rejected or suspended as beliefs beyond reality-evaluation in principle or in *pro tem* practice, but which cannot be accepted as knowledge; that debate of opinion/counter-opinion is merely debate of belief/counter-belief supported by partially selected facts/counter-facts, neither set of which is debate-terminating knowledge; that the outcome is thus merely a transient belief-consensus which can vary from debate to debate and even flip to the counter-consensus; and that such is no basis for progress in reality.

3 Indeed, this analysis has shown[3] that while reality-evaluation of beliefs as specific hypotheses has peacefully created the knowledge which is craftsmanship, science and technology, belief-consensus not only varies or flips peaceably, it also breaks down in disharmony, violence, revolution or war; that while such has recurred since time immemorial, initiating-dissentions could have been resolved peaceably had available knowledge been applied, had conflicting beliefs been reality-evaluated to positive or negative knowledge or had believers/disbelievers agreed to differ pending reality-evaluation; and that current MEPC dissention would be resolved were reality-evaluation to be seen as the general means of transforming disharmonious beliefs/counter-beliefs to harmonious knowledge[7].

4 Thus, while ISCO had intended to report back to the MEPC as its TG reportage[4]drew to a close, it does so

now because the TG has been subsumed in the PPR, and because developing States and the shipping industry are increasingly dissenting from the belief-consensus which is seen by some to have pushed regulation beyond known need and/or known capability and has thus exposed global society to costs beyond unavoidable need. Accordingly, after reviewing the extent to which belief thwarts knowledge in release-response, this document differentiates the belief-/knowledge-contents of existing and proposed regulations in respect of operational discharges, ballast-water management, and exhaust-gas emission control with the objective of restoring harmony to the MEPC by replacing belief with knowledge to the cost-benefit of member States, shippers, producers, and global society alike.

Knowledge/Belief in Respect of Policy and Regulation on Release-Response.

5 With this new differentiation, we see that the belief in naturally dispersed oil droplets being the cause of species-extinction/ecological-disaster was reality-evaluated as a series of hypotheses by the UK's Warren Spring Laboratory (WSL) to the positive knowledge that oils disperse from floating layer-thicknesses of around 0.1mm; that while water-in-oil emulsion formation may increase these thicknesses to around 0.4mm, the oil content is unchanged; that were these thicknesses to disperse instantaneously with retention in the top metre of the water column, the resulting concentration would be 100ppm; that oils with high rates of natural dispersion (e.g. Ekofisk crude) disperse totally while producing top metre concentrations of no more than 1-2ppm; that these dilute further with diffusion and turbulent mixing throughout the entire water column in which they are biodegraded by the micro-organisms which biodegrade the entire marine biomass; that such natural dispersion proceeds to completion with slick half-lives being dependent on their viscosities unless interrupted by stranding; that diluting and biodegrading concentrations at depths of 10-15 metres are ~ 0.05ppm while those in the top metre beneath naturally dispersing sheens in the micron range of thickness outside the main slick are in the 0.1- 0.01ppm range[1-3].

6 Again, we see that the belief in dispersant-induced oil droplets being the cause of species-extinction/ecological-disaster was reality-evaluated by WSL to the knowledge that five minutes after dispersant-application, top metre oil concentrations average 20ppm, while after 10 minutes and within an hour they average 5ppm and 2ppm respectively; that volatile oil components cannot reach saturated vapour pressure because they dilute into the atmosphere and degrade by photolysis or biodegrade in the sea after rain-out as do non-volatiles directly; and that LC_{50} values are cited by believers regardless of initial concentrations and their subsequent dilution and degradation. Indeed, as a matter of public record, we know[1,2] that the UK Ministry of Agriculture Fisheries and Food exposed the test organism *Crangon crangon* to early hydrocarbon-based dispersants for times and at concentrations sufficient to produce measurable LC_{50} values; that when the toxicity of the new concentrates was too low to be thus measured, the test organisms were exposed to 1000ppm of oil (fresh Kuwait crude) dispersed in water with 1000ppm of dispersant or with 100ppm of the later concentrates; that while the earlier test was sufficient to ensure use of only the least toxic dispersants, the later testing revealed a reluctance to recognise the non-toxicity of the new concentrates and a desire to continue measuring the 'toxicity' of dispersed oil despite the risk of thus accepting only the least effective dispersants; that neither test took account of the concentrations in the sea as measured (paragraph 5), and that these 'toxicity' measurements themselves reality-refuted the belief, as had all casualty-releases to-date[1-3].

7 Thus, we conclude as a matter of reality-validated knowledge that the thinness of floating oil layers, their rates of natural dispersion, and the increases induced by dispersant application are such as to ensure the concentrations in the top metre, let alone at deeper levels, are too low to produce toxicity in the water column; that oil released to the sea is not a biocide in respect of the micro-organisms which biodegrade it; that the bans and restrictions on dispersant-use arise from belief rather than from knowledge; and that the duration of net-fishing bans may owe more to belief than to knowledge while filter-feeding shellfish may be freed of oil droplets by routine pre-sale depuration[1-3].

8 Again, with this new differentiation, we see that the belief in physical coating of individual organisms being the cause of species-extinction/ecological-disaster was reality-evaluated as a hypothesis by WSL to the knowledge[1,2] that manmade structures such as boat-slipways denuded of organisms by deliberate cleaning for pedestrian safety or in the removal of stranded-oil, are re-colonised by the planktonic life-stages of the species removed; and that the former operation has to be repeated prior to and during every boating-season, just as gardens have to be continually weeded. As to the physical oiling of birds, no ornithologist was/is willing to reality-evaluate the above belief by comparing the species-specific numbers dying from oil-coating in any incident with the numbers naturally birthing and dying in the maintenance of these species populations. Indeed the ornithologist who accompanied the WSL team to the Ekofisk blow-out refused to report the absence of oiled birds, all species which dive on fish from the air having vacated the area in which sight of them had been obscured by the slick. Thus, is knowledge obscured to preserve belief by self-styled scientists.

9 As to the belief in exposure to HNS being the cause of species-extinction/ecological-disaster, this new differentiation permits us to see that this belief was also reality-evaluated as a series of hypotheses by WSL in the

light of the physicochemical knowledge[1-3] that some disperse, dilute and biodegrade as do oils; that others dissolve, dilute and biodegrade; that some evaporate including the volatile components of oils; that yet others are neutralised by the inorganic content of sea water; that while some are non-dispersing/non-soluble solids, the behaviour of all of them is predictable from the known values of their relevant physicochemical properties as it is for all the oils; that whether they are components of oils or are individual HNS, all with boiling points < 250°C evaporate in < 5 hours to the extent of 20-30% or to 100% by weight respectively; that the atmospheric concentrations of volatiles with respect to altitude are similar to those of dispersers/dissolvers in the sea with respect to depth; that while water-in-oil emulsions naturally disperse at rates dependent on their measurable viscosities (paragraph 5), floating non-volatile HNS have slick thicknesses no more than 0.1mm, do not form emulsions and thus disperse to concentrations limited by layer thickness at rates dependent on their known viscosities; that these are generally in the gasoline-diesel range (< 5cSt at 15°C) which disperse without dispersant inducement; that all HNS which thus disperse, dissolve or evaporate, need neither induced dispersion nor recovery; and that recovery of all such is needless/impossible after natural dispersion, solution or evaporation, whatever their LC_{50} values.

10 Again, we see that beliefs as to the effectiveness of dispersants and mechanical recovery were reality-evaluated as hypotheses by WSL to the knowledge[1-3] that both are limited by pollutant viscosity, the former more than the latter, though the latter additionally varies with individual design-principles; that the banning or restriction of dispersants to arbitrary water depths and/or distances from shore is based on the belief in species-extinction/ecological-disaster which was reality-refuted in the mid 1970s as recalled in paragraphs 5 - 9; that recovery involves downstream processing to separate co-collected water, to break water-in-oil emulsions, and to separate the demulsified water from the demulsified oil; that this same reality-refuted belief prohibits *in situ* discharge of all such water, having classified it as a controlled waste lest any oil droplets be returned to the sea however much the dilution; that this belief-only regulation requires all such processing to be conducted at approved sites such as refineries of which the capacities are limited to their own requirements. Thus, we know, as reported to the IOPCF[6], that a belief, reality-refuted in the mid 1970s, continues to reduce the cost-effective rate at which available knowledge would return environments to their pre-incident conditions (paragraphs 5 - 9).

11 However, in addition to knowing that oil/HNS concentrations in seawater are limited by their physicochemical properties, and that the regulations which prohibit *in situ* discharge of processed water are expressions of mere belief, we also see that other hypotheses were reality-evaluated by WSL to the knowledge[1-3] that the encounter rate of response units with floating layers is limited by layer-thickness, swath width of the response unit and its travel-speed during the encounter; that for a response unit of 1m swath width travelling at 1 knot, the encounter rate with a pollutant layer-thickness of 0.1mm is 0.18 m^3h^{-1}; that while a sweeping boom system may increase the effective swath width of a recovery system to 100m, its towing speed is limited to 1 knot if pollutant-loss beneath the unit is to be avoided; that such a system would need two ships to tow the boom and one to recover the pollutant; that while encounter rate would thus be $18m^3h^{-1}$, the recovery rate would nonetheless be viscosity-limited, and at best would be only $6m^3h^{-1}$ per ship; and that contingency plans reliant on recovery units nominally rated at $100m^3h^{-1}$ owe more to belief than to knowledge. Again, we see that yet other hypotheses were reality -evaluated by WSL to the knowledge[1-3] that with an effective swath width of 20m, a ship-mounted spray set travelling at 5 knots would have an encounter rate of $18m^3h^{-1}$ while an aircraft with a swath width of 16m travelling at 125 knots would encounter 360 m^3h^{-1}, though this would need a payload of 18 -36 m^3 for an hour of spraying, while, for example, the dispersant payload for a DC 3 is only about $2m^3$.

12 Thus, we conclude from reality-validated knowledge that the maintenance of a response capability for releases of more than the 3,000-5,000 m^3 expected from damage to one cargo tank, is unrealistic, that to expect to avoid shoreline cleaning in the event of a total release of cargo and bunkers is even more so; but that those who believe in species-extinction/ecological-disaster do all they can to prevent the safe-haven cargo/bunker transfer which would prevent the initial impact-release from one or two tanks from becoming the release from all those subsequently weather-damaged at the exposed location of initial impact. Thus, we see the inconsistency of believers in species-extinction/ecological-disaster in citing this belief to avoid a low risk of small releases in a haven while accepting the high risk of massive releases outside it while ignoring the third-party commercial losses likely to arise from the latter, despite this belief having been reality-refuted in the mid 1970s and despite species-extinction/ ecological-disaster never having arisen from any release or discharge thus far (paragraphs 5 - 9)[6].

Invitation to Believers

13 This invitation arose from our knowledge-only approach having reminded us that believers in species-extinction/ecological-disaster deny the biodegradation which recycles all organic substances to the carbon dioxide from which they were photosynthesised; that they deny the re-colonisation/ regeneration which naturally returns sedentary and mobile species to their pre-incident population levels; that they use these denials to prohibit dispersant-use, discharge of post-recovery process-water and emergency-use of safe havens; and that they further use them to justify their regulation of operational discharges beyond known need and beyond the unavoidable costs of shipping operations in general. Again, our new approach reminded us that believers in anthropogenic global warming also deny the recycling of carbon and the other life-essential elements such as sulphur and

nitrogen; and that they use this denial to justify their regulation of exhaust-gas emissions beyond known need and beyond unavoidable operating costs[4]. However, having announced our intention at MEPC 64, to invite believing NGOs to reality-evaluate these beliefs to positive or negative knowledge, and having issued the invitation itself on 15 November 2012, no reply has been received.

14 This invitation sought to encourage reality-evaluation of these beliefs as specific hypotheses by asking the following questions. Why should we believe in species-extinction/ecological-disaster when we know that the concentrations of exposure are low enough to account for their absence in all incidents thus far, that re-colonisation/regeneration rates are high enough and physical coating extents are low enough to account for their absence in all incidents thus far, and that no believer has yet reality-evaluated any such hypothesis by comparing incident deaths with the annual birth/death rates of the relevant species populations? Again, why should we believe in anthropogenic global warming when we know that we combust only part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through the atmosphere and biomass just as initially photosynthesised and now 'fossilised' oils and their organic HNS derivatives recycle after release or discharge? Yet again, with atmospheric carbon dioxide recycling through the biomass by photosynthesis and biodegradation, and through carbonate rock by the tectonically driven Urey reaction and its volcanic reversal, why should we believe in anthropogenic global warming when no believer has yet reality-evaluated any hypothesis as to the rate at which increased carbon dioxide release in one of these cycles would cause increased abstraction in the other or both, and when known variation in vegetative-mass with variation in carbon dioxide concentrations in controlled horticultural atmospheres is an obvious place to start?

Knowledge-Only Response Planning

15 Having, rejected the belief in species-extinction/ecological-disaster as reality-refuted by the knowledge summarised in paragraphs 5 -12, and having invited believers to respond as suggested in paragraphs 13 and 14, ISCO has been reporting progress on its new approach to knowledge-only contingency and incident-specific response planning to TG meetings 10 - 16[4] (paragraph 1) while Cormack's Column in the ISCO Newsletter[5] has been more extensively reviewing all of the knowledge relevant to our new approach to all aspects of casualty-response planning and execution.

16 Accordingly, the ISCO approach will comprise a repository of knowledge supportive of a contingency plan based on the physicochemical parameters which control the fates and effects of oil/ HNS releases, which determine prevention and response, and which by their incident-specific values predict incident-specific fates and effects, thus enabling incident-specific prevention and response to be cost-effective[6]. Thus, on completion of the new ISCO approach to oil/HNS release-response, IMO member states will have access to a repository of knowledge secure against staff changes in member states and a contingency plan from which even fresh staff in member states will be able to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors used, results obtained and costs incurred to be reported to the IOPCF and P&I Clubs for expeditious claim-settlement in absence of the belief/counter-belief dissention which currently prolongs all such negotiations, and to the IMO for enhancement of the knowledge repository which could thus be maintained as a back-up for all member states[6] (paragraphs 5-12 and 52 - 55).

Consequences of Mistaking Belief for Knowledge

17 This document recognises that belief has thus far been mistaken for knowledge by a ubiquitous human failure to recognise the absence or presence of the reality-evaluation which now differentiates them for the first time[3]; that consequently belief in species-extinction/ecological-disaster did more to establish the MEPC agenda in the aftermath of the *Torrey Canyon Incident* than did knowledge of casualty-induced third-party commercial losses; and that without this belief, no-one would have paid for the knowledge-acquisition cited in paragraphs 5 - 12, 15 and 16. Nonetheless, this document also recognises that in the absence of this belief, the MEPC would not have gone beyond known need as far as it has in regulating operational ship-discharges which cause insignificant commercial loss in comparison with casualty-releases; and that such over-regulation imposes needless costs on ship-owners and society in general; but that with these costs not being too unacceptable, and with compliance being facilitated by onshore reception, the regulating belief in species-extinction/ecological-disaster remained unchallenged, despite being reality-refuted by every release, let alone every discharge.

18 Again, this document recognises that the MEPC Member States have devoted much less attention to their response to casualty-releases than to their regulation of operational discharges, despite being the designated agents for all aspects of response to such releases as recognised by the Powers of Intervention conferred upon them by the Convention as *quid pro quo* for the associated costs and third-party compensation being borne by the releaser; that while the belief in species-extinction/ecological-disaster is the stated motivation of all casualty release-response, no member state has yet conducted a response capable of preventing such extinction/disaster had it been other than mere belief; that this belief nonetheless opposes dispersant use; that despite supporting mechanical recovery, it prevents the decanting of co-collected and demulsified water; that despite the limitations of both dispersants and

mechanical recovery, it prevents the movement of casualties to safe havens for the cargo/bunker transfer which is the only means of limiting the releases which would otherwise increase third-party commercial losses and cause the species-extinction/ecological-disaster which such believers are ostensibly seeking to prevent, despite its non-existence (paragraphs 10 - 12).

19 Thus, this document recommends the MEPC Member States to accept that the inadequacy of release-responses to date has collectively confirmed the impossibility of species-extinction/ecological-disaster by its having been absent at all of them, however large or prolonged they may have been; that rejection of this response-thwarting belief will enable knowledge-only response to minimise third-party commercial losses more cost-effectively than any Member State attempt thus far, these attempts having been motivated and thwarted by the same reality-refuted belief; and that the interruption of commercial activity is the only significant consequence of casualty-releases, let alone operational-discharges[6] (paragraphs 52-55).

Knowledge/Belief in Respect of Oil-Discharge Regulation.

20 With our new differentiation, we see WSL hypothesising as early as 1960[1,2] that the oil-content of bilge water would normally be low; that it would be somewhat higher in the initial stages of discharge; that it would be significantly higher in the last few minutes before discharge is stopped; that the latter increase would occur because the oil floating on top of the bilge water would enter the pump inlet as the last of the water was removed; and that the former increase would occur because the last stage of the previous discharge would have coated the internal pipeline-surfaces with oil. Thus by reality-evaluating this hypothesis by direct measurement in four separate cases, WSL acquired the knowledge that concentrations of oil in bilge water averaged 111ppm for the initial stage, 32ppm for the bulk of the discharge, and 10% for the final stage, though spreads ranged respectively from 25 - 209ppm, 8 - 90ppm, and 1.7% - 15%. Again, in 1962, by the reality-evaluation of direct measurement in nine fuel tank ballast water discharges WSL acquired the knowledge that the oil contents of the final stage of approximately 5 minutes duration (equivalent to 1-10% of the total de-ballasting time) averaged 35%, though the inlet spread was 0.12% - 91.70% (paragraph 23). However, while the belief-consensus in species-extinction/ecological-disaster required bilge-water discharges from oil-water separators to have oil-contents < 100ppm, and fuel tank ballasting to be prohibited, the likely expense caused no overt dissention from the initiating consensual belief (paragraph 17).

21 Nonetheless, it was already known from reality-evaluation of specific hypotheses that the performance of gravity separators depends on the rate at which oil droplets rise through the water to coalesce as a continuous phase on top of the aqueous phase; that small droplets rise more slowly than larger; that such droplets are always formed when water and oil are co-agitated; and that creation of the very small droplets of so-called secondary dispersion should be avoided because they are subject to Brownian Movement and do not rise at all. Thus, to limit such agitation within the pump delivering to the ship-borne gravity separator, WSL reported the results of reality-evaluating pump-specific droplet size variation in 1962. The starting point was the theoretical considerations which suggested that seagoing gravity separators would be unable to intercept droplets smaller than 254μm, though this size is considerably larger than that corresponding to the onset of secondary dispersion. However, examples of ten different pumping principles were reality-evaluated, the results being expressed as the percentage of the oil present as droplets < 254μm in diameter after passing through the pumps.

22 These results showed that the triple vane pump caused 12% of the oil to be in droplets < 245μm, the best principle of all; that the centrifugal pump, the most commonly used on ships, caused 56% of the oil to be in this size range; that de-rating the pumps from 10 tonnes per hour to six tonnes per hour improved the performance of all pumps except the centrifugal which remained at 56%, while the triple vane performance was improved from 12% to 3%, and while the de-rated flexible vane gave 98% < 245μm and was thus not evaluated at its nominal 10 tonnes per hour. Thus, with any pump producing > 2% of droplets < 254μm, an inlet concentration as low as 5000ppm (0.5%) would result in any gravity-separator discharging in excess of the IMO Member States' arbitrary limit of 100ppm.

23 Nonetheless, WSL proceeded to reality-evaluate the performance of gravity-separators operating on the fuel tank ballast water discharges cited in paragraph 20. Thus, with the maximum inlet concentrations delivered to the separators being 0.12, 0.17, 0.19, 0.39, 32.60, 44.20, 69.10, 78.20 and 91.70%, the maximum discharge concentrations were 675, 477, 140, 242, 300, 579, 768, 881 and 615ppm. Nonetheless, while all outlets were greater than the arbitrary limit of 100ppm, the separators could be said to have performed more or less equally for inlet concentrations varying from 0.12% to 91.70% with ~ 99.9% efficiency having been achieved at the highest oil-contents, a performance which could have been judged satisfactory given that slippage would further dilute and biodegrade in the proximate environment. However, nothing less than 100% retention onboard is acceptable to the believer in species-extinction/ecological-disaster, despite its absence even in casualty-releases, though amenity-loss from the stranding of some operational discharges had caused WSL to reality-evaluate hydrocarbon-based dispersants for small scale cleaning prior to the *Torrey Canyon Incident* of 1967.

24 To reduce the tendency of pumps to deliver small droplets to the gravity separator (paragraph 22), WSL reality-evaluated the hypothesised benefits of drawing the oily water through the separator with the pump operating in suction mode. Thus, laboratory evaluation of separator performance, showed that with a centrifugal pump delivering inlet concentrations of 200 - 8000ppm in normal mode, the outlet concentrations ranged from 70 - 225ppm; that with a positive displacement pump delivering inlet concentrations of 12,000 and 20,000ppm in normal mode, the outlet concentrations were 100 and 170ppm respectively, while in suction mode for these inlet concentrations, the outlet concentrations were respectively 3 - 16ppm in no particular sequence, and a steady ~13ppm.

25 By 1977, WSL had constructed a reality-evaluation facility for oil-water separators according to the agreed IMO test specification and published its earliest results. There is no doubt that the discharge limit of 100ppm had been set before such a performance had been demonstrated or the test specification had been established, and that while the concept of forcing development by strengthening regulation is often cited, it is impossible to force droplets to form a continuous phase by regulation alone. Nonetheless, a final discharge of 15ppm was already being proposed by believers in species-extinction/ecological-disaster, the suggested means being a downstream coalescence/filtering stage, while the IMO test specification was calling for inlet oil concentrations of 0.5%, 25% and 100% and for three outlet samples to be taken at timed intervals during the 0.5% and 25% inlet periods, one during the 100% period and one during the zero period after cessation of the 100% input.

26 The results obtained by WSL with the first 10 tonne per hour gravity separator to be reality-evaluated at each of the two permitted pump-operating conditions without an additional coalescer were 135ppm (at 0.5% input) and 630ppm (at 25% input) under the first pump condition, and 870ppm and 2,335ppm under the second, while with an additional coalescer they respectively averaged either 3.5ppm or rose from 4 to 73ppm over the eight samples. Again, with a second separator of this capacity, the results with coalescence/filtering, averaged 2.9ppm over the eight samples, while without the coalescence/filtering stage the result for the 25% oil inlet was 1,932ppm.

27 Thus, having shown that new knowledge of oil-water separation had to be acquired for compliance with a Convention belief in the need for an oil-discharge limit of 100ppm, that the knowledge thus acquired had enabled the initial requirement to be exceeded; and that species-extinction/ecological disaster from such individual sources would be impossible anyway: this document asks whether zero discharge in so-called special areas is really necessary when a discharge of 5ppm from a 10 tonne per hour separation system travelling at 10 knots would be discharging 5 x 10^{-5} tonnes of oil per hour or 5 x 10^{-6} tonnes per nautical mile prior to further dilution and subsequent biodegradation. However, with the costs of onboard equipment and shore-reception not being too unacceptable to ship-owners or global society and with operational discharges close to shore having already caused some small amenity-losses, the belief-consensus call for 5ppm or zero discharge caused no overt dissent (paragraph 17).

Knowledge/Belief in Respect of HNS-Discharge Regulation

28 Having shown that a discharge limit of 100ppm was set for oil before any knowledge was acquired as to how it might be met, this document now shows that a pre-wash residue onboard (ROB) limit of < 1 tonne per tank was set for HNS parcel tankers before any knowledge was acquired as to the magnitude of such residues, the motivation again being belief in species-extinction/ecological-disaster. To acquire this knowledge, WSL decided in 1977 to measure these residues onboard an operating parcel tanker as functions of their relevant physicochemical properties. At the outset, WSL noted that the ROB = $Q_b + Q_p + Q_s$ per tank, where the summed quantities are those on the tank bottom, in the associated pipelines, and adhering to internal tank-surfaces; that Q_b and Q_p, could be determined geometrically; that only the Q_s was cargo specific; that the relevant parameters were viscosity and melting point, neither of which was related to LC_{50} values; that at the time, only 15 HNS had viscosities > 5cSt at 15°C, while only 20 had melting points > 10°C for which Q_s might be greater than for liquids; and that volatiles might vent to zero ROB.

29 Further to theory, WSL recognised that $Q_b = (d + a \tan \alpha + b \tan \beta)^3 / 6 \tan \alpha \tan \beta$, where d is the depth in metres of liquid at the suction-point at the end of discharge, a is the distance from the centre of the suction point to the aft bulkhead, b is its distance from the inboard bulkhead, α is the trim angle in degrees and β is the list angle in degrees. If there is a well, the quantity Q_w is computable from its dimensions, while the quantity which does not drain into the well is Q_b from the above equation with d being zero, while $\alpha = \tan^{-1}(h_2 - h_1) / l$ where h_1 and h_2 are the draught-marks at bow and stern and l is the waterline length of the ship and β is the angle directly read from the ship's inclinometer. Thus, when the depth at the suction-point and the dimensions of the well are known, it is possible to compute Q_b without entering the tank. Again, WSL noted that film thickness on vertical surfaces in meters is 1.6 $(U_L \mu / \rho)^{2/3}$ where U_L is the lowering velocity in ms^{-1}, μ is the viscosity in Nsm^{-2} and ρ is the density in kgm^{-3}, while for solidifying products, film thickness on vertical surfaces is 6.5 x 10^{-5} $(T_1 - T_2)$ where T_1

is the product melting point and T_2 is the tank-wall temperature, thus permitting Q_s to be computed

30 As to Q_p it was known that this depends on the type of pump used; that when air is drawn into a centrifugal pump at the end of discharge, it loses suction and the content of vertical pipe sections falls back into the tank and adds to Q_b; that positive displacement pumps do not lose suction in this way, that consequently their vertical pipe sections remain full; that it is possible with low viscosity HNS to clear horizontal pipe sections by blowing nitrogen from the top of the tank to the discharge manifold or by flushing more viscous HNS from the manifold back to the tank with water; that with positive displacement pumps, it is possible to nitrogen-purge along the discharge sections from the pressure side of the pump; and that Q_p can thus be computed from the dimensions of the pipelines which remain full.

31 In addition, WSL recognised that residues could be determined by measuring wash water volume and the concentration of the residue in it; that volume could be measured either by installing a flow meter in the washing machine supply line or by measuring the tank ullage at the end of the wash period and consulting the tank ullage tables; that wash water samples can then be analysed for residue concentration, thus giving the total quantity in the total volume; that for insoluble residues, emulsifiers can be added and samples taken after homogenisation, or a flow meter and static mixer can be installed on the discharge manifold without or with added emulsifier and samples taken during the normal washing procedure while simultaneously measuring the slop volume discharged. Again, WSL recognised that if Q_{res} is the residue at time t, Q_{dh} is the dynamic hold-up of well-mixed slops and F is the wash water flow rate, then $dQ_{res}/dt = (-Q_{res} / Q_{dh}) F$, which integrates to $\ln Q_{res} = (-1/Q_{dh}) Ft + K$; that when $t = 0$, Q_{res} = ROB, K = ln ROB, and $\ln Q_{res} = (-1/Q_{dh})Ft + \ln ROB$; that Q_{res} / Q_{dh} = slop concentration = C; that $\ln C = (-1/Q_{dh})Ft + \ln (ROB/Q_{dh})$; and that a plot of ln C versus Ft (slops volume) is a straight line of gradient $-1/Q_{dh}$ and intercept ROB/Q_{dh}; and that the ROB can thus be determined from the plot now known as the washing curve.

32 Some samples were analysed as they were taken onboard, others after they arrived at the laboratory five weeks later, microbial biodegradation in the latter having been avoided by addition of the biocide hibitane. The two sample sets were in good agreement as was that between the quantitative analysis and the theoretical analysis reviewed in paragraphs 28 - 31. Thus, confirmation was obtained with fish and soybean oil, tallow and seawater that Q_b can be determined by applying a single measurement of the depth of liquid at the suction-point, d, to the equation in paragraph 29; that methyl-isobutyl-ketone, ethylene-glycol, isobutanol and seawater confirmed that Q_p can be determined from pipeline dimensions by draining at the pump and measuring the volume directly and with caustic soda by flushing back into a clean tank with $10m^3$ of seawater and determining Q_p by analysis of samples taken from the tank. Again by transferring surface films of soybean oil and tallow from a measured area to an absorbent, followed by solvent extraction and quantitative analysis, it was confirmed that Q_s can be determined from the viscosity equation in paragraph 29, though fish oil could be thicker than the liquid film when semi-solid deposits were present (again, paragraph 29) Yet again, removal of volatile ROB by ventilation was confirmed by a water-driven fan ($1m^3s^{-1}$) mounted on a Butterworth hatch with exhaustion through the coaming which removed hexane in 45minutes while with drop-line exhaustion, some methyl-isobutyl-ketone remained after 4 hours, both in accordance with known volatilities.

33 As to total ROB, this was quantified by analysis of equilibrated homogeneous tank washings for acetone, ethoxyethanol, ethylene glycol, methylmethacrylate, propan-2-ol, propylene glycol and soybean oil and from the washing curve for alkylbenzene, aniline, butan-2-ol, butoxyethanol, ethoxyethanol, methylmethacrylate and soybean oil. Thus, the conclusions of 1977 were that with identifiable volatiles the ROB can be zero; that for liquid and non-solidifying substances and the tank sizes investigated, ROB ranged from 0.5 - 2.0 m^3 as measured; that with list and trim minimised during cargo discharge and with all pipelines purged to shore, ROB per tank could be < $1m^3$ and thus be in compliance with the Convention; that it could be further reduced by stripping-pumps if required; that with the contribution from liquid films on internal surfaces being independent of tank-coating and insignificant within the viscosity range (< 5cSt at 15°C) of almost all HNS, and with pipelines being purged to shore as cargo, a simple equation involving one measurement of depth at suction-point and operational measurements of list and trim would enable all individual tank ROB to be determined; and that as of 1977, further work was indicated only for the 20 HNS which might solidify on tank-surfaces.

34 However, beyond the quantities which believers in the LC_{50} approach might or might not permit to be discharged prior to 1977 (paragraph 6), the Convention had stipulated concentration limits at a point of discharge in the ship's wake regardless of subsequent water-column dilutions. Accordingly, by 1976, The Netherlands Maritime Institute had related the product discharge rate Q_p in m^3s^{-1} to its concentration in the wake C_p by the equation $Q_p = 0.003t^{0.4} L^{1.6} V^{1.4} C_p$ where t is time astern of the ship in seconds (s) , L is ship length (m), and V is ship speed (ms^{-1}). However, having agreed on a time of 300 seconds behind the ship, the equation became $Q = 4.3 \times 10^{-5} L^{1.6}V^{1.4}$ for a stipulated concentration in the wake of 1ppm and $Q = 4.3 \times 10^{-4} L^{1.6}V^{1.4}$ for a wake concentration of 10ppm. Of course, in tank cleaning, pure product is not discharged and so $Q_d.C_d$ is substituted for Q_p in the above equations, Q_d being the wash water discharge rate and C_d being its product concentration.

35 While WSL continued to reality-evaluate HNS tank washing procedures on ocean-going and coastal

tankers, it is inappropriate to report all of the results here. Suffice it to say that these evaluations included optimisation of tank cleaning in port for immediate back-loading of different HNS, stripping pumps further to reduce Q_b, space requirements for intermediate slop tanks at sea, evaluations of partial pre-wash at sea in relation to the washing curve and slop-tank capacity, and consideration of soluble/ insoluble HNS mixtures in slop tanks and the discharge of pure and water homogenised substances.

36 Thus, having shown that new knowledge of HNS had to be acquired for compliance with a Convention belief in the need for ROB to be limited to < 1 tonne per tank, that the knowledge thus acquired had enabled the initial requirement to be met and even exceeded; and that species-extinction/ ecological-disaster from individual tank-washing discharges would be impossible anyway: this document asks whether the foregoing work programme was fully necessary when an ROB of < 1 tonne in a 1000 tonne tank of wash water has a concentration < 1000ppm (0.1%), when such could be further diluted prior to discharge and when gravity separators presented with inputs of 5000ppm (0.5%) are known to produce outputs of just over 100ppm, and of < 5ppm with coalescence/filtering under IMO test conditions. However, with costs of onboard equipment and shore reception not being too unacceptable to ship-owners and global society, belief-consensus calls for 10ppm, 1ppm or zero discharge caused no overt dissent (paragraph 17).

Knowledge/Belief in Respect of Ballast-Water Regulation

37 This document has already recognised that casualty-responses have done little or nothing to minimise third party commercial losses, these responses having been motivated and thwarted simultaneously by the reality-refuted belief in species-extinction/ecological-disaster[6] (paragraphs 5 - 12 and 13 - 19); that this belief nonetheless proceeded to regulate limits for operational discharges of oil/HNS before the knowledge needed to meet them had been acquired; but that the necessary knowledge was acquired in time to save these regulations from overt and disruptive dissension or from reality-induced collapse (paragraphs 20 - 36).

38 However, with ballast-water, we again see attempts being made to regulate performance before the necessary knowledge has been acquired. As of now, this document recognises that organisms are transferred between differing ecosystems in ballast-water; that incoming species have thrived in some locations; that ecologists transfer species when it suits their self-interest without reality-evaluation of hypotheses as to whether or not such transfer will cause local species-extinction/ecological-disaster; that, if needed, it should not be difficult to kill all organisms in a tank of ballast-water, hibitane having killed them in the wash water samples transported from ships to WSL (paragraph 32); that additives could be specifically designed for such purposes; that this option has not been pursued presumably because of concern over the LC_{50} values of such additives, despite tank-concentrations being subsequently discharged to seawater of effectively infinite dilution; that herbicides have meanwhile been designed to kill weeds and to degrade spontaneously before affecting the subsequent crop; and that ballast-water exchange *en route* may not yet have been fully evaluated.

39 Again, this document recognises that those who cite LC_{50} values for regulatory purposes regardless of actual seawater-concentrations (paragraphs 5 - 9) are not best fitted to consider all potential options for ballast-water management; that at least three of the ballast water management systems voluntarily installed as approved by the self-styled group of experts on the scientific aspects of marine pollution (GESAMP) have been reported as failing in shipboard operation; that shipping NGOs are thus now less inclined to accept the costs of these systems than they were to accept the lesser costs of those produced for compliance with oil/HNS discharge regulations (paragraphs 17, 20, 27 and 36); but that no laboratory now acts as WSL previously acted on behalf of global society, all of its knowledge-acquisitions having been placed in the public domain in their sequence of acquisition.

40 However, as to this further example of having agreed a Convention before acquiring the knowledge needed for its compliance, this document now recognises that States which have approved forty-two ballast water management systems as operational when perhaps none of them are, and which will ratify in sufficient numbers and tonnages to bring the Convention into force, will presumably have to reduce the stringency of its regulatory limits until more efficient or totally different systems are developed (paragraphs 20 - 36). As to next steps, this document recognises that proposals might be invited from pesticide producers as to how best to define this problem for knowledge-only solution; that owners who have installed approved but failing equipment should not be penalised while enabling-knowledge is being acquired; that such a sequence of post-Convention knowledge-acquisition differs little from those which previously saved the MARPOL Convention (paragraph 37); and that in any case, knowledge-acquisition is preferable to the belief/counter-belief debate which is now causing increasingly overt dissent within the MEPC (paragraphs 52-55).

Knowledge/Belief in Respect of Exhaust-Gas Regulation

41 Here again, we see emissions of the oxides of nitrogen, sulphur and carbon being regulated on arbitrary belief, while we already know from reality-evaluation of specific hypotheses that life-essential trace elements such as sulphur and nitrogen are incorporated in the photosynthesis of atmospheric carbon dioxide which continuously

produces the entire biomass of land and sea; that these biomasses are continuously degraded directly by micro-organisms or indirectly by combustion of their 'fossilised' residues; that consequently the entire global biomass continuously recycles all of its carbon, sulphur, nitrogen, oxygen *etc*, through atmosphere, soil, and water as carbon dioxide, sulphur dioxide, nitrogen oxides *etc* unless oxygen supply is interrupted; that for its photosynthetic combination with carbon, the nitrogen is previously 'fixed' with oxygen as nitrates by micro-organisms which thus fertilise the soil directly and symbiotically in the root nodules of legumes in crop rotation; and that nitrate fertilisers are additionally manufactured by the Haber process.

42 In the Haber process, a large alternating current is flashed between water cooled copper poles and spread by an intense magnetic field into a disc of energy about 2 metres in diameter through which air (nitrogen and oxygen) is passed to form nitrogen dioxide (NO_2) which in the presence of water oxidises to HNO_3 (nitric acid) for nitrate-fertiliser manufacture. Previously, Nernst had investigated the equilibrium concentrations of N_2,+ $O_2 \leftrightarrow NO_2$ mixtures and had shown that 3,000°C produces an equilibrium of only 5% NO_2, this reaction being very endothermic while its reverse is equally exothermic. Thus, while heat-engine emissions contain concentrations of sulphur and nitrogen oxides according to the presence of sulphur and nitrogen in the fuels, any additional NO_2 is due to the Nernst equilibrium in air at the cylinder temperature of such engines while all of it dissociates back to Nernst equilibrium (N_2 + O_2) at atmospheric temperatures on emission, unless oxidised to HNO_3 in water. However, nitrogen was being oxidised to nitrogen dioxide by micro-organisms in soil/water fertilisation long before our seasonal cropping of the land required supplementary nitrates in the form of Chile Nitre or guano imports, the 1914-18 blockade of which resulted in the Haber process. Thus, with nitrogen oxides being essential to life and micro-biological in formation, they cannot be toxic *per se*.

43 It is estimated that the atmosphere above 1 acre of global surface contains 35,000 tons of N_2 while prior to Haber, not a molecule could enter the biological cycle as protein for example, without the intervention of 'nitrogen-fixing' bacteria. Thus, while lightening combines nitrogen with hydrogen from water to form NH_3 (ammonia), this is oxidised to the nitrite ion NO_2^{-1} after rain-out by the *Nitrosomonas* genus*;* while the *Nitrobacter* oxidises this to the nitrate ion NO_3^{-1} which is needed for growth of the higher plants; while the *Azotobacter* transforms atmospheric N_2 to nitrite directly while utilising nitrites and nitrates produced by the others; while the *Nitrobacterieae* transforms NH_3 directly to nitrate; and while the *Rhizobium* symbiotically transforms atmospheric N_2 directly to nitrate.

44 As to the cycling of other life-essential elements, we know, for example, that the *Nitrosomonas* will grow in a buffered solution containing only ammonium sulphate (2.0 gm), potassium hydrogen phosphate (1.0gm), magnesium sulphate (0.5gm), iron sulphate (0.4gm), sodium chloride (0.4gm) and water (1.0 litre). Thus, by the reality-evaluation of direct observation, we know that nitrogen, sulphur, phosphorus, magnesium and iron recycle through the biomass, atmosphere, rain, soil and sea; and that we cannot know that their anthropogenic emissions are damaging without taking account of their molecular forms and their exposure concentrations to plants, animals and man. As to nitrogen in the form of nitrates we know that its contribution to food production results in a significant percentage of current humans owing their existence to the Haber process; and that any contribution from marine engine-emissions is likely to be insignificant in comparison to their natural production by micro-organisms. As to sulphur, we know that this is recycled through the atmosphere as hydrogen sulphide and sulphur dioxide by tectonically driven volcanism and through the biomass in such as the essential oils and proteins of onions, garlic, mustard, horseradish, eggs, hair *etc*; and that its removal from heavy fuel oil raises further questions as to capability for which there are as yet no knowledge-only answers. However as of now, this document has to conclude that environmental policy and regulation are generated on belief-only; that such belief ignores available knowledge; but that all such policy and regulation must ultimately rely on knowledge for compliance even if such compliance is unnecessary in reality (paragraphs 5 - 12, and 20 - 36).

Knowledge/Belief in Respect of Technology/Environmental-Regulation

45 Having shown that all the chemical elements essential to life including carbon itself, recycle through the biomass, atmosphere, soil and water in their various molecular arrangements as indeed they must for global life to continue, this document recognises that all anthropogenic emissions and discharges take place within this cycle; that their regulation must therefore express the knowledge which is in harmony with it and must reject all beliefs counter to it unless they can be reality-validated to additional knowledge of it. As to carbon dioxide in particular, this document recognises that anthropogenic global warming (AGW) is currently only belief; that believers denote non-believers as sceptics or deniers; that this is the language of belief/disbelief and not of knowledge; that while this belief currently has consensual acceptance in the so-called developed world, it is increasingly disbelieved in the developing world in yet another dissention of belief/counter-belief; and that this dissention can only be resolved by agreeing to reality-evaluate this belief to positive or negative knowledge (paragraphs 13 and 14) while developing the fuel-efficient technology which will be beneficially cost-effective for all, whether belief in AGW is reality-validated or reality-refuted in the longer term.

46 Thus, while we know that belief/counter-belief in AGW is causing overt dissention within the MEPC, we also know that dissention has never arisen from improvements in fuel-efficiency; that Watt's steam engine removed all possibility of dissention by rapidly recovering its purchase-cost through its fuel-savings; that the improvement was achieved by Watt's separate-condenser which put Joseph Black's discovery of the latent heat of steam to practical use without need of enforcing regulation; and that improvements in engine-efficiency have been accompanied by fuel-savings ever since. Thus, for example, we know that the first Otto-Langen gas-engines of the 1880s weighed 200kg per generated horsepower; that the Wright Brothers flew in 1903 with an engine of 6kg per hp; that prior to World War I, Seguin's Gnome engine had achieved the efficiency of 1.5kg per hp; that the V-12 Liberty engine of 1kg per hp was the highest wartime achievement; that the Wright Cyclone engines of the B-29 bombers of 1944 achieved 0.5 kg per horse power; and that such efficiency improvements have continued with their successor jet engines: all without enforcing regulation.

47 Again, marine engines have shown parallel development from early Watt-types through triple expansion steam, to Parson-turbines; and from coal to oil and now to natural gas, while fresh attention within the MEPC is now turning to increased engine/hull efficiencies now that fuel-cost has become a very significant percentage of overall operating-cost. Thus, while this document recognises belief in AGW as having reinforced the fuel-cost pressure for more efficient engines, its knowledge-only approach to the environment in general concludes that this belief should never have been permitted to impose penalties on carbon dioxide emissions without first having been reality-validated as positive knowledge; and that such penalties should now be withdrawn pending the possibility of its reality-refutation to negative knowledge (paragraphs 13, 14, 45, 46 and 52 - 55). As of now, this document has to conclude that policy and regulation have for too long been generated on belief-only, there having thus far been no recognition of the need to reality-evaluate beliefs before implementing or dropping them, and no recognition of knowledge as the only possible solution to any real problem.

Knowledge/Belief in Respect of Science/Pseudoscience

48 Having definitively differentiated knowledge from belief to show that the knowledge which is craftsmanship, science and technology has resulted from reality-evaluation of beliefs as hypotheses (paragraphs 1 - 4), and having thus differentiated knowledge from belief in all subsequent paragraphs, this document now differentiates science from pseudoscience. Thus, it recognises that science is reality-evaluation by the direct observation which describes and classifies, or by the experimentation which elucidates cause-effect relationships; that science varies the cause and observes variation of effect in isolation from all other causal-interference; that having thus established a quantified cause-effect relationship, it can predict future effects from future causes and *vice versa*; that its knowledge-acquisition is continual because each hypothesis for reality-evaluation has been derived from the knowledge acquired by reality-validation or reality-refutation of a previous hypothesis. In contrast, this document notes that pseudoscience is neither descriptive nor classifying, nor does it establish cause-effect relationships; that it arbitrarily selects one parameter as causing an effect on another and justifies this pseudo-relationship by statistical analysis or mathematical modelling; that in doing so it ignores all the other parameters which could have had just such a statistical/modelled correlation with either or both; and that the belief which chose the pseudo-correlated pair remains belief, no matter how valid the statistics or modelling may have been *per se*. Indeed, statistics *per se* is incapable of deciding which is cause or which is effect, even supposing such a relationship had been fortuitously chosen at the outset. In short, science is reality-evaluation of belief as specific hypothesis while pseudoscience is ignorance of the need for reality-evaluation of belief as specific hypothesis.

49 Another way of contrasting science with pseudoscience is to recognise that the quantified cause-effect relationships of the former can be given mathematical expression in equations which enable predictions to be made which are verifiable by observation, while the latter is incapable of prediction because its correlated parameters are not cause and effect, having been arbitrarily correlated on the basis of arbitrary belief. Again, while the former creates internally consistent knowledge, the latter does not. Indeed, the latter does nothing other than assert the dire consequences of its belief while collecting what it calls evidence in its support, without recognising that its disbelievers do nothing other than collect counter-evidence. Thus, this document recognises that pseudoscience is always engaged in a debate of fact/counter-fact in support of belief/counter-belief; that such debate can only be terminated by reality-evaluation of belief (hypothesis) to positive or negative knowledge (*i.e.* to science); and that pseudoscience thus defines itself as, and is synonymous with, belief-consensus and is thus no basis for progress in reality (paragraphs 1 - 4). As of now, this document has to conclude that policy and regulation are generated and implemented without any differentiation of science from pseudoscience.

Knowledge/Belief in Respect of Assent/Dissent

50 This document recognises that assent to belief-consensual policy and regulation is only simulated when dissent is suppressed by the *pro tem* majority-voting which does nothing to eliminate it; that assent to knowledge is unreserved, dissent from it being the irrationality of madness; but that in contrast, assent/dissent to/from belief-consensus is merely to/from belief/counter-belief. Thus, this document recognises that were the MEPC member States to review their current positions on zero discharge requirements, ballast-water management and exhaust-gas

emission control with respect to the new differentiation of knowledge/belief (paragraphs 1 - 4) they would dispel all dissention within the MEPC while facilitating assent to the new ISCO knowledge-only approach to contingency and incident response planning (paragraphs 5 - 19)[6]. Again, were they to disseminate this document's use of this differentiation throughout the UN system, they would provide the UNCCC with the opportunity to declare a moratorium on its belief-only charges for carbon dioxide emissions while it transforms its belief in AGW to positive or negative knowledge by reality-evaluation of specific hypotheses (paragraphs 1 - 4, 13 and 14) and while the MEPC reduces carbon dioxide emissions through pursuit of knowledge-only improvements in fuel-efficiency (paragraphs 41 - 49).

51 Furthermore, this document concludes that UN agencies and their individual member States would be more effective as knowledge-only facilitators than they can ever be as belief-only enforcers; that anything seen to work is emulated without enforcement as was the technology of the industrial revolution; that democracy itself will not be emulated until it is universally seen to work through adoption of knowledge-only policies instead of failing to work on its current belief-only policies no matter how many elections are held to adjudicate on belief/counter-belief options; that even current democracies will be secured only when their electorates are asked to prioritise knowledge-only policies for implementation within known resource limits; and that thus far, belief-only policies and regulations have been generated and implemented on majority assent without any recognition of the need to reality-evaluate all belief prior to implementation or non-implementation in reality[7].

Next Steps

52 ISCO will collate the knowledge repository supportive of its knowledge-only contingency plan from which all future incident-specific oil/HNS response plans will be derivable. The contingency plan will identify the physicochemical parameters which control the fates and effects of oil/HNS releases, which determine prevention and response, and which by their incident-specific values predict incident-specific fates and effects, thus enabling incident-specific prevention and response to be as cost-effective as possible. This contingency/incident-specific approach will cover casualty-preparation for safe- haven entry; cargo/bunker transfer; and release-clearance at sea, on inshore waters and on shorelines[6].

53 On completion of this approach, member States will have access to a repository of knowledge secure against staff changes and a contingency plan from which even fresh staff will be able to prepare and execute incident-specific plans which will enable predictions made, decisions taken, accredited contractors used, results obtained and costs incurred to be reported to the IOPCF and P&I Clubs for expeditious settlement of claims and to the IMO for enhancement of the then shared knowledge repository which will thereafter exist as an ever-developing backup to all member states[6].

54 At this point, this document recommends member states to adopt in principle the knowledge-only approach to contingency/incident-specific oil/HNS response planning as outlined in paragraphs 5 - 12, 15-19, 52 and 53. Again,, this paper recommends that member States invite the UNCCC to reality-evaluate its belief in AGW with reference to paragraphs 1 - 4, 13, 14 and 45 - 49); that member States themselves review attitudes to operational oil/HNS discharge regulation in light of paragraphs 17 - 36; consider interim arrangements for ballast water as suggested in paragraphs 37 - 40; and reconsider exhaust-gas emission control in light of paragraphs 41 - 47 and in light of any knowledge on AGW which may arise from paragraphs 1 - 4, 13, 14 and 45 - 49. Yet again member States are recommended to adopt the general approach to knowledge-only policy formulation advocated in paragraphs 48 - 51[4-6].

55 Thus, having differentiated knowledge from the beliefs which have opposed it to the detriment of release-response, having differentiated the beliefs/counter-beliefs which are causing MEPC dissention from the knowledge which would resolve it, and having thus harmonised, or at least shown how to harmonise technology and environment, this document intends this new differentiation of the knowledge/belief dichotomy to be the means of resolving all national and international dissention[7].

References

1 Response to Oil and Chemical Marine Pollution, D. Cormack, Applied Science Publishers, 1983.
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack, Kluwer Academic 1999.
3 The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack, Bright Pen, 2010, from www.authorsonline.co.uk
4 Knowledge-Based Response Planning, MEPC/OPRC-HNS/TG papers for Meetings 10 - 16.
5 Cormack's Column, the ISCO Newsletter, weekly articles from 8 November 2010.
6 Compensation for Casualty-Response, ISCO Document for IOPCF/Oct/15/.
7 www.knowledgeonlypolicy.weebly.com

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The previous document IOPCF/OCT14/4/6 had informed Delegates in its Introduction that knowledge of the physicochemical parameters which control fates effects of releases and of the incident-specific values of these parameters which determine cost-effective incident response, could have been available to coastal states from the mid 1970s onwards had it not been suppressed by counter-beliefs; that this knowledge suppression cannot be overturned unless coastal States and the secretariats of the IMO and the IOPCF recognise their capture by knowledge-countering beliefs which are incompatible with each other, while all are incompatible with 'protection of the marine environment'. Given the extent and persistence of this suppression and capture, the document showed that my newly definitive knowledge/ belief differentiation, which differentiates what works in reality and what does not, was the only innovation capable of preventing overt dissention from my documents to the TG, the MEPC and the IOPCF, by those who have thus far captured by the beliefs which thus far have been suppressing the knowledge without which cost-effective incident response will never be achieved.

Further to encourage knowledge-acceptance by such policy-makers, my subsequent document IOPCF/ APR 15/4/5 recalled the part-acceptance which had permitted the procurement of equipment stockpiles and service contracts scaled for single-tank releases but which had not permitted creation of knowledge-accepting/belief-rejecting contingency plans for the use of these stockpiles and contracts, and the unhappy consequences of this part-acceptance as exemplified by the *Sea Empress* response. In addition, reference to MEPC 67/19/INF.13 document recalled the extent to which belief-acceptance still drives oil/HNS and ballast-water discharge regulation, and the regulation of carbon dioxide, sulphur dioxide, nitrogen dioxide emissions and even those of carbon itself, despite our already available knowledge that discharges of oil/HNS result in extremely low, non-toxic and localised concentrations in seawater, that while killing organisms in the sea with dispersed oil is thus impossible, killing them in a ballast tank with a suitable toxin is entirely possible though not thus far permitted, that sulphur and nitrogen oxides are life-essential and thus non-toxic *per se*; that carbon emissions in the form of soot are regulated in the arctic in the belief that solar absorption by such black particles will deleteriously melt the ice; and that belief-acceptance and knowledge-rejection remain alive and well.

As to next steps, policy-makers were invited to note that my proposed knowledge repository, and knowledge-only contingency/incident-specific planning approach were almost completed for ubiquitous access by member States; but that the benefits of such access would require knowledge-acceptance and belief-rejection by policy-makers.

Document IOPCF/APR15/4/5 is reproduced below for ease of reference to the knowledge repository of this website.

COMPENSATION FOR CASUALTY-RESPONSE
KNOWLEDGE-REPOSITORY, CONTINGENCY AND INCIDENT-SPECIFIC PLANS
Submitted by the International Spill Control Organisation (ISCO)

Introduction

1.1 Knowledge of the physicochemical parameters which control the fate and effects of oil/HNS releases to the marine environment and of the incident-specific values of these parameters which determine cost-effective incident response, would have been available to coastal States from the late 1970s had it not been suppressed by counter-beliefs throughout the intervening 35 years.

1,2 However, knowledge suppressed or otherwise lost by staff-change frequency and incident infrequency, is now being collated as the referential repository for a knowledge-only contingency plan from which even fresh staff can prepare and execute knowledge-only incident-specific plans from which predictions made, decisions taken, accredited contractors employed, results obtained, and costs incurred can be reported to the IOPC Fund and P&I Club secretariats in fully documented form for expeditious settlement of claims and to the IMO secretariat for repository enhancement with knowledge of equipment performance in respect of incident-specific viscosities and sea states (c.f. paragraph 5.1).

1.3 However, before response contractors can be accredited as to their knowledge of this new approach; before coastal states and Fund and P&I Club secretariats can expeditiously settle claims derived from it; and before further acquisitions of incident-specific knowledge can be disseminated by IMO: national policy-makers must recognise that they have thus far been captives of the knowledge-countering beliefs of self-appointed pressure groups; and that all such belief must be rejected for cost-effective response to be possible.

1.4 As to the overarching belief in species-extinction/ecological-disaster, policy-makers must recognise that it prohibits or restricts dispersant-response to arbitrary distances from shore and/or to arbitrary water-depths, thus increasing the physical coating of shorelines and organisms which they ostensibly seek to avoid; that it restricts recovery by prohibiting *in situ* discharge of co-collected and demulsified water, thus wasting recovery-storage and obstructing oil-recycling of which they ostensibly approve; that it prohibits cargo/bunker transfer in safe havens, thus permitting single-tank release to become the total cargo/bunker release which they ostensibly seek to avoid; that in any case, these restrictions and prohibitions are counter to the long available knowledge that seawater concentrations arising from natural or induced dispersion are incapable of any such extinction/disaster however large the release/ discharge may be; that the number of organism-deaths from physical-coating is insignificant compared to the numbers dying and birthing annually in the maintenance of species-populations; that no extinction/disaster has arisen from any incident thus far; and that were these belief-only prohibitions to be rescinded, commercial activities would be resumed much more cost-effectively than they are now.

1.5 Yet again, before this new knowledge-only approach can improve the current guidelines for claim submissions and for selection of self-styled experts for their assessment, policy-makers must recognise with ISCO document[7] IOPCF/OCT 14/4/6 that debates of opinion/counter-opinion are merely debates of belief-counter-belief supported by partially selected facts/counter-facts, neither set of which is debate-terminating knowledge; that there are as many opinions as there are self-styled experts; that debate produces only a transient belief-consensus; that no such consensual majority ever eliminates minority dissention; and that dissention over the undefined terms ‘reasonable’ and ‘proportionate’ as cited in the MARPOL Convention, is resolvable solely by the knowledge which would define them.

1.6 However, despite this previous absence of recognition, no dissention arose on sequential presentation of the new knowledge-only approach to meetings 10-16 of the OPRC-HNS Technical Group of the MEPC[5]; that this absence of dissent was its first, though covert, recognition of the irrationality of preferring belief to knowledge; and that the summarising document[6] MEPC 67/19/ INF.13 on Harmonisation of Technology and Environment now requires overt recognition by policy-makers that the preference for belief over its refuting-knowledge is the irrationality of madness.

2 Extent and Persistence of Knowledge Suppression by Belief

2.1 Knowledge has been suppressed for policy-makers by continuous re-iteration of the belief in species-extinction/ecological-disaster and its derivatives by self-serving pressure groups since the *Torrey Canyon Incident* of 1967. Meanwhile, consequent to that incident, the knowledge which refutes this belief was being sequentially reported by such as the chemical engineering division of the UK Warren Spring Laboratory (WSL) even prior to 1967; by the international training courses of the subsequent oil/HNS Division of WSL from 1974 -79; by its open R&D reports from 1974 - 94; by contributions from WSL and the UK Marine Pollution Control Unit to the biennial international oil spill conferences from 1975-89, and by this author’s chairmanship of the working group on the IMO Manual on Spill Response and of the OTSOPA working group of the Bonn Agreement. Again, this belief-only capture of policy-makers and of those who thus ceased to be scientists, continued despite publication of this author’s first book[1] at the request of Elsevier in 1983, despite all belief-only papers being rejected by Elsevier’s Marine Pollution Journal under his editorship in the late 1980s/early1990s, and despite publication of his second book[2] at the request of Kluwer Academic in 1999.

2.2 Thus, we must now conclude that this knowledge was indeed extensively and persistently suppressed by reiterative assertion of its counter-beliefs by self-appointed pressure groups; that these groups thus captured the exclusive attention of policy-makers and the general public; that this capture was maintained by presenting beliefs as scientific knowledge to those unable to differentiate scientific knowledge from the beliefs of pseudoscience; and that politicians have accepted all aspects of the ensuing belief-consensus as vote winners in ignorance of the longstanding need for belief to be differentiated from knowledge or *vice versa*.

3 Definitive Differentiation of Knowledge from Belief

3.1 Thus, before resuming his lifelong attempt to liberate knowledge from suppression by belief, this author recognised that success would require knowledge to be definitively differentiated from belief. Fortunately, his earlier ambition to write a history which would differentiate science from pseudoscience had revealed the need to definitively differentiate the knowledge/belief dichotomy and with it those of truth/falsehood, wisdom/folly, right/wrong and good/bad for the first time ever. Thus, prior to this resumed attempt, he had resolved epistemology by differentiating knowledge-only craftsmanship, science and technology from all belief-only systems and from all mixtures of belief and knowledge such as metaphysics, religion, behaviour-codes, economics, sociology, psychology, law, literature, politics, etc, while differentiating the knowledge-contents from the belief-contents in all such mixtures. Thus, it was on this basis that he sought to liberate knowledge from suppression by belief by his weekly articles in the ISCO Newsletter from November 2010 to August 2014 and by his documents to the OPRC-HNS Technical Group, to MEPC 67 and 68, and to IOPCF/14/4/6 (paragraphs 1.5 and 1.6).

3.2 Thus, his third book[3] of November 2009 showed for the first time ever that our senses stimulate our imaginations to beliefs; that these are validated to positive knowledge or refuted to negative knowledge only by our evaluation of their compatibility or incompatibility with reality; that those which are beyond this reality-evaluation in principle or *pro tem* practice remain beliefs in perpetuity or until they can be reality-evaluated to positive or negative knowledge; that rationality *per se* cannot reach valid conclusions from premises without both being reality-evaluated; and that while our physical and social progress is entirely dependent on knowledge-acquisition, belief/counter-belief debates lead only to dissention, violence, revolution or war (paragraphs 1.5 and 1.6).

3.3 Accordingly, with this differentiation making rejection of knowledge and acceptance of its counter-belief rationally impossible, and with no dissent having arisen from its application to casualty-response in the ISCO Newsletter articles[4] or in the concurrently serialised documents to meetings 10-16 of the IMO Technical Group, this author invited belief-only pressure groups either to accept that their belief in species-extinction/ecological-disaster had already been reality-refuted by measurement of seawater concentrations or to reality-evaluate it for themselves by comparing the numbers of organisms dying at incidents with those dying/birthing annually in stable species-populations, by observing the rates at which shorelines denuded of organisms by oil and/or by cleaning, are re-colonised by their respective planktonic life-stages; the rates at which boat-slips denuded of organisms for pedestrian safety are thus re-colonised; and the rates at which weeded gardens are re-colonised by airborne seeds.

3.4 At the same time, this author invited these belief-only pressure groups to reality-evaluate their belief in anthropogenic global warming (AGW) with reference to our knowledge that the entire biomass of land and sea is produced from atmospheric carbon dioxide by photosynthesis and returns to the atmosphere by its biodegradation to carbon dioxide, that this biodegradation is interrupted solely by the absence of oxygen which converts intermediate biodegradation products to natural gas, oil and coal; and that anthropogenic combustion of such 'fossil' fuels or their resumed biodegradation when released to the environment, returns to the atmosphere only part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through the global atmosphere and biomass. Again, this author invited them to reality-evaluate their belief in AGW with reference to our knowledge that carbonate rock is produced from atmospheric carbon dioxide by the Urey reaction with silicates and returns to the atmosphere by subsequent volcanic degradation to carbon dioxide, both processes being driven by tectonic plate movement; and that were there no volcanic-return all photosynthesis would have ceased long ago, all atmospheric carbon dioxide having been sequestered as carbonate rock.

3.5 Accordingly, this author invited believers to reality-evaluate specific hypotheses as to whether an increase in carbon dioxide return to the atmosphere by one of those cycles would result in an increase in abstraction by the other or both; and suggested that hypotheses derived from our knowledge of crop-yields being increased by increasing the carbon dioxide content of controlled atmospheres would be a good place to start. It should be noted that he issued these invitations and suggestions in November 2012; and that there has been no response thus far, though none was expected of those who rely solely on belief un-submitted to reality-evaluation.

3.6 Clearly, this author's definitive knowledge/belief differentiation has provided the first reliable means of terminating the knowledge-suppression which has permitted policy-makers to be captured by counter-beliefs since publication of Rachel Carson's *Silent Spring* in 1962. However, in writing his first book of 1983, this author was aware that its knowledge, though acquired by reality-evaluation of specific hypotheses by direct measurement and/or by designed experimentation (i.e. by the scientific method as he now defines it), might not be permitted to overcome belief-consensual opposition to its publication even at the invitation of Elsevier, this opposition already having caused the contingency plan of the new Marine Pollution Control Unit to be largely a list of the so-called interested parties to be called to discuss any proposed response to specific-incidents whether or not they accepted or rejected the knowledge which WSL had been paid by government to acquire, and which was now being downgraded to opinion/counter-opinion for debate. Therefore, when DTI suggested publication by HM Stationary Office, this author invoked the Elsevier invitation to preclude 'official-editing' of his text.

3.7 Nonetheless, such was the pressure of the prevailing belief-consensus that the preface of his first and second books quoted the first six lines of the poem by S.G. Saxe, *The Blind Men and The Elephant* to indicate that while the individual blind men came to differing beliefs as to the nature of the elephant depending on which part of it they happened to touch, those who approached the nature of casualty-response with no prior knowledge of it, would come to differing responses/non-responses depending on their differing beliefs as to the nature of the problem (the elephant). Thus, by omitting to declare that casualty-response blindness was due to such beliefs, his prefaces merely implied that the nature of response would be grasped only through knowledge of its controlling parameters, and thus these prefaces merely hoped that knowledge would defeat belief in whatever debates might ensue.

4 Progress towards Liberating Knowledge from Suppression by Belief

4,1 However, with his third book having differentiated knowledge from belief now and for ever, this author is confident that his now overt campaign for knowledge-only contingency and incident-specific planning will be implemented cost-effectively on the knowledge that there is no possibility of species-extinction/ecological-disaster; that the only significant consequences of cargo/bunker releases are the losses arising from interruption of commercial activities; that the layer thinness of releases and discharges which limit seawater concentrations and thus preclude species-extinction/ecological-disaster, also limit at-sea response to releases of about 3,000 tonnes prior to residual stranding in onshore winds; and that while offshore winds permit entire cargoes to evaporate, disperse, dissolve, dilute and biodegrade without need of response, the potential for commercial loss under onshore winds necessitates emergency removal of cargo/bunkers in safe havens to prevent weather-damage releases from exceeding the design-limited release of about 3,000 tonnes per impact-damaged tank which fortuitously matches the thinness-limited capacity to respond to any slick (paragraphs 8.1 - 8.4).

4.2 As to general dissention within the MEPC, the ISCO document MEPC 67/19/INF.13 on Harmonisation of Technology and Environment shows that all would be resolved were knowledge to replace belief; that while dissent over the costs of belief-only discharge regulations became covert when the knowledge needed for compliance was subsequently acquired, it again became overt when its initiating belief in species-extinction/ecological-disaster insisted on zero discharge despite total cargo/ bunker releases being known to be incapable of any such consequence; that dissent over ballast water regulation is now overt because belief-only approaches to compliance have yet to be reality-evaluated; that dissent over emissions of sulphur, nitrogen and carbon dioxides is yet again over costs, while their belief-only regulation ignores the natural recycling of all life-essential elements through biomass and environment, those of sulphur, nitrogen, phosphorus, magnesium, iron etc, being abstracted from the environment in photosynthesis and returned to it by biodegradation, as is carbon itself; and that this dissent would be resolved by agreement to rely on reality-validated increases in fuel-efficiency pending belief in AGW being reality-evaluated as specific hypotheses which will either refute or validate it, though reality-evaluation is avoided by all who expect it to refute their beliefs (c.f. paragraph 3.5).

4.3 However having noted in paragraphs 1.6 and 3.3 that no dissention arose when this knowledge-only approach to casualty response was reported to meetings 10-16 of the OPRC-HNS TG, it is now noted that the correspondence sub-group of the TG was concurrently producing guidelines on dispersant use at sea as requested by MEPC 61; that these guidelines have been brought to the attention of PPR 2 for onward transmission to MEPC 68 (now 69); and that it is now possible to evaluate the extent to which these guidelines accept or reject the beliefs which reality itself refuted forty years ago as was recalled in ISCO document MEPC 67/19.INF.13 on Harmonisation of Technology and Environment.

4.4 Thus, while ISCO took no part in the correspondence group on dispersant guidance to avoid association with what could well have been yet another round of belief-inspired suppression of knowledge, this document now reports that while the belief in species-extinction/ecological-disaster has previously suppressed all knowledge of the benefits of dispersant use, the Correspondence Group now accepts that the known concentrations of oil in seawater are insufficient to cause such effects; that dispersants are less toxic than oil at the concentrations of exposure; and that the oil slick thickness which is the only source of such seawater concentrations is of the order of 0.1mm; that dispersed oil dilutes and biodegrades in the water column; and that dispersants prevent the physical coating of organisms and shorelines and eliminate the need for recovered pollutants to be processed: all of which is an acceptance of part of the ISCO knowledge repository as previously presented to the TG and to the MEPC, though the correspondence group made no reference to it.

4.5 However, the Correspondence Group has yet to accept that the belief in extinction/disaster which still prohibits dispersant use in shallow waters and/or specified distances from shore has been refuted by the absence of any such effects at all incidents thus far; and that the maximum concentration to be expected from instantaneous dispersion of a 0.1mm slick would be 100ppm even if all of it were permanently retained in the top metre of the water column. Again, while the Group accepts that dispersants prevent the physical coating of birds, animals and shorelines, it still cites the belief that the concentrations resulting from their use are disadvantageous to the organisms of the water column despite their being biodegraded by them at the now admitted concentrations of exposure. Yet again, the Group still claims that the advantages and disadvantages of dispersant use are such as to require net environmental benefit analysis (NEBA) to be conducted by discussion (debate), despite the advantages being known and the disadvantages being merely belief, despite the latter having been refuted by known seawater concentrations, despite the total absence of quantified permanent effects at any and every oil release thus far irrespective of water-depth or stranding, and despite the ineffectiveness of all responses thus far having been incapable of preventing any such extinction/disaster had it been other than belief.

5 The New Knowledge-Only Approach to Contingency and Incident-Specific Planning

5.1 The information provided in document IOPCF/OCT14/4/6 on the knowledge repository and knowledge-only contingency and incident-specific plans which constitute the new knowledge-only approach to casualty-response, have been presented more fully in the ISCO document for MEPC 68 and are thus not repeated here. The full approach itself will be provided in due course (paragraph 9.1). However, the results obtained from the twelve identified steps of the new incident-specific planning approach will facilitate the assessment of compensation claims submitted to the IOPCF and P&I Club secretariats while reportage of these results to the IMO secretariat will enhance the repository with more precise knowledge than is now available on the relationships of pollutant-viscosity to dispersion half-life and dispersant-effectiveness, and of pollutant-viscosity and sea-state to recovery-effectiveness (paragraphs 1.1- 1.6). In the meantime, the present document recalls where and by whom most of the knowledge for the proposed repository was acquired in the first place, and reveals the ease with which it was lost not only by being suppressed by counter-belief, but also by incident infrequency and staff-change frequency even in the country of its initial acquisition (paragraphs 6.1 - 7.2).

5.2 As to acquisition of knowledge of the influence of physicochemical parameters on the fate and effects of releases/discharges and on responses to them by what this author defines as the reality-evaluation of specific hypotheses, he acknowledges the roles of his former colleagues in the oil/HNS division of the UK's Warren Spring Laboratory, of their unique authorisation to discharge potential pollutants at sea and on shorelines for R&D purposes, and of the ship *Seaspring*, converted to the seagoing aspects of the R&D programme and professionally crewed for five days per week for three years and 10 months initially and until the need became so intermittent as to require its sale.

5.3 With these advantages, the division under the direction of this author investigated the physicochemical factors which determine the fate and effects of any and every release; evaluated all of the design principles of available recovery units and collection booms as to effectiveness in respect of pollutant-viscosity and sea-state by appropriate combinations of laboratory and sea trials of the most promising commercially available examples of these principles; designed its own *Springsweep System*; investigated the relationship of slick thickness to remote-sensing imagery and to the concentrations in seawater produced by natural and induced dispersion; quantified the parameters controlling airborne application of dispersants; and tested the effectiveness of all commercial dispersants as they became available. Again, the division investigated all aspects of temperate zone shoreline cleaning in respect of recovery, downstream processing, dispersant use and surface film application. Yet again, it investigated the performance of ship borne oil/water separators, measured the performance of commercially available separators for regulatory purposes, and quantified the post-discharge residues onboard ocean-going and coastal HNS tankers, their tank cleaning processes, and their modifications as described in MEPC 67/19/INF.13.

5.4 In the early days from October 1974 until this author was invited to join the Marine Pollution Control Unit (MPCU) as a founder-member in March 1979, the division consisted of 22 persons including this author and his secretary, these persons constituting the knowledge-repository of a potentially new knowledge-only approach to incident response. Thus, while seagoing incident response was in those days led by the nearest principal officer of the marine survey service of the department of trade and industry (DTI) the response itself relied on WSL-designed shipboard dispersant application systems as advised by appropriate WSL (DTI) staff while inshore/onshore clearance was led by the senior emergency control officer of the affected local authority (Department of Environment, DoE) the techniques and equipment having been devised/approved by WSL and used as advised by its staff.

5.5 Accordingly, when this author was informed of the department's intention to create the new MPCU at headquarters to manage seagoing response, he proposed that his WSL division be the management unit for both sea and shore response in respect of the differing responsibilities of his department and those of the department of environment. However, his proposal was rejected in inviting him to join the new unit as its science member. Having concluded that this invitation would enable him to link the new unit to the knowledge repository which was the collective WSL division, he accepted the invitation, but it took the intervention of the then Royal Commission on the Environment, before DTI would permit him personally to liaise with local authorities from his position in the new MPCU. Again, while within the MPCU, this author successfully called for a national stockpile of equipment for oil/HNS emergency transfer; for mechanical recovery of releases at sea; and for airborne dispersant application and remote-sensing: support from the afore-mention Royal Commission was again needed before he could establish a national stockpile for shoreline/inshore cleaning as a back-up for the equipment already held to varying degrees by individual local authorities (c.f. paragraph 8.2).

6 Loss of Knowledge by Staff-Change Frequency and Incident Infrequency

6.1 Despite acquisition of the above stock-piles, the contingency plan itself was written by a DTI administrator without any attempt to preserve the then available knowledge against the infrequency of incidents and the frequency of staff changes, thus precluding any possibility of this knowledge becoming institutionalised. As to its actual loss, the first step was this author's return to WSL on promotion to deputy director in charge of its then four environmental divisions on oil/HNS release and discharge, on industrial/domestic recycling and/or waste disposal, on national air quality monitoring, and on abatement of industrial and automotive emissions to the atmosphere, while the two oil/HNS division colleagues who had subsequently joined him in the MPCU were soon to retire, the marine directorate itself having already gone to the Department of Transport (previously road and rail only).

6.2 However, before being promoted to Director of WSL, this author had already created an addition division on abatement of industrial emissions to the atmosphere, had converted those on mineral processing and metal extraction to one on the remediation of contaminated land, had distributed the staff of the former materials handling, and computerised chemical-engineering divisions across the now six divisions, and had converted the chemical analysis section to be fully supportive of this new arrangement in the renamed DTI Agency on

Environmental Science and Technology, WSL thus being the first government laboratory to acquire agency status. However, despite DTI having agreed this rearrangement for a staff of around 400 persons and having conferred upon them this enhanced status, regulatory policy-makers in all departments of state continued to prefer belief-consensus to knowledge.

7 Example of the Consequences of Knowledge Loss and Belief Retention

7.1 Further to staff-change frequency and incident infrequency, it must be acknowledged that the total replacement of MPCU staff together with the absence of incidents from 1986 onwards, left no-one in a position to formulate knowledge-only response to the *Sea Empress Incident* of February 1996; and that while initial grounding caused a reported release of 3,000-5,000 tonnes of cargo in the entrance to Milford Haven, thus offering a textbook opportunity to re-float and to discharge at a Haven terminal, a further 69,000 or 67,000 tonnes were permitted to escape from re-floating/re-grounding on successive tides at the initial grounding location before the casualty was brought to such a terminal, and discharged under her own power, of the then remaining 58,000 tonnes.

7.2 Again, it must be acknowledged that the belief in species-extinction/ecological-disaster which had prohibited earlier discharge of *Sea Empress* cargo and bunkers went on to require recovered-emulsions to be processed at approved refinery-sites rather than *in situ*; to prohibit dispersant-use within the Haven; and to prohibit it outside until offshore winds had driven the releases far enough from shore to satisfy requirements long-since reality-refuted; and that these belief-only prohibitions thus caused compensation claims to be for release of 72,000 tonnes, while knowledge-only/cost-effective claims for release of only 3,000-5,000 tonnes would have been sufficient to clear any residual stranding for the ensuing Easter holiday, rather than for that of 1997 (paragraph 1.4).

8 Restoration of Knowledge

8.1 The need for cargo/bunker transfer and for avoidance of excess provision for release-response, can only be met by restoring the knowledge that a release of 1000 tonnes covers an area of $10km^2$ to a thickness of 0.1mm; that when this area is scaled down to $1m^2$, a 50m recovery vessel travelling at 1 knot in recovery mode is scaled down to one of 0.5mm in length travelling at 0.2mm per hour, i.e. at about $1/5^{th}$ of the speed of the tip of the hour hand of a watch; that consequently the full-scale ship must take a very unhelpful time to recover 1000 tonnes of oil; that at full-scale the 1 knot encounter rate with a slick of 0.1mm thickness is only $0.18m^3h^{-1}$ per metre swath width (i.e. $1/5^{th}$ of a tonne per hour per metre); and that a single ship with a boom-entrance of 15m will encounter/recover 3 tonnes per hour or 12 tonnes of 80% water-content emulsion, while a ship spraying dispersant over a swath width of 15m at 10 knots will treat 30 tonnes of oil per hour, and while an aircraft with this swath width at 100 knots will treat 300 tonnes of oil per hour, subject to the needs to reload. Indeed at the Ekofisk blow-out *RV Seaspring* collected 9 m^3h^{-1} of 60-70% water-content emulsion with a 15m boom-entrance, a 4 inch diameter floating hose and a deck-mounted Spate pump, the simplest recovery principle of all.

8.2 Thus, we must restore the knowledge that it is futilely expensive to attempt to recover or disperse total cargo or un-capped-well releases, and that this author accordingly limited his MPCU response capacity to release from a single impact-damaged tank or expeditiously capped well, this amounting to two DC3 and six Islander aircraft with a total dispersant load of 10 tonnes per sortie, one *Springsweep System* (15m swath and vacuum-recovery) for *RV Seaspring* and two for two coastal tankers of opportunity and one sea-going *Oil Mop* for such an offshore supply ship; that while aircraft spraying rates depend on reloading-logistics, these provisions were intended to prevent the stranding of residuals from a single damaged-tank ; that their adequacy needed evaluation at future incidents; and that cargo/ bunker transfer and well-capping remained the primary elements of response. However, while the six seagoing systems assembled for the *Sea Empress Incident* recovered only a negligible fraction of that release, no-one then reality-evaluated the potential adequacy of such equipment for future incidents.

8.3 Again, we must restore the knowledge that floating slicks evaporate, disperse and/or dissolve over their entire areas while recovery or dispersants can be applied only to small localised sub-areas; that whatever the release-quantity and its viscosity might be, it will disperse naturally in seven half-lives unless residuals strand in the meantime; that however much is spent in provisioning for more than release from a single tank, any benefit will rapidly diminish to zero, further provision being more effective for shorelines; and that while *RV Seaspring* was recovering $9m^3h^{-1}$of Ekofisk emulsion, some $250m^3$ of oil was evaporating per $1000m^3$ in < 5 hours of release, while the $750m^3$ of non-volatiles had become at least $2,250m^3$ of emulsion which was naturally dispersing by half, in successive half-life intervals of 12 hours, i.e. by 1,125, 562, 281, 140, 70. . . m^{-3} per thousand released.

8.4 Thus, we must restore the knowledge that response to residual quantities just prior to stranding is cost-effective; that attempts to provide for all of it without benefit of pre-stranding natural dispersion is futile whatever it costs; and that this author's initial stockpiling took account of these considerations, with its insistence on cargo/bunker transfer provision, its avoidance of over-provisioning for releases at sea, and its provision for shorelines in anticipation of his seagoing provision being unable to prevent the stranding of residuals (paragraphs

4.1, 8.2 and 8.3).

9 Next Steps

9.1 The knowledge repository will now be collated and the knowledge-only contingency and incident-specific planning approach will now be completed from the references chronologically listed below, the intention being to make the ensuing documents available to all; to accredit response contractors as to competence in their use; and to liaise with IMO and IOPCF secretariats, member States and P&I Clubs to enhance customer-contractor interaction, to expedite claim settlement, and to enhance the knowledge repository itself through incident reportage to IMO as in paragraphs 1.2 and 5.1. As to further applications of this newly defined knowledge/belief differentiation, readers may wish to visit a website which this author is currently developing[8].

1 Response to Oil and Chemical Pollution, D. Cormack, Elsevier Applied Science, 1983.
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack, Kluwer Academic, 1999.
3 *The Rational Trinity: Imagination, Belief and Knowledge* available from www.authorsonline.com
4 Cormack's Column, ISCO Newsletter, weekly/intermittent articles from 8 November 2011
5 Knowledge-based Response Planning, OPRC-HNS Documents for MEPC/TG Meetings 10-16
6 Harmonisation of Technology and Environment, ISCO Document MEPC 67/19/INF.13
7 Compensation For Casualty-Response IOPCF/OCT 14/4/6
8 www.knowledgeonlypolicy.weebly.com

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Document MEPC68/20/INF.6 informed MEPC Delegates that knowledge of the physicochemical parameters which control the fates and effects of oil/HNS releases and of the incident-specific values of these parameters which determine cost-effective incident-response would have been available to coastal States from the late 1970s had it not been suppressed by counter-beliefs; that this suppression could not be reversed unless coastal States accepted knowledge and rejected belief; and that this necessity was being brought to the attention of the IOPCF.

As to the liberation of knowledge from suppression by belief through my newly defined knowledge/ belief differentiation, the document noted that there was no dissent from the sequential documents previously presented to Technical Group meetings 10-16, and none from documents previously submitted in summary form to the IOPCF and MEPC; that there had been no response to the invitation to belief-only NGOs to reality-evaluate for themselves their continuing beliefs in species-extinction/ ecological-disaster and in anthropogenic global warming, despite the former having long since been reality-refuted by the oil concentrations in seawater being non-toxic and by the absence of any such extinction/disaster at all incidents thus far, and despite the latter having never been either reality-validated or reality-refuted thus far.

As to the knowledge repository, the document recalled that the previously lost knowledge was now being restored. As to the contingency plan, it recalled that this would abstract all the knowledge from the repository which is relevant to the creation of each and every incident-specific plan by applying the incident-specific values to all of the physicochemical parameters of the contingency plan which are relevant to the specific incident. As to each and every incident the document outlined the twelve steps to be followed by the coastal State and/or its contractors to achieve a cost-effective response, these steps providing structure to the response itself and a template for the preparation of compensation claims and for the reporting of incident-acquired knowledge for enhancement of the repository.

Having thus outlined the content of the knowledge repository, knowledge-only contingency plan and the steps to be followed as appropriate in implementing each and every incident-specific plan, this document commended the new knowledge-only approach to the Member States of the MEPC and of the IOPCF, to their respective secretariats, to the secretariat of the International Group of P&I clubs, to the secretariats of individual P&I Clubs and to individual response contractors.

Document MEPC 68/20/INF.6 is reproduced below for ease of reference to the knowledge repository of this website.

KNOWLEDGE-ONLY CONTINGENCY AND INCIDENT-SPECIFIC RESPONSE PLANS
Submitted by the International Spill Control Organisation (ISCO)

Introduction

1. Knowledge of the physicochemical parameters which control the fate and effects of oil/HNS releases to the marine environment and of the incident-specific values of these parameters which determine cost-effective incident-specific response would have been available to coastal States from the late 1970s, had it not been

suppressed by counter-beliefs throughout the intervening thirty-five years .

2 However, knowledge suppressed, or lost by staff-change frequency and incident infrequency, is now being collated as the referential repository for a knowledge-only contingency plan from which even fresh staff can prepare and execute knowledge-only incident-specific plans from which predictions made, decisions taken, accredited contractors employed, results obtained, and costs incurred can be reported to IOPCF and P&I Club secretariats in fully documented form for expeditious settlement of claims and to the IMO secretariat for repository enhancement with knowledge of equipment performance in respect of incident-specific viscosities and sea states (paragraphs 27 - 29).

3 However, before response contractors can be accredited as to their knowledge of this new approach; before coastal states and IOPCF and P&I Club secretariats can expeditiously settle claims derived from it; and before further acquisitions of incident-specific knowledge can be disseminated by the IMO secretariat: national policy-makers must recognise that they and their predecessors have been captives of the anti-knowledge beliefs of self-appointed pressure groups; and that cost-effective response requires rejection of all such beliefs.

4 As to the over-arching belief in species-extinction/ecological-disaster, policy-makers must recognise that it prohibits or restricts dispersant-response to arbitrary distances from shore and/or to arbitrary water-depths, thus increasing the physical-coating of shorelines and organisms which they ostensibly seek to avoid; that it restricts recovery by prohibiting *in situ* discharge of co-collected and demulsified water, thus wasting recovery-storage and obstructing oil-recycling of which they ostensibly approve; that it prohibits cargo/bunker transfer in safe havens, thus permitting single-tank release to become the total cargo/bunker release which they ostensibly seek to avoid; that in any case, these restrictions and prohibitions are counter to the long available knowledge that seawater concentrations arising from natural or induced dispersions are incapable of any such extinction/disaster however large the release/discharge; that the number of organism-deaths from physical-coating is insignificant compared to the numbers dying and birthing annually in the maintenance of species-populations; that no extinction/disaster has arisen from any incident thus far; and that the cost-effectiveness of casualty-response would increase immediately on rejection of these belief-only restrictions and prohibitions.

5 Yet again, before this new knowledge-only approach can improve current guidelines for claim-submissions and for selection of self-styled experts for their assessment, policy-makers must recognise with the ISCO document[7] IOPCF/OCT14/4/6 that debates of opinion/counter-opinion are merely debates of belief-counter-belief supported by partially selected facts/counter-facts, neither set of which is debate-terminating knowledge; that there are as many opinions as there are self-styled experts; that debate produces only a transient belief-consensus; that no such consensual majority ever eliminates minority dissention; and that dissention over the meaning of the terms ‘reasonable’ and ‘proportionate’ in the MARPOL Convention will be terminated only by the knowledge which defines them[3].

6 In contrast to such dissention, it is here recorded that none arose when this new knowledge-only approach to casualty-response was presented as weekly ISCO Newsletter articles[4] or when these were presented in sequential summaries[5] to meetings 10-16 of the OPRC-HNS Technical Group; that this absence of dissention was the first, though covert, recognition by the TG of the irrationality of suppressing knowledge with counter-belief; and that the summarising document MEPC 67/19/INF.13 on Harmonisation of Technology and Environment[6] now requires overt recognition by policy-makers that suppression of the knowledge which refutes belief is the irrationality of madness.

Suppression of Knowledge by Belief

7 On this basis, we can now universally recognise that knowledge was suppressed for policy-makers by the continuous re-iteration of the belief in species-extinction/ecological-disaster and its derivatives by self-serving pressure groups, despite the knowledge which refutes it having been progressively reported by such as the chemical engineering division of the UK’s Warren Spring Laboratory (WSL) consequent to the *Torrey Canyon Incident* of 1967; by the international training courses of the oil/HNS division of WSL from 1974 -79; by its open R&D reports from 1974 - 94; by WSL and UK Marine Pollution Control Unit contributions by this author to the biennial international oil spill conferences from 1975-89, and by his chairmanships of the IMO spill response manual working group and of the OTSOPA working group of the Bonn Agreement. Again, this belief-only capture of policy-makers and of those who thus ceased to be scientists, was maintained despite publication of this author’s first book[1] at the request of Elsevier in 1983, despite Elsevier’s Marine Pollution Journal publishing no belief-only papers under his editorship in the late 1980s/early1990s, and despite publication of his second book[2] at the request of Kluwer Academic in 1999.

8 Thus, we can now universally conclude that knowledge was indeed suppressed by reiterative assertion of its counter-belief by self-appointed pressure groups; that these groups thus captured the exclusive attention of policy-makers and the general public; that this capture was maintained by presenting beliefs as knowledge to those

unable to differentiate scientific knowledge from the beliefs of pseudoscience; and that politicians have accepted all aspects of the ensuing belief-consensus as vote winners in ignorance of the need for belief to be differentiated from knowledge and *vice versa*[3].

Liberation of Knowledge from Suppression by Belief

9 Before attempting this liberation through the submission of documents to the IMO[5,6] and to the IOPC Fund Assembly[7], and concurrently through weekly articles in the ISCO Newsletter[4] from November 2010 to August 2014 and intermittently thereafter, this author had recognised that success would require definitive differentiation of knowledge from belief. Fortunately, his earlier ambition to write a history which differentiated science from pseudoscience had driven him to this first ever definitive differentiation of the knowledge/belief dichotomy and with it those of truth/falsehood, wisdom/folly, right/wrong and good/bad[3]. Thus, prior to this campaign, he had resolved epistemology by differentiating knowledge-only craftsmanship, science and technology from all belief-only systems, and from all thus far undifferentiated belief/knowledge mixtures such as those of metaphysics, religion, behaviour-codes, economics, sociology, psychology, law, literature, politics, etc, while differentiating their harmonious knowledge-contents from their disharmonious belief-contents for the first time ever.

10 Thus, this author's third book[3] of November 2009, had definitively differentiated knowledge from belief for the first time by showing that our senses stimulate our imaginations to produce beliefs transformable to positive or negative knowledge only by evaluation of their compatibility or incompatibility with reality, or to those which are beyond this reality-evaluation in principle or *pro tem* practice and which thus remain beliefs in perpetuity or until they can be reality-validated to positive knowledge or reality-refuted to negative knowledge; that rationality *per se* cannot reach valid conclusions from premises without both being reality-evaluated; and that while peaceful progress depends on knowledge, belief/counter-belief dissention progresses to violence, revolution or war.

11 Accordingly, with this differentiation making suppression of knowledge by its counter-belief rationally impossible, and with no dissention having arisen from its application to casualty-response in the ISCO Newsletter articles[4] or to the concurrently serialised ISCO documents[5] to meetings 10-16 of IMO Technical Group, this author invited belief-only pressure groups either to accept that their belief in species-extinction/ecological-disaster had already been reality-refuted by measurement of seawater concentrations, or to reality-evaluate it for themselves by comparing the numbers of organisms dying at incidents with those dying/birthing annually in stable species-populations, by observing the rates at which shorelines denuded of organisms by oil and/or by cleaning, are re-colonised by their respective planktonic life-stages, by observing the rates at which boat-slips denuded of organisms for pedestrian safety are thus re-colonised, and by observing the rates at which weeded gardens are re-colonised by airborne seeds.

12 At the same time, this author invited these belief-only pressure groups to reality-evaluate their belief in anthropogenic global warming (AGW) with reference to our knowledge that the entire biomass of land and sea is produced from atmospheric carbon dioxide by photosynthesis and returns to the atmosphere by its biodegradation to carbon dioxide, that this biodegradation is interrupted solely by the absence of oxygen which converts intermediate biodegradation products to natural gas, oil and coal; and that anthropogenic combustion of such 'fossil' fuels or their resumed biodegradation when released to the environment, returns to the atmosphere only part of a 'fossilisation' but for which all of its carbon dioxide equivalent would already be recycling through the global atmosphere and biomass. Again, this author invited them to reality-evaluate their belief with reference to our knowledge that carbonate rock is produced from atmospheric carbon dioxide by the Urey reaction with silicates and returns to the atmosphere by subsequent volcanic degradation to carbon dioxide, both processes being driven by tectonic plate movement; and that were there no such volcanic-return, the atmosphere would no longer contain the carbon dioxide necessary for life, all of it having been thus sequestered as carbonate rock.

13 Accordingly, this author invited believers to reality-evaluate hypotheses as to whether an increase in carbon dioxide return to the atmosphere by one of these cycles would result in an increase in abstraction by the other or both, to which end, he suggested that reality-evaluation of hypotheses derived from horticultural knowledge of crop yields being increased by increasing the carbon dioxide content of controlled atmospheres, would be a good place to start[3]. It should be noted that these invitations and suggestions were issued by ISCO in November 2012; and that there has been no response thus far, though none was expected of those who rely solely on belief un-submitted to reality-evaluation[3].

14 Clearly, this author's definitive knowledge/belief differentiation of 2009 has provided the first reliable means of terminating the knowledge-suppression which has permitted policy-makers to be captured by counter-beliefs since publication of Rachel Carson's *Silent Spring* in 1962. Indeed, in writing his first book of 1983, this author was aware that its knowledge, though acquired by reality-evaluation of specific hypotheses by direct measurement and/or designed experimentation (i.e. by the scientific method as now defined[3]) might not be

permitted to overcome belief-only opposition to its publication even at the invitation of Elsevier, such belief already having caused the contingency plan of the new Marine Pollution Control Unit to be largely a list of the so-called interested parties who would be called to discuss any proposed response to incidents whether or not they accepted or rejected the knowledge which the government had paid WSL to acquire, and which was now being downgraded to opinion/counter-opinion for debate. Therefore, when DTI suggested publication by HM Stationary Office, this author invoked the Elsevier invitation to preclude 'official-editing' of his text.

15 Nonetheless, the preface of this author's first book[1] and that of his second[2] of 1999, made reference to the first six lines of the poem by S.G. Saxe, *The Blind Men and The Elephant* to indicate that while the individual blind men came to differing beliefs as to the nature of the elephant depending on which part of it they happened to touch, those who approached the nature of casualty-response as policy-makers, mariners, lawyers, etc, would come to differing responses/non-responses depending on their differing beliefs as to the nature of the response-problem (the elephant). Thus, by avoiding any overt declaration of blindness in casualty-response being due to such beliefs, this author's prefaces merely implied that the nature of casualty-response could be grasped only through knowledge of its controlling parameters whatever the beliefs of the so-called interested parties might be, and thus these prefaces merely hoped that knowledge would defeat belief in whatever debates might ensue.

Progress towards Liberating Knowledge from Suppression by Belief

16 However, with this author's third book[3] having definitively differentiated the knowledge/belief dichotomy now and for ever, he is confident that his now overt campaign for knowledge-acceptance and belief-rejection will result in universal recognition that there is no possibility of species-extinction/ ecological-disaster arising from the seawater concentrations resulting from accidental and operational discharges from ships; that the only significant consequences of cargo/bunker releases are the losses arising from interruption of commercial fishing and/or amenity-enjoyment; that the layer thinness of releases and discharges which limit seawater concentrations and thus preclude species-extinction/ ecological-disaster, also limit at-sea response to releases of about 3000 tonnes prior to residual stranding in onshore winds; and that while offshore winds permit entire cargoes to evaporate, disperse, dissolve, dilute and biodegrade without need of response, the potential for commercial loss under onshore winds necessitates emergency removal of cargo/bunkers in safe havens to prevent weather-damage releases from exceeding the design-limited release of about 3000 tonnes per impact-damaged tank which fortuitously matches the above thinness-limited capacity to respond.

17 Again, having noted in paragraph 6 that no dissention arose when this new knowledge-only approach to casualty-response was sequentially presented to meetings 10-16 of the OPRC-HNS TG, it is recalled here that a correspondence sub-group of the TG was concurrently producing guidelines for the use of dispersants at sea as requested by MEPC 61; that these guidelines have been brought to the attention of PPR 2 for onward transmission to MEPC 68; and that it is now possible to evaluate the extent to which these guidelines accept or reject the beliefs which were thus refuted forty years ago as recalled in ISCO document[6] MEPC 67/19/INF.13 on Harmonisation of Technology and Environment.

18 Thus, while ISCO took no direct part in the correspondence group on dispersants to avoid association with what could well have been yet another round of belief-inspired suppression of knowledge, this ISCO document now reports that while belief in species-extinction/ecological-disaster has previously suppressed all knowledge of the benefits of dispersant use, the correspondence group now accepts that the known concentrations of oil in seawater are insufficient to cause such effects; that dispersants are much less toxic than oil at seawater concentrations; and that the oil slick thickness which is the only source of such seawater concentrations is of the order of 0.1mm; that dispersed oil dilutes and biodegrades in the water column; and that dispersants prevent physical-coating of organisms and shorelines and eliminate the need for recovered pollutants to be processed: all of which is an acceptance of part of the ISCO knowledge repository as presented to the Technical Group and to the MEPC[6], though the correspondence group made no reference to these presentations.

19 However, the correspondence group has yet to accept that the belief in extinction/disaster which still prohibits dispersant use in shallow waters and within specified distances from shore has been refuted by the absence of any such extinction/disaster at all incidents thus far; and that the maximum concentration to be expected from instantaneous dispersion of 0.1mm thick slicks would be 100ppm even if all of it were permanently retained in the top metre of the water column. Again, while the group accepts that dispersants prevent the physical coating of birds, animals and shorelines, it still cites the belief that the concentrations resulting from their use are disadvantageous to the organisms of the water column, despite being biodegraded by them at the admitted concentrations of exposure. Yet again, the group still claims that the advantages and disadvantages of dispersant use are such as to require net environmental benefit analysis (NEBA) to be conducted by interested-party discussion, despite the advantages being known and the disadvantages being merely belief, despite the latter having been refuted by known seawater concentrations, despite the total absence of quantifiable permanent effects at any and every oil release thus far, and despite the ineffectiveness of response thus far having itself shown that extinction/disaster would not have been 'prevented' had it been other than mere belief.

20 Thus, this document reports that this latest correspondence-group guidance has made recordable progress towards ultimate acceptance of the knowledge-only approach advocated by ISCO; and that full acceptance cannot now be long delayed, given that rejection has now been shown to require definitive belief to be preferred to the definitive knowledge which refutes it[3].

The Knowledge Repository

21 Thus, further to paragraphs 1-20, the repository advocated by ISCO will contain the reality-validated general knowledge that identifiable physicochemical parameters determine fate, effects and response, whichever oil/HNS is released; that these parameters determine whether releases evaporate, dissolve, disperse, float, sink or solidify; that these parameters cause atmospheric and seawater concentrations from surface spreading floaters to be effectively non-toxic whether natural or dispersant induced; that the natural evaporation and dispersion rates which apply to the whole slick are far greater than the localised encounter/recovery rates of response-units; that releases or the components of releases which have evaporated, dissolved or dispersed cannot be recovered; that those which disperse naturally or by inducement do not act as biocides to organisms which biodegrade them to carbon dioxide and water; that the localised application/dispersion rates of dispersants are vastly exceeded by the natural dispersion rate of the whole slick; that the effectiveness of dispersants is viscosity-limited; that the effectiveness of recovery systems is viscosity- and wave-limited; that the overall effectiveness of both dispersant and recovery techniques is limited by encounter-rate to the extent of necessitating the removal of cargo and bunkers preferably in the nearest safe haven to prevent any weather-damage releases beyond the 3000-5000 tonnes expected from impact-damage to a single cargo tank.

22 Further to release-quantities and their fates, effects and potential responses, the repository will acknowledge that the contents of containers and packages are very much smaller than those of integral cargo tanks or indeed of bunker tanks; that these contents will either evaporate, dissolve, disperse, dilute and photolytically or biologically degrade, without the possibility of recovery or the need for dispersants; that those which are liquid and sink may be recovered to some extent by pumping if deep enough pools have collected in hollows of the seabed; that in any case these will dissolve, disperse dilute, biodegrade or neutralise with seawater through their surfaces of contact as do floating slicks and soluble solids; that the resulting seawater concentrations will be comparable to those from floating slicks; that the seawater thus affected will be much more localised than from the greater surface area of floating slicks, but will be just as transient; and that floating solids are best recovered after stranding.

23 In addition, the repository will include reality-validated knowledge of the equipment necessary for cost-effective cargo/bunker transfer; for over-containment of damaged HNS packages recovered at sea and on shorelines; for slick detection at sea; for slick-response at sea, on inshore waters, shorelines and manmade coastal structures of all types, whether by mechanical recovery, dispersant treatment, or surface-film application; for separation of water-oil emulsions from co-collected water and co-collected beach material; and for the processing of recovered emulsions to their separate oil and water phases. Again, it will acknowledge that HNS do not form emulsions and that the contents of damaged HNS-packages should be subject to the normal waste-disposal procedures of the chemical industry while undamaged packages should be routed to their intended recipients. Yet again, the knowledge repository will relate the potential use of shoreline techniques and equipment to shoreline types and tidal ranges. Thus, it will acknowledge that while UK shoreline types include mud-flats, salt-marshes, poorly- and well-drained sand, and shingle, pebble/cobble, rock and cliffs, all subject to substantial tidal ranges, others may be predominantly sand, mangrove or coral, while others may be non-tidal and thus unable to expose inter-tidal widths for the stranding of releases.

24 Again, the repository will include reality-validated knowledge as to dispersant effectiveness in relation to pollutant viscosity, and as to the comparative performance of differing recovery principles in relation to pollutant viscosity and wave tolerance. Yet again, the repository will include the knowledge needed to repeal the regulations currently imposing water-depth limits on dispersants, thus maximising their useful scope; and those currently prohibiting *in situ* discharge of all co-collected free and processed water, thus maximising the use of onboard storage at sea and minimising the volumes which otherwise have to be transported from shoreline recovery operations, these regulations having been inspired by the now reality-refuted belief in species-extinction/ecological-disaster and having now been seen to be needless barriers to otherwise cost-effective response.

The Knowledge-Only Contingency Plan

25 Supported by the knowledge repository, the knowledge-only contingency plan will relate the physicochemical parameters of oils and HNS to the full range of fates and effects to be expected from their releases; identify the fates and effects which need and which do not need response; and identify the techniques and equipment best suited to whichever responses are needed. In doing so it will recognise that cargo/bunker transfer

is the primary aspect of shipping-casualty response; that the natural processes of evaporation, solution, dilution and biodegradation are the ultimate self-protectors of the environment; that human response contributes only in so far as it enhances dispersion rates and thus biodegradation rates, or engages in recovery when dispersion/biodegradation rates are too slow for timely resumption of interrupted commercial activities; and that incurred costs are acceptable only in so far as they are commensurate with commercial loss-minimisation, belief in species-extinction/ ecological-disaster having been reality-refuted some forty years ago (c.f. paragraphs 1 and 2).

26 Again, while reality-validated equipment is available to reduce the quantity which would otherwise strand on tidal shorelines, the new knowledge-only contingency plan will recognise that non-tidal shorelines combined with onshore winds are more effective than any floating boom in increasing the layer thickness beyond that of windrows at sea and hence the encounter rates of inshore recovery systems; that even for tidal shorelines, coastal States with a limited range of shoreline types need use only a limited range of equipment types; that with seawater concentrations being effectively non-toxic, the only choice in respect of dispersant-use/mechanical recovery, is to select the most viscosity-tolerant options; and that for response at sea it is best to work on the slick edge closest to shore to minimise the quantity likely to strand and to maximise the benefit of natural dispersion prior to stranding.

27 Yet again, the new knowledge-only contingency plan will recognise that the quantity eventually stranded can be estimated from the length, width and thickness of the coverage and/or from the quantities subsequently recovered or dispersed, the latter being estimated from the quantity of dispersant used; that the quantity stranded also equates to the quantity released less the sum of the quantities evaporated, dispersed naturally (estimated from the known half-life and time from release to stranding) dispersed by dispersants (estimated from the quantity applied) and the quantity recovered from water surfaces prior to stranding; that such mass-balancing was applied by the author to quantify the benefit of cargo/bunker transfer in five salvage adjudications prior to termination of Lloyds chapter XIV; and that reporting to IMO of such mass-balancing at future incidents will increase the precision of current viscosity/half-life allocations, viscosity/dispersant-efficiency ratios and recovery-principle/ efficiency ratios with respect to viscosity and sea-state (c.f. paragraph 2).

The Knowledge-Only Incident-Specific Plans

28 As to incident-specific planning, when a liquid non-solidifying release arises from an impact- damaged casualty, we now know that the first step is to avoid subsequent weather-damage releases by cargo/bunker transfer; that the second is to ascertain the values of the physicochemical parameters relevant to its cargo and bunkers; that the third is to note the fates and effects of any releases in terms of floating or sinking, of fractional or total evaporation, total solution or progressive dispersion according to the densities, distillation profiles and viscosity/half-life relationships already tabulated for crude oils and bunkers and applicable to HNS, some of which are soluble; that the fourth is to calculate the fractional evaporative loss for any crude oil from its distillation profile as already tabulated, this being usually 25-30% (or 100% for volatile HNS) in < 5 hours; that the fifth is to calculate the time for the non-volatile fraction to reach shore by applying the vector sum of 100% of the tidal vector and 3% of the wind vector to the distance from the arrival location; that the sixth is to apply the respective viscosity-dependent half-life to the non-volatile fraction of the quantified cargo and bunker oil releases and/or to the quantified non-volatile insoluble HNS releases and to the above estimated time to reach shore, in order to estimate the quantities likely to arrive on shoreline types identified at these locations; that the seventh is to consider, on the basis of known viscosities and half-life dispersion rates, whether dispersants or recovery, both, or neither, should be applied at sea, there being no need to enhance or prevent the natural dispersion which of itself would prevent any onshore arrival.

29 Again, the incident-specific plan will recognise that the eighth step is to repeat the sixth to estimate the quantity likely to strand just prior to its arrival, having been further reduced by the quantities already recovered or dispersed by the quantity of dispersant already applied at sea, and by the quantity naturally dispersed according to the allocated half-life; that the ninth is to revise the shoreline types and lengths, widths and thicknesses of impaction; that the tenth is to identify the techniques applicable to each shoreline type and its contiguous waters; that the eleventh is to activate transport of the associated equipment in quantity and sequence appropriate to likely need at these differing locations; and that the twelfth is to warn those who might wish to receive oils for heat-raising purposes or who might accept shoreline recovered emulsions for processing to oil or for bioremediation by ‘land-farming’, all such potential recipients having been identified in the national/regional contingency plan.

30 Thus, we see that these sequential steps will not only give directional structure to all incident-specific response, they will also increase the precision of our viscosity/half-life allocations and of our viscosity and sea-state/efficiency ratios for reportage to the IMO secretariat for enhancement of the knowledge repository; and that they will provide a format for claim submission and subsequent settlement to and by IOPCF and P&I secretariats (c.f. paragraphs 2, 21, 24 and 27 - 29).

31 As to the banning of net- and line-fishing and of shellfish harvesting, the incident-specific plan will recognise that fish never contact floating slicks unless they break the surface or are drawn through it in nets or on

hooks; that seawater concentrations arising from such slicks never reach toxic levels even when these are dispersant-induced; that such measured concentrations are consistent with the absence of taint reported by tasting panels served with fish caught at such as the Ekofisk blow-out; and that oil- or emulsion-coated shellfish harvested from shores or cultivation stakes are as un-sellable as fish drawn through slicks, while those exposed only to the concentrations of naturally dispersed oil which have no effect on fish, are in any case depurated prior to sale; and that shellfish are in any case constantly exposed to the equilibrium concentrations of land-source oil discharges; and that this differentiation of physical coating from exposure to naturally dispersed oil would reduce compensation claims currently caused more by the bans themselves than by contamination *per se* (paragraph 2).

The Need to Liberate Knowledge from Suppression by Beliefs in the Regulatory Field

32 While this ISCO document shows that our newly defined knowledge/belief differentiation[3] is now terminating belief/counter-belief dissention in the domain of incident-response, the previous ISCO document[6] MEPC 67/19/INF.13 has already shown that it would also terminate the currently increasing belief/counter-belief dissention in the domain of regulation; that while such dissention over the oil/HNS discharge regulations became covert only when the technical knowledge needed for compliance had been developed, it again became overt when its initiating belief in species-extinction/ecological-disaster insisted on zero discharge in so-called special areas despite accidental releases of total cargoes and bunkers being incapable of any such consequences; and that belief/counter-belief dissention over ballast water regulation is now overt because current approaches to its compliance have yet to be reality-validated despite our knowledge that the problems arising from this un-natural transport of species are real enough to require knowledge-only solution.

33 Again, we know that dissention over the regulation of emissions of sulphur, nitrogen and carbon dioxides arises from their cost-implications while we already know that such elements together with phosphorus, magnesium, iron, etc, are integral with the biological and geological cycles which sustain global life (paragraphs 11 -13); that while nitrogen and oxygen are the main constituents of the atmosphere, they can only be incorporated by the higher plants as the nitrate ion NO_3^{-1} prior to consumption by animals and humans; that while this ion is available only through the intervention of specific micro-organisms, the intermediate NO_2 produced by these micro-organisms or in emissions from ships is converted to nitrate on contact with water, while sulphur oxides are similarly converted to sulphite and sulphate by contact with water; that natural nitrate and sulphate production is insufficient for our food-cropping needs; that consequently we have to add chemically synthesised nitrate and sulphate to our crop-yielding fields; and that consequently a little more in the sea from ship-emissions is unlikely to be harmful. Thus, we know that all life supporting elements are abstracted from the environment in photosynthesis and returned to it by biodegradation; and that without this biological and geological recycling there would be no life on earth as is recalled in document[6] MEPC 67/19/INF.13 and in paragraphs 12 and 13.

34 Thus, we see that current belief/counter-belief dissention as to the deleterious effects of ship-source emissions to the atmosphere including carbon as soot would be resolved by agreement to rely on knowledge-only increases in fuel-efficiency, pending hypotheses derived from the belief in AGW being either reality-validated or reality-refuted; that belief in the negative effects of NO_2 and SO_2 emissions might also be thus reality-evaluated; and that the extension of special-area/zero-discharge regulation might be suspended if not reversed on knowledge long available. Meanwhile, we may conclude that reality-evaluation is being avoided by all who now expect it to reality-refute their belief in AGW.

35 To avoid misunderstanding at this point, it should be noted that releases of cargo and bunkers from marine casualties cause sufficient interruption of commercial activities to justify response by all available cost-effective means, even if this is the main if not the only reason for such response. However, further to such response, it should be noted that the slick thickness which limits seawater concentrations also limits the encounter rates and thus the recovery and dispersion rates of all such means; that these limitations thus require the areas of slicks to be limited by emergency cargo/bunker transfer; that equipment holdings to minimise stranding can thus be realistically scaled to releases from an impact-damaged tank, greater areas of greater releases being known to disperse naturally at greater rates than are achievable by equipment holdings however great; that consequently the temptation to ever-greater holdings to eliminate stranding should be resisted; but that realistic holdings should include equipment capable of clearing realistic residual-stranding quantities within realistic timescales. Similar considerations apply to oilfield releases with well capping replacing cargo/bunker transfer.

36 Again, to avoid misunderstanding, it should be noted that whereas regulations for the operation of ships by owners are intended to be mandatory under any Convention currently in force, only guidance has thus far been offered to States as to response to accidental releases from ships, these States being thus free to accept or reject such guidance as belief/counter-belief might indicate; but that with respect to the drafting of regulations, individual States are free to accept knowledge, to reject beliefs already reality-refuted, and to suspend beliefs awaiting reality-evaluation, without requiring endorsement by any IMO or other UN committee, or indeed by any authority other than reality itself[3].

Next Steps

37 Further to this document and to those submitted to the IOPC Assembly meetings 14[7] and 15, the knowledge repository will now be collated and the knowledge-only contingency and incident-specific planning approach will now be completed from the references chronologically cited below, the intention being to make the ensuing documents available to all; to accredit response contractors to competence in their use and to liaise with IMO and IOPCF secretariats, member States and P&I Clubs to enhance customer-contractor interaction, claim-settlement expedition and the knowledge repository itself through incident-reportage to the IMO secretariat as in paragraphs 2, 21, 24 and 27 - 29. As to application of this newly defined knowledge/belief differentiation to yet other fields of belief/counter-belief dissention, readers may wish to visit a website[8] which the author is also developing.

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ANNEX II
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ANNEX III
Record of Further Progress Towards Knowledge-Only Marine Policy

It had been intended to announce the availability of this website to MEPC 69 by means of the following document and, with appropriate modification, to announce it to IOPCF/APR/16. However, with website compilation having been more time consuming than expected, the announcement was postponed to MEPC 70 and to IOPCF/OCT/16. In anticipating its availability, the intention had been to summarise it and to clarify the respective need for it in response to accidental releases; in regulation of operational discharges and emissions from ships; and in compensation for the commercial losses caused by accidental releases and for the costs incurred in responding to them. However, to avoid repetition, only the document intended for MEPC 69 is reproduced below to provide a summary of this website; and to recall that its objectives are achievable only by the newly definitive differentiation which identifies knowledge for acceptance and its counter-beliefs for rejection. Thus, with this website having been completed as of July 2016, its availability was announced by the subsequent documents for MEPC 70 and IOPCF/ OCT/16 now included here.

KNOWLEDGE-ACCEPTANCE/BELIEF-REJECTION

ANNOUNCEMENT OF A NEW WEBSITE

Initially Intended for Submission to MEPC 69

Summary. This new website is the knowledge repository which relates the physicochemical parameters of accidental oil/HNS releases to their effects, fates, and responses, and which relates incident-specific values of these parameters to incident-specific/cost-effective removal of effects in compliance with natural fates. Thus, acceptance of knowledge now enables belief/counter-belief dissention to be rejected in the settlement of claims for compensation, and enables further knowledge to be acquired from the incidents themselves. It also identifies the knowledge yet to be acquired respecting regulation of operational discharges and emissions, if belief/counter-belief dissention is ever to be resolved.

References. ISCO documents to OPRC-HNS TG 10-16 and to MEPC 67 - 68.

Action to be taken. Paragraph 30

Introduction

1. ISCO has advocated knowledge-acceptance/belief-rejection in release-response and in the regulation of discharges and emissions in documents to TG 10-16, IOPCF/OCT14 & APRIL15, and MEPC 67 & 68, a sequence intended to give Member States time to adjust to this acceptance/rejection. However, while absence of overt adjustment caused the sequence to be somewhat repetitive, the absence of overt dissent coupled with the assent exhibited by the recent IMO Guidance on Dispersant Use has encouraged wider and fuller advocacy through this new website.

2. As to release-response, the cited documents recalled that while the *Torrey Canyon* incident of 1967 had forced the UK government to acquire knowledge of how to respond to the observed effects of such incidents, the international belief-consensus held the effect to be species-extinction/ecological-disaster; that while the chemical engineering division of Warren Spring Laboratory (WSL) had produced tug-mountable dispersant spray-equipment by the early 1970s, the belief-consensus advocated so-called recovery; but that the UK policy of October 1974 was for all options to be investigated by a new oil/ HNS division at WSL supported by a newly converted ship, *Seaspring*, available from June 1975. Again, these documents recalled that having refuted the belief in extinction/disaster by direct measurement of seawater concentrations, and having noted the absence of these effects at all incidents to-date, the knowledge of fates, effects and responses acquired by 1979 had caused the stockpiling of dispersant and mechanical-removal equipment for use at sea, inshore and onshore, scaled to damage-release from a single tank (~ 4000 tonnes) and cargo/bunker transfer equipment scaled to prevent further release. Yet again, these documents recalled that airborne dispersant-spraying for single tank release was contracted together with remote-sensing of slick thickness to optimise pollutant encounter rates; and that all was successively and collectively published[1] for general access by 1983, a national Marine Pollution Control Unit (MPCU) having thus been established at DTI headquarters in 1979.

3. However, while the knowledge relating these stockpiles and contracts to the physicochemical parameters of individual pollutants was thus capable of predicting all future fates, effects and response-outcomes only if embodied in a national response plan, these documents recalled that policy-makers preferred the belief-consensus

which predicts nothing; that their so-called contingency plan was to invite self-styled interested parties to reach belief-consensual responses to belief-consensual fates and effects at successive incidents, the WSL-acquired knowledge being thus demoted to debatable opinion; and that with this contingency plan being in no sense a knowledge repository to be institutionalised by training to compensate for staff-change frequency and incident infrequency, the outcome was the loss of knowledge exemplified by the totally inept response to the *Sea Empress* incident of 1996[2], the MPCU staff having changed many times in the intervening seventeen years of no significant release.

4. Now, if belief-consensus could replace knowledge acquired by creation of an R&D division, purchase/conversion of a ship, and permitted the discharge of oil/HNS to sea and shorelines, what chance was there for it to be accepted by coastal States which did not self-acquire it and were thus exposed only to the otherwise universal belief-consensus? Indeed, if a State ignores its self-acquired knowledge, why should any other State accept it from any visitor to an ongoing incident in the absence of any prior preparation for knowledge-acceptance/belief-rejection in any of them?

5. As to belief, the cited documents to the TG and MEPC collectively recalled that belief in species-extinction/ecological-disaster had caused the MARPOL Convention of 1973 to limit the oil-content of operational discharges to 100ppm, despite the chemical engineering division of WSL having reported by direct measurement as early as 1962 that this limit could not be met by onboard gravity-separators; and that in 1977, again by direct measurement, the new WSL oil/HNS division reported the need for downstream coalescence and filter units if this limit was ever to be met by such separators. Again, these documents recalled that in 1977, this new division showed how the Convention’s post-discharge limit of one tonne of HNS per cargo tank and its associated limits for wash-water concentrations could be met in practice; and that meanwhile it had confirmed its earlier trials results by showing that the seawater concentrations which arose from the Ekofisk blow-out of 1976 were incapable of species-extinction/ecological-disaster, let alone those arising from operational discharges of oily bilge water.

6. Thus, the cited documents collectively recalled that earlier belief/counter-belief dissention over discharge regulations were resolved only by later acquisition and acceptance of the knowledge needed for compliance, whether or not the chosen limits were/are known or only believed to be needed; and that the need for knowledge-acquisition is again exemplified by the current dissention over ballast water discharges from cargo tanks and over engine emissions to the atmosphere, regulatory limits being set for the former before the means of compliance are known, and for the latter before either need or means are known. Thus, as with current belief/counter-belief dissention over claims for IOPCF compensation, we know that policy-makers and their executors will always operate within one or other belief-consensus, unless prior preparation is made for knowledge-acceptance/belief-rejection (paragraph 4).

Preparation for Knowledge-Acceptance/Belief-Rejection

7. Further to release-response, the cited documents collectively recalled that previous efforts to achieve knowledge-acceptance/belief-rejection were unsuccessful because the synonymous use of these terms since time immemorial has elided/conflated their meanings; that clarification of meaning thus required a first-ever definitive differentiation of the knowledge/belief dichotomy and with it those of truth/ falsehood, wisdom/folly, right/wrong and good/bad; and that this now available differentiation is the preparation which leaves policy-makers no option other than to accept knowledge and to reject belief[3].

8. To clarify this new differentiation as used in all of the cited documents, it is here repeated that belief invariably precedes knowledge-acquisition; that our imaginations are first stimulated by our senses to beliefs as to the nature of reality; that such beliefs are transformable to knowledge of reality solely by evaluation of their compliance or non-compliance with it, or are beyond reality-evaluation in principle or in *pro tem* practice, thus remaining beliefs in perpetuity or until reality-validated or reality-refuted to positive or negative knowledge by later practice; and that no reliance can be placed on belief *per se*, however rational it purports to be. Thus, it is here repeated that policy-makers must now accept that opinion/counter-opinion is belief/counter-belief supported by partially selected facts/counter-facts, neither set being debate-terminating knowledge; that the outcome of debate is one or other belief-consensus, neither being knowledge, debate *per se* being the absence of knowledge before and after; that belief-consensus is elective and is achieved by rhetorical use of facts/counter-facts according to the respective skills of debaters and the shared gullibility of electors and debaters; that belief-consensus cannot thus be expected to apply to reality; that belief must be reality-validated prior to implementation as policy, if knowledge is to be acquired and accepted, and belief is to be identified and rejected; and that reality-evaluation of belief (hypothesis) produced the knowledge which is craftsmanship, science, technology and the knowledge-content of traditional behaviour codes, all else being largely belief-driven dissention, violence, revolution or war interspersed with periods of transient belief-consensus[3].

9. Thus, the cited documents were reinforced with this newly definitive knowledge/belief differentiation in recalling that by the mid 1970s the belief in species-extinction/ecological-disaster had been reality-refuted by

direct measurement to the knowledge that floating slicks are too thin for the seawater concentrations arising from them to be toxic to the marine organisms which biodegrade them to carbon dioxide and water; that the numbers of organisms dying from physical-coating are well within the known annualised birth/death rates of the species involved, and are thus not high enough to result in extinction/disaster as has been confirmed by the absence of any such effects at all incidents thus far.

10. As further preparation of policy-makers for knowledge-acceptance/belief-rejection, the cited documents collectively recalled that with implementation of reality-refuted belief being a rejection of reality, it could only have paradoxical consequences; that the reality-refuted belief in species-extinction/ ecological-disaster thus limits or prohibits the non-toxic dispersant-use which would avoid the physical- coating which does kill individual organisms, and does interrupt amenity enjoyment and the cropping of inter-tidal shellfish; and that it prevents safe-haven use for the cargo/bunker transfer which limits releases to those of initial tank-damage and thus prevents further releases from causing more of the effects which do arise in reality, while those of the reality-refuted belief-consensus never arise in reality.

11. Further to this preparation of policy-makers, the cited documents collectively recalled that this reality-refuted belief restricts dispersant-use which is possible only in sub-areas of slicks while the entire area is naturally dispersing at the viscosity-limited rate which would disperse/biodegrade all of it were sufficient time available prior to any of it stranding; that this reality-refuted belief wastes the storage available for pollutant transportation by preventing *in situ* discharge of the free water co-collected with it and the water released from its emulsions at up to four times their oil volumes; that this prevention in turn prevents the small oil-contents of these waters from being biodegraded with those arising from the natural dispersion of the slick itself; and that this prevention in turn requires all such water to be transported at needless cost to approved processing centres such as oil refineries.

12. Again, the cited documents recalled that these paradoxical consequences continue with emulsions thus transported being biodegraded by land-farming when they could have biodegraded in seawater, with the oil quantity thus biodegraded on land being much greater than that within the process waters which could have been discharged *in situ* for biodegradation with the naturally dispersing slick, with the cost of storage and transport of that which could have been biodegraded and/or processed *in situ* being entirely pointless, and with the increased releases arising from embargoes on safe-haven use risking species-extinction/ecological-disaster were these not merely expressions of reality-refuted belief.

13. Yet again, the cited documents recalled that the oil-slick thinness (0.1mm) which limits seawater concentrations of oil to non-toxic levels whether dispersing naturally or by dispersant-inducement, also limits slick-encounter rates for all response techniques to 0.18 tonnes per hour, per metre swath width, per knot of advance. Indeed, it was this knowledge which caused the MPCU stockpiles and contract to be scaled for response to the non-volatile residues from impact damage to a single tank, allowance being made for natural evaporative and dispersive reduction of such release prior to stranding; and which caused the stockpiled cargo/bunker transfer equipment to have the capacity to prevent further releases from being beyond interception of any significant fraction prior to stranding[1,2].

14. As to regulation of the related operational discharges of oil/HNS, the cited documents collectively recalled that currently attainable limits are known to be more than adequate for avoidance of the species-extinction/ecological-disaster not observed even for total releases of cargo and bunkers; that there is thus no real need for the zero discharge requirement of so-called Special Areas; and that alien organisms could be killed prior to ballast water discharge were biocides added to tanks at concentrations detoxified by post-discharge dilution. As to operational emissions of carbon dioxide, the cited documents recalled that the entire biomass of land and sea is continuously recycled from and to the atmosphere as carbon dioxide by the photosynthesis which abstracts it and the post-mortem biodegradation which releases it; that 'fossil' fuels arise in the first place from anaerobic interruption of this biodegradation; that it is aerobically resumed on release of oil and its HNS derivatives; that carbon dioxide is abstracted from the atmosphere by the Urey reaction with silicates which produces carbonate rock in tectonic mountain-raising and is released to the atmosphere by the volcanism which arises from tectonic subduction beneath continental margins of marine sediments containing mountain-eroded/river-transported carbonate rock sediments; that an increase of release in one of these cycles might increase its abstraction by the other or both; and that the belief in anthropogenic global warming (AGW) could thus be reality-evaluated via hypotheses derived from such as our horticultural knowledge of heavier crops being produced by increasing the carbon dioxide concentrations of controlled atmospheres.

15. As to the regulation of emissions of nitrogen and sulphur oxides, the cited documents recalled that these and other trace elements such as phosphorus, iron etc, are life-essential and consequently recycle through biomass and environment by photosynthesis and post mortem biodegradation; that atmospheric nitrogen would be unavailable to plants, animals and humans and thus unavailable for protein biosynthesis, for example, were it not 'fixed' with atmospheric oxygen to nitrogen dioxide and hence to nitrate by specific micro-organisms; that this natural nitrate no longer satisfies our global food requirement; that we thus supplement it with nitrate produced from air by the

industrial Haber process of nitrogen-oxygen 'fixation'; that while our current additions of life-essential elements to farmed-land are necessary and significant, our addition of some of them to the natural biota of land and sea by 'fossil' fuel combustion is insignificant; and that believers in the latter being deleterious need to reality-evaluate this belief if they believe its reality-validation possible given the knowledge already cited.

The Knowledge Repository: Preamble

16. Having recalled the UK government's acquisition and subsequent down-grading of knowledge to opinion for debate with counter-opinion, having recalled the advantages of knowledge and the disadvantages of belief, and having recalled the documented steps more recently taken to prepare the policy-makers of Member States for knowledge-acceptance/belief-rejection (paragraphs 3, 5 - 6 and 7 -15), this document now describes the new website itself[4]. Its repository contains the knowledge rejected previously by belief-consensus or otherwise lost by staff-change frequency and incident infrequency, this knowledge now being embodied in the new contingency plan from which incident-specific plans are derived by applying incident-specific values to the physicochemical parameters which the contingency plan identifies as the general determinants of release fates, effects, and responses.

17. Prior to the repository itself, the preparatory preamble recalls the knowledge that organic substances are biodegradable; that such cannot act as biocides at the concentrations which permit biodegradation; that the entire biomass of land and sea recycles through the atmosphere as carbon dioxide and as the oxides of nitrogen and sulphur while others recycle through the general environment without any extinction/disaster (paragraphs 14 - 15). Thus, with dilution and harmless biodegradation being the ultimate fate of all such releases, the preamble notes that any contingency plan derived from the knowledge repository must recognise the only significant effect of oil releases as being the physical- coating which interrupts commercial amenity enjoyment and the harvesting of sedentary shellfish.

18. As to magnitudes, the preamble recalls that the estimated annual quantities of oil entering coastal waters from land sources were larger and more coastally localised than those annually released and discharged to the sea by ships; and that biodegradation maintains land run-off concentrations of oil and pre-oil bio-source hydrocarbons in coastal waters at no more than ~0.01ppb while the highest concentration measured immediately beneath the micron-thin films of the final stages of natural dispersion is ~ 0.1 - 001ppm as exemplified by the Ekofisk release of 1976. Again, the preamble dispels the delusion of toxicity being independent of concentration and dispels the delusions arising from statistical analysis or mathematical modelling of arbitrarily paired-parameters neither having been reality-validated as cause or effect of the other. Yet again, it describes the nature of water-immiscible substances respecting the dispersion or emulsification of the one with the other; the oxy-derivatives which arise within emulsified slicks and droplets as intermediates to full biodegradation; the considerations governing the current formulation of dispersants and the possibility of attaining more effective formulations were interest in dispersants to revive; and the paradoxical nature of current toxicity-testing and use-regulation.

19. Further to the fates and effects of oil/HNS releases, the preamble identifies the physicochemical parameters which determine whether the release will be gas, vapour, liquid or solid, and whether it will float, sink, evaporate, dissolve or disperse, while recognising that evaporators and dissolvers need no encouragement and cannot be subsequently collected. Again, the preamble recalls that evaporation/ non-evaporation is dependent on known distillation profiles; that half-lives are attributable to naturally dispersing non-volatiles on the basis of their viscosities, thus enabling predictions to be made as to the quantity arriving on shore from the time taken to arrive and the known quantity released; that the efficiencies of dispersion and removal techniques depend mainly on pollutant viscosity; that dispersion increases the rate of natural biodegradation, while removal slows it down through downstream-processing prior to transportation to biodegradation or combustion; and that fast or slow, they always return to the oxides of carbon, nitrogen, sulphur etc from whence they came (paragraphs 14 -15).

The Knowledge Repository: Techniques, Equipment, and Procedures of Response

20. Following the preamble, the knowledge-repository recalls the knowledge of cargo/bunker transfer needed to restrict release to that of initial impact-damage, and to preserve the onboard safety of salvors. As to release-response, the repository identifies the knowledge which determines the choice and optimal use of response techniques and equipment at sea, inshore, and on shorelines of differing types whether tidal/non-tidal or temperate/tropical; which identifies bioremediation as the natural and ultimate response/fate mechanism; which specifies the remote-sensing needed to discriminate slick thicknesses for optimisation of the encounter rates of response equipment on water surfaces as and when necessary to reduce stranding potential; which specifies the optimal means of shoreline clearance; which processes removed pollutants including their separation from co-collected and demulsified water; and which separates pollutants from particulate beach material before or after collection, particularly when viscosity has prevented earlier dispersion from water surfaces or later dispersion from shorelines.

21. For completeness, the knowledge repository identifies the beliefs which have thus far thwarted available response-knowledge. by identifying specific knowledge/counter-belief pairs, by showing knowledge to be the sole

restorer of localities to their pre-incident conditions quickly and cost-effectively, and by identifying the specific benefits of knowledge-acceptance/belief-rejection, knowledge and belief having recently been definitively differentiated for this and all parallel purposes[3].

The Knowledge-Only Contingency Plan

22. The term ‘knowledge-only’ is used to denote the absence of belief, and ‘belief-only’ to denote the absence of knowledge. While recognising the sovereign rights of individual member States which need no international endorsement, this knowledge-only contingency plan recognises its own endorsement by reality itself in describing the operational means of casualty-stabilisation for safe-haven cargo/bunker transfer and the safety of salvors onboard; optimisation of dispersant-use and/or mechanical removal at sea and onshore; and the *in situ* discharge of process water in these removals. Further to shoreline response, the new plan describes the means of separating pollutants from underlying beach materials prior to or post initial collection; and the benefits of preventing stranding by prior application of surface film chemicals. It also describes dispersion from shore, recognising that no more oil thus enters the sea than would have, had it dispersed naturally prior to any of it stranding.

23. The new knowledge-only contingency plan identifies the physicochemical parameters which determine whether pollutants sink, float, solidify, evaporate, dissolve or disperse, and whether they evaporate partially or totally, thus identifying the need and means of response depending on whether the release evaporates, dissolves or disperses either directly or as emulsions with immiscible water and the rate at which it does so, thus enabling incident-specific fates and effects and response outcomes to be predicted from the incident-specific values of the parameters relevant to any future incident. Again this new plan notes that while response at sea is mainly dependent on pollutant-viscosity, the sea being the sea, shoreline responses depend also on type and on whether tidal/non-tidal, temperate/tropical; and that shoreline plans thus differ in not all needing the full range of response equipment and techniques.

Incident-Specific Plans: Constituent Steps

24. Having explained the transformation of the contingency plan to incident-specific plans and having described the latter, the following steps are identified. When a liquid non-solidifying release arises from an impact-damaged tank, the first step is to avoid weather-damage releases by cargo/bunker transfer; the second is to ascertain the values of the physicochemical parameters relevant to its cargo and bunkers; the third is thus to consider the fates and effects of any releases in terms of floating or sinking, fractional or total evaporation, total solution or progressive dispersion; the fourth is to calculate the fractional evaporative loss from any crude oil cargo from its fractional distillation profile as co-tabulated with the half-lives of dispersion, the former being usually 25-30% for crude oils and 100% for volatile HNS in < 5 hours; the fifth is to calculate the time to reach shore from the vector sum of 100% of the tidal vector and 3% of the wind vector; the sixth is to apply the respective viscosity-dependent dispersion half-lives of the non-volatile fractions of the cargo and bunker oils and of the non-volatile insoluble HNS to the quantified releases and to the calculated time to reach shore in order to estimate the quantities likely to arrive on the shoreline types identified at these locations; the seventh is to consider, on the basis of known viscosities and half-life dispersion rates, whether dispersant or removal techniques, both or neither, should be applied at sea, there being no need to enhance or prevent natural dispersion which of itself would prevent any onshore arrival. Thus, were this sequence to be followed, it would not only give structure to the response, it would also provide a format for claim submission and settlement.

25. Again, when a solidifying release occurs, the format of the incident-specific plan notes that all such oils/HNS have been identified; that with removal being the only option, it will best be achieved onshore; that when a soluble HNS is released it will dilute and biodegrade if organic or dilute/neutralise with the mineral content of the seawater if inorganic; that soluble HNS half-lives will be shorter than or comparable to those of floating insoluble oils of viscosity < 5cSt at 15°C as most HNS are; that there is no need to assist these natural processes, no possibility of collecting evaporators or dissolvers, and no need to remove rapid dispersers; but that known toxicity-concentration relationships may require down-tide HNS concentrations to be monitored with respect to bathing and fishing.

26. In continuance of the above sequence, the eighth step is to repeat the sixth to estimate the stranding quantity just prior to its arrival, having been further reduced by the quantities removed and/or actively dispersed at sea as estimated from the quantity of dispersant applied; the ninth is to revise the identification of the shoreline types to be impacted and the lengths, widths and thicknesses of these impactions, later to be corrected where appropriate by direct measurement; the tenth is to identify the response techniques applicable to each shoreline type and to its contiguous waters including the return of stranded quantities to inshore waters for easier removal or for natural or induced dispersion; the eleventh is to activate transportation of the associated equipment in the quantity and sequence appropriate to these various locations; and the twelfth is to identify and warn all who might receive oils for heat-generating combustion or ‘land-farming’, or HNS for onward sale or disposal by the techniques normal to the chemical industry.

27. Again, this sequence gives structure to the response and provides a format for claim submission and

settlement by the secretariats of the IOPCF and P&I Clubs. Yet again, mass balancing of quantities released with the quantities evaporated and dispersed, removed by dispersant-use/mechanical-means, and eventually stranded, as obtained in the above steps, will make our current knowledge more precise respecting the relationship of viscosity-values to half-lives and to the effectiveness of dispersant formulations and mechanical design-principles, such knowledge being reportable to the IMO secretariat for repository enhancement and for improving the cost-effectiveness of future fishing bans.

Knowledge Yet To Be Acquired

28. As to casualty-response, the website concludes that knowledge-acceptance/belief-rejection is the first step to acquiring further knowledge as to the relationship of pollutant-viscosity to half-lives and to dispersant-formulation and mechanical design-principles. As to operational discharges and emissions, the website concludes that knowledge-acceptance/belief-rejection is the first step to acquiring the knowledge which, through reality-evaluation of specific hypotheses, will terminate the currently divisive debates on ballast water management, AGW, and emissions regulation.

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Next Steps

29. With the first paragraph of this document having recorded that Member States have begun to adjust to knowledge-acceptance/belief-rejection, they and the MEPC, IOPCF and P&I Club secretariats are now referred to the new website for the knowledge needed to free claims-settlement from belief/ counter-belief dissention; to enhance the repository itself with further knowledge acquired from successive incidents; to accredit response contractors as to their competence, perhaps through independent accreditation agencies; to thus enhance customer-contractor relationships; to adopt a knowledge-acceptance/belief-rejection approach to ballast water and emissions regulation within the MEPC; and to reality-evaluate the belief in AGW through the UNCCC. In taking these steps now, no culpability attaches to the failure to take them earlier, the underlying failure to differentiate knowledge from belief having been ubiquitous since time immemorial and only recently rectified[3].

References

1 Response to Oil and Chemical Pollution, D. Cormack, Elsevier Applied Science, 1983.
2 Response to Marine Pollution - Review and Assessment, Douglas Cormack, Kluer Academic, 1999.
3 The Rational Trinity: Imagination, Belief and Knowledge, Douglas Cormack, Bright Pen 2010, available from Amazon or book shops.

Action to be taken

30. The MEPC, is invited to take note of the information contained in this document.

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Having thus summarised the website by reproduction of one of the documents prepared in anticipation of its completion, and having thus specified its intended use by MEPC, IOPCF and P&I Club members and secretariats prior to the availability of this website, the documents which now announce this availability to MEPC 70 and to MEPC/OCT/16 are reproduced below.

With respect to the overall involvement of the MEPC, we start with the document for MEPC 70 and continue with the document for IOPCF/OCT/16.

MEPC 70

CASUALTY-RESPONSE AND DISCHARGE-/EMISSION-REGULATION

ANNOUNCEMENT OF A NEW WEBSITE

Submitted by

THE INTERNATIONAL SPILL CONTROL ORGANISATION (ISCO)

Summary: In recollection of previous documents on the benefits of knowledge/belief differentiation, this document announces the creation of a website repository of the knowledge needed to replace belief in contingency and incident-specific response planning, in claim submission and settlement, and in discharge and emission regulation, while adding further knowledge to the repository.

Action to be taken: Rationality itself, now requires Member States to act on the knowledge which refutes its counter-belief in casualty-response and discharge-/emission-regulation.

Introduction

1 The document MEPC67/19/INF.13 covered both casualty-response and discharge-/emission-regulation while the document MEPC/68/20/INF.6 concentrated on the former, both being intended to inform the Committee of the author's newly definitive knowledge/belief differentiation and of its ramifications as submitted progressively to Meetings 10 - 16 of its subordinate Technical Group, these progressive submissions having themselves been derived from the author's two previous books via a series of articles in the ISCO Newsletter. Thus, these documents for MEPC 67/68 demonstrated that no beneficial change will ever be possible so long as casualty response and operational-regulation rest on adjudications of belief/counter-belief rather than on definitive knowledge; that until such knowledge is centrally collated and incorporated in contingency/incident-specific plans and operational regulations, staff-change frequency and incident infrequency will continue to prevent the preparation and execution of incident-specific plans which would enable predictions made, decisions taken, accredited contractors employed, results obtained and costs incurred to be reported to the IMO for enhancement of the knowledge repository and to the IOPCF for expeditious claim-settlement; and that the knowledge now collated for these purposes has existed for ~35 years though the efforts to promote it have never been sufficient to suppress the counter-beliefs promoted by environmentalist pressure groups.

Knowledge/Belief Differentiation

2 The foregoing documents used the author's recently definitive knowledge/belief differentiation to differentiate environmentalist beliefs from the environmental knowledge which refutes them; and to identify environmentalist beliefs which have not yet been reality-validated to positive knowledge nor reality-refuted to negative knowledge. Thus, the first of these documents showed that the reality-refuted belief in oil/HNS releases and discharges causing species-extinction/ecological-disaster ignores the absence of such effects at all releases and discharges thus far, and paradoxically thwarts knowledge-only response to all such releases; that the belief in anthropogenic global warming does not recognise the photosynthesis/biodegradation which recycles carbon dioxide through the atmosphere and biomass/ petroleum, nor the Urey-reaction/volcanism which recycles carbon dioxide through the atmosphere and carbonate rock; that hypotheses as to how an increase in carbon dioxide release in one of these cycles would increase its abstraction by the other or both, could be reality-validated or reality-refuted; and that no response has been received from environmentalist NGOs invited to conduct such reality-evaluation.

Knowledge Repository, Contingency/Incident-Specific Planning and Operational Regulation

3 The MEPC 67 document reviewed the benefits of applying the newly definitive knowledge/ belief differentiation to contingency and incident-specific response planning; described the means by which environmentalist NGOs were invited to treat their beliefs as hypotheses for reality-evaluation; considered the advantages of knowledge-only response planning and the disadvantages of mistaking belief for knowledge; and described the advantages of applying this knowledge/belief differentiation to the regulation of operational discharges of oil/HNS and ballast water, to the regulation of emissions, to the harmonisation of technology and environment, to the differentiation of science from pseudoscience, and to the replacement of inter-delegate dissent with the unity of delegate assent.

Further Encouragement to Knowledge-Acceptance/Belief/Rejection

4 As to such encouragement, the MEPC 68 document emphasised and exemplified the current suppression of knowledge by belief and the need to liberate it from this suppression; encouraged this liberation by re-emphasising the benefits of applying the new knowledge-only approach to contingency and incident-specific planning; defined the twelve steps of the latter; demonstrated how adoption of these steps will produce the more precise prediction of fates, effects and response outcomes which will in turn enhance the knowledge repository and progressively facilitate claim settlement; and re-emphasised the now pressing need to adopt the new knowledge-accepting/belief-rejecting approach wherever and whenever possible, and to recognise and terminate all belief-acceptance in the absence of the knowledge which may yet refute it as exemplified by the current belief in AGW.

The Website[1]

5 The Website is constructed in book-form with an Overview, Foreword, Preface and Acknowledgements to indicate the author's lifelong interest in the knowledge/belief dichotomy, the means by which he definitively differentiated this dichotomy for the first time ever, the thanks he owes to colleagues for their acquisition of now definitive knowledge despite the opposition of those who prefer definitive belief. Its Contents comprise the articles which first appeared in Cormack's Column in the ISCO Newsletter, but which he has re-edited to 177 articles, now grouped under main-section and sub-section titles to facilitate access and cross-reference to subjects of specific interest at any time.

6 Thus, we have 'The Knowledge Repository: Preamble' consisting of articles 1 - 38 grouped under sub-

section titles 1 - 12; 'The Knowledge Repository: Fate and Effects', articles 39 - 49 under sub-section titles 13 - 15; 'The Knowledge Repository: Response Techniques', articles 50 - 115 under sub-titles 16 - 35; 'Knowledge Suppressed by Belief', articles 116 - 129 under sub-titles 36 - 38; 'Towards Knowledge Supremacy in Practice', articles 130 - 155 under sub-titles 39 - 45; 'Knowledge-Only Approach to Incident Response', articles 156 - 162 under sub-titles 46 - 47; 'Wider Benefits of Knowledge/Belief Differentiation', articles 163 - 176 under subtitles 48 - 54; and 'Adoption of the Knowledge-Only Approach Thus Far', article 177 under subtitle 55. The average length of these articles is one page. Following the Contents, the Website Intentions are set out in less than one page.

7 The ISCO documents presented to MEPC and IOPCF are reproduced at Annex I for ease of comparison with the Knowledge Repository to which they refer, while the references from the author's first and second books are listed at Annex II to indicate the context in which the Knowledge was initially acquired. It is intended that progress towards adoption of knowledge-acceptance/belief-rejection in marine policy-making will be recorded at Annex III as such progress occurs.

Next Steps

8 The Committee is invited to recognise that rationality itself requires policy-making to accept knowledge and to reject belief (i.e. to be knowledge-only); and that acceptance of the newly definitive knowledge/belief differentiation as applied by this website to casualty-response and discharge/emission regulation, is the only means of acting on knowledge rather than on belief/counter-belief adjudications.

1 http://knowledgeonly-marinepolicy.weebly.com

2 See also,www.knowledgeonlypolicy.weebly.com

IOPCF/OCT16/4/

CASUALTY-RESPONSE

ANNOUNCEMENT OF A NEW WEBSITE

Submitted by

THE INTERNATIONAL SPILL CONTROL ORGANISATION (ISCO)

Summary: In recollection of previous documents on the benefits of knowledge-acceptance/belief-rejection as respectively identified by the author's newly definitive knowledge/belied differentiation, this document announces the creation of a website which provides the referential knowledge repository from which a general contingency plan is derived for all aspects of casualty-response, and from which in turn incident-specific response plans are derivable, provided all counter-beliefs are rejected.

Action to be taken: Rationality itself now requires Member States to act on knowledge rather than on belief refuted by it.

1 Introduction

1.1 ISCO document IOPCF/OCT14/4/6 responded to the secretariat document IOPCF/May14/4/1 and to the France/Spain/UK document IOPCF/May/14/4/2 on guidance for claim submission and settlement, by suggesting that the need for guidance arose from the belief/counter-belief nature of current response; and that so long as the guidance addressed only this belief/counter-belief without reference to the available knowledge of response, no beneficial change would be possible. The ISCO document also suggested that until the available knowledge was centrally collated and incorporated in national contingency plans, staff-change frequency and incident infrequency would continue to prevent the preparation and execution of incident-specific plans which would otherwise enable predictions made, decisions taken, accredited contractors employed, results obtained and costs incurred to be reported to the IOPCF secretariat in fully documented form for claim settlement, and to the IMO secretariat for enhancement of the thus shared knowledge repository. Again, ISCO document IOPCF/ APR15/4/5 recalled that this knowledge has existed for ~ 35 years, though it has never been perpetrated as continuously and ubiquitously as have been the beliefs which oppose it.

2 Knowledge/Belief Differentiation

2.1 The foregoing ISCO documents used the author's recently definitive knowledge/belief differentiation to differentiate environmentalist beliefs from the environmental knowledge which refutes them; and to identify the environmentalist beliefs which have not yet been either reality-validated to positive knowledge or reality-refuted to negative knowledge. The first of these documents showed that the belief in oil-releases being the cause of species-extinction/ecological-disaster ignores the absence of such effects at all releases and discharges thus far, and paradoxically thwarts knowledge-only response to these releases; and that the belief in anthropogenic global warming does not recognise the photosynthesis/biodegradation which recycles carbon dioxide through the atmosphere and biomass/ petroleum nor the Urey-reaction/volcanism which recycles carbon dioxide through the atmosphere and carbonate rock, both of which are more fully treated and referenced in the corresponding ISCO documents MEPC67/19/INF.13 and MEPC68/20/INF.6.

3 The Knowledge Repository and Its Contingency/Incident-Specific Plans

3.1 Document IOPCF/OCT14/4/6 outlined the intention of covering all aspects of casualty response with a knowledge repository, a contingency plan identifying the physicochemical parameters which control all aspects of release fates, effects and appropriate responses; and from which incident-specific plans are derivable by applying incident-relevant values to the incident-specific parameters of the contingency plan. Thereafter, it identified the 12 steps of the incident-specific plan which quantify all aspects relevant to any casualty-response, while IOPCF/APR15/4/5 used the newly definitive knowledge/belief differentiation to reveal the extent and persistence of knowledge suppression by belief; to liberate the former from suppression by the latter; and to explain how these steps of the new knowledge-only contingency/incident-specific planning approach were now able to enhance the repository with further knowledge acquired from successive incidents as to the relationship of pollutant viscosity to dispersion half-life, to dispersant efficiency, and to the effectiveness of mechanical removal. Again, these documents together showed how this new contingency/incident-specific planning approach would prevent the knowledge-loss through staff-change frequency and incident infrequency which was exemplified by the response to the *Sea Empress* incident seventeen years after the initial knowledge acquisition.

4 Further Encouragement to Knowledge-Acceptance/Belief-Rejection

4.1 As this further encouragement respecting casualty-response, delegates are invited to read documents MEPC 67/19/INF.13 and MEPC 68/20/INF.6 to see how this preference has already been beneficial respecting operational discharges of oil/HNS; and how it could now be beneficial in ballast water management, in evaluating the effect of sulphur, nitrogen and carbon dioxides and of carbon itself, in distinguishing science from pseudoscience, and in resolving inter-delegate dissent to assent.

5 The Website[1]

5.1 The Website is constructed in book-form with an Overview, Foreword, Preface and Acknowledgements to indicate, the author's lifelong interest in the knowledge/belief dichotomy, the means by which he definitively differentiated this dichotomy for the first time ever, the thanks he owes to colleagues for their collective knowledge acquisition despite the opposition of those who prefer belief. Its Contents comprise the series of Articles which first appeared in Cormack's Column in the ISCO Newsletter, but which he has re-edited to 177 Articles now grouped under a series of main section titles under which they are sub-grouped under sub-section titles to facilitate access and cross-reference.

5.2 Thus, we have 'The Knowledge Repository: Preamble' consisting of articles 1 - 38 grouped under sub-section titles 1 - 12; 'The Knowledge Repository: Fate and Effects', articles 39 - 49 under sub-section titles 13 - 15; 'The Knowledge Repository: Response Techniques', articles 50 - 115 under subtitles 16 - 35; 'Knowledge Suppressed by Belief', articles 116 - 129 under sub-titles 36 - 38; 'Towards Knowledge Supremacy in Practice', articles 130 - 155 under sub-titles 39 - 45; 'Knowledge-Only Approach to Incident Response', articles 156 - 162 under subtitles 46 - 47; 'Wider Benefits of Knowledge/Belief Differentiation', articles 163 - 176 under subtitles 48 - 54; and 'Adoption of the Knowledge-Only Approach Thus Far', article 177 under subtitle 55. The average length of these articles is one page. Following the Contents, The Website Intentions are set out in less than one page.

5.3 The ISCO documents presented to IOPCF and MEPC are reproduced at Annex I of the Website for ease of comparison with the Knowledge Repository, while the references from the author's first and second books are listed at Annex II to indicate the context in which the Knowledge was acquired. It is intended that progress towards adoption of this new knowledge-only approach to marine policy will be recorded at Annex III as such progress occurs.

6 Next Steps

6.1 With the knowledge/belief dichotomy having been definitively differentiated for the first time, rationality itself now requires belief to be rejected by the knowledge which refutes it; and thus requires the knowledge collated in this website to be accepted as the only means of settling compensation claims cost-effectively in the absence of all belief/counter-belief dissention

1 http://knowledgeonly-marinepolicy.webbly.com

2 see also www.knowledgeonlypolicy.weebly.com

This website was first posted on 29 June 2016, improved as to presentation on 7 July, and the content of Annex III added on 18 July. As to adoption of its newly definitive knowledge/belief differentiation by UK policy-makers from this point onwards, I conclude that the timing of the BREXIT vote and the formation of the New Cabinet increase the chances of UK policy becoming knowledge-only wherever knowledge permits and whenever knowledge-acquisition permits; that within the UK this differentiation may first be adopted to re-make policy on energy and the environment; that EU policy may follow this example; and that with rationality itself now requiring this newly definitive knowledge/belief differentiation, its adoption must surely become ubiquitous within the otherwise 'Disunited Nations'.

I intend to update this Annex with initiatives taken and progress made towards this global objective.