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CONCLUDING


Safety Offshore Eastern Canada

CONCLUDING

INTRODUCTION

As a conclusion to the Conference on Safety Offshore Eastern Canada, the Chairmen of each of the four Technical Sessions were requested to comment on the major issues identified in their respective areas during the Conference. These summarizing remarks were then followed by a final discussion session with participation from the floor.

The Conference was officially adjourned after closing remarks by Conference Chairman Dr. O.M. Solandt and a closing statement by the Chairman of the Royal Commission, Chief Justice The Honourable T.A. Hickman.

Mr. R.A. Hemstock, P. Eng.
President-Elect
Canadian Council of Professional Engineers
Chairman
Session Two
Environment & Design

CONCLUDING REMARKS

We are now at the end of a Conference that brought together a great deal of expertise to discuss various factors that are pertinent to safety of men and equipment offshore. I hope that the discussions have been useful to you and I think that perhaps bringing together this group in itself was very useful.

The subject matter presented in the Conference was logical in its order. On the first day we discussed the critical environmental factors and how they are input into design and the principles used in doing that. We talked about critical systems and the continuity of engineering responsibility. As a professional engineer, I believe that the profession must assume more responsibilities than they have in the past for the professional tasks that they are charged with doing. These factors are pretty well tied together in our knowledge of environment and our ability to design machines for it. We then heard a very lucid description of operator competence regarding systems. We talked about organization and management, which described the ability of men to work with machines, and it was then that I began to pick up a thread of a concern that I will come back to later. Following that we heard about escape and survival, and operations research as applied to rescue, or in other words, our ability to react to emergencies when things go wrong. And finally, we heard this morning comments from four people on regulatory systems.

I agree with and urge your attention to many of the points raised by Gordon Harrison in his paper "Perspectives on Safety". He made the point that we already have a good knowledge of the environmental factors, the selection of design criteria, safety factors, qualifications of designers and so on. I think it came through that, in general, our technology is pretty good, and it usually is not the cause of failure. Let me hasten to add, that does not mean we should lessen our efforts to improve environmental data and should certainly not decrease our design criteria. I think it does mean that we could look to other areas to achieve the most significant improvements in safety.

Perhaps I could list in point form factors which I think are important with respect to safety. First of all, a breakdown in safety is common even in the most regulated and the most sophisticated society. In most cases the cause of failure is not lack of technical knowledge but it is a lack of communication, continuity, and management. In other words, it seems to be a failure in the human to human interface. With respect to the man/machine interface, we must realize that in emergency situations the capability of a person to perform, even minimal tasks, may be limited. We have to make greater efforts to accommodate this factor. We need better methods to handle the mass of data that is being collected from many sta-

tions and many locations today. That data, which is in files that can not be retrieved, will not be much use.

I think that training may be the most cost effective way to spend our time and money for better safety. One thing that came through, but I do not think that anyone particularly addressed it, is the matter of language of regulation, of design, of operation; in fact, the whole industry is becoming so complex and so full of jargon that we are adding to our own problems. Just to give an example, the use of acronyms is now so prevalent with engineers and the bureaucracy, it must be our way of getting even with the lawyers, whose language is rendered almost incomprehensible with big words and with their wherefore's and whereas's and the occasional bit of Latin that is thrown in to avoid any possibility of clarity coming through. We are doing that, too, and we should get back to talking in plain English and try to avoid baffling people with science.

And finally, I think that we are making progress rapidly but the technology of today is also moving very rapidly. We are on the very frontiers of our geography and our knowhow, so we cannot let up in our efforts. I would like to try and sum up what I have been saying by introducing you to FREDS, a Fairly Remote Exploration Drilling System.

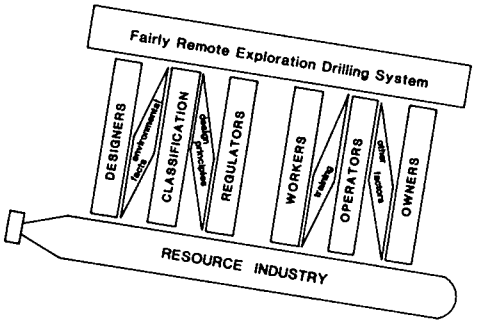
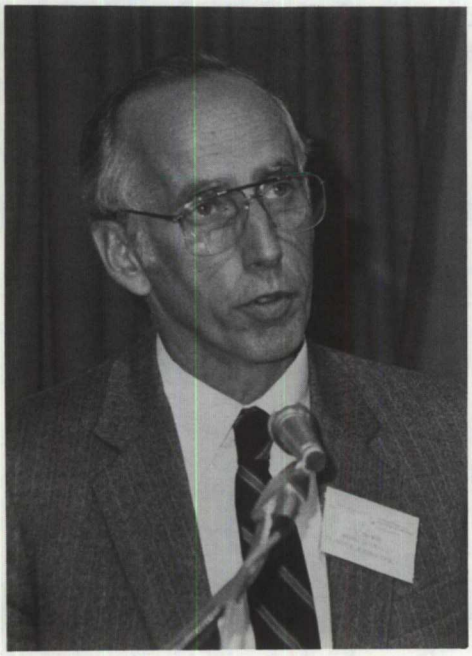


FIGURE 1 "FREDS"

FREDS is now listing because of incidents such as the *Ocean Ranger*. Maybe there is a little ballast in some of the wrong tanks and there are some external forces of public and political pressure which are appropriately shown by that wind reaction. FREDS main support comes from the lower pontoons, which are the resource industry, and the columns are the designers and classification people, the regulators, workers, operators, and owners. We strengthen the structure with the environmental knowledge, design principles, training and so on.

We had a very learned paper that told us that the weakest points in a structure like this are at the junctions of the various members. The individual members are okay but we have to continue to improve them. The main problem is at the joints where we get these stress concentrations. Those main joints or tie-ins of various involved people and agencies, of course, are illustrated by the communication problems that occur. The best opportunity we have for improvement is to work on those connections to ensure that better communication and better transfer of strength (information) is possible and we must strengthen the joint system (communication) for better management. That is one of the points that Gordon Harrison was making.



Dr. G.M. MacNabb
President
Natural Sciences and Engineering Research Council
Chairman
Session Three
Man/Machine Interface

CONCLUDING REMARKS

The Tuesday morning session on man/machine interface was extremely interesting. The first portion related to operator competence in relation to critical systems technology, and I came to this Conference with a pre-conceived notion that I would be having to deal with problems regarding man's ability to accept and to cope with technology, as that is something that we are seeing elsewhere in society. Also, I thought we would be dealing with concerns about information overload, or operators being exposed to so much information that they have difficulty making appropriate choices. But the discussion I have heard has not borne that out although concerns were expressed about, I believe the expression was "moron technology" and the degree of danger of repetitive training leading to complacency.

Dr. Foley graphically illustrated the flaws in our every-day designs and I am sure that each one of us has experienced the frustration from such lack of common sense. Dr. Haakonson gave examples of the increasing incidence of jobs where, in his terms, there are long periods of boredom, interspersed with short periods of absolute terror. Technology, unfortunately, is leading us more and more in that direction in many professions. We run increasingly the danger of being lulled into complacency and boredom because of technology and we must in the words of one of the participants in my panel, "pay attention to incidents to stop them from becoming accidents." Technology is making us complacent to the point of where we are not paying adequate attention to incidents.

My reaction to the first portion of the session, operator competence, was that I heard concerns about too much technology, too much simplification of tasks, yet I heard no evidence that we have reached that stage of man/machine interface in the offshore region. This leads me to my conclusion on this subject, and I must make comparisons to high technology industries and the nuclear industry. I have seen very excellent applications of high technology in the offshore of bringing a rig onsite and maintaining it properly over the hole, and of well logging and interpretation. I have not heard or seen evidence of any dramatic increase in the use of high technology in the actual drilling operation itself onboard – of employing high technology to the optimum. I do not mean the maximum, I mean the optimum.

Let me take the most extreme example, and here is where I must make a comparison. The extreme example on the platform is the activation of blowout preventers. I could liken that action to a problem in a nuclear plant where there is a loss of coolant.

Without human involvement whatsoever, the emergency core cooling system is activated by a machine and the plant is shut down by a machine. There is no human override involved whatsoever. We have all watched the space shuttles go down to the last two seconds and the machine shuts down without a human pushing a button, because of the lack of performance, quite often, of some relatively minor part of the total makeup. So when you compare that, you can see my confusion about what I understand is the case when you lose mud pressure in a hole being drilled and there is high potential of leading to a blowout; there is no electronically monitored display and there is no automatic action by the machine to activate the blowout preventers, not even one that gives you ten seconds for manual override. My question to the learned audience is, why not? Given the consequences of such problems in a drilling operation, both human and environmental, why is that we still have the hands-on attitude of the human operator at that point in time? Are we not inviting the obvious consequences of "fixations" or "cognitive locking" by humans, which happens in extreme stress? Obviously the attitude of the operator is that it cannot happen, or it can be fixed in time.

Mr. Hielm, on my panel, observed the problems with a surplus of confidence by people, or the human tendency to "tie solution to situation, rather than situation to solution." Today's modern machines are excellent in tying situations to solutions and presenting solutions very, very quickly to the human being. So, why has not the ability of today's technology to analyze a situation and suggest a solution been used in this very critical operation?

The offshore activity draws on two very interesting sectors of the economy: the marine industry with its long history and tradition, one of acceptance of the perils that are out there because that is part of the job, a degree of fatalism that a speaker mentioned yesterday; and the petroleum industry which is much newer and brings with it an element of feeling of the frontier where it has always worked with very much a degree of individualism and hands-on attitude. I suppose there have been many studies about that mix of our inheritances in the offshore operation. It appears we are dealing with an emotion, but do not quite have a true mix as yet. So my observation on the first part of the session is that I do have doubts that this industry has used the rapid advance in technology to its optimum capacity in all its aspects.

The second portion of the session dealt with organization and management. Mr. McGrath's paper was an interesting mix of satisfaction with the existing organizational and management structures, but at the same time it expressed concern with such things as "one person should be clearly in command at all times." It would appear that there are situations where this is not the case, and it would also appear that some in the industry defend that on the basis that change-over in command takes place by an official sign-over procedure. In normal circumstances that might be all right, but surely in the case of an emergency, especially where there may be somewhat different objectives, that is not an acceptable situation; I detected a strong view that, in all cases one person must have final authority at all times.

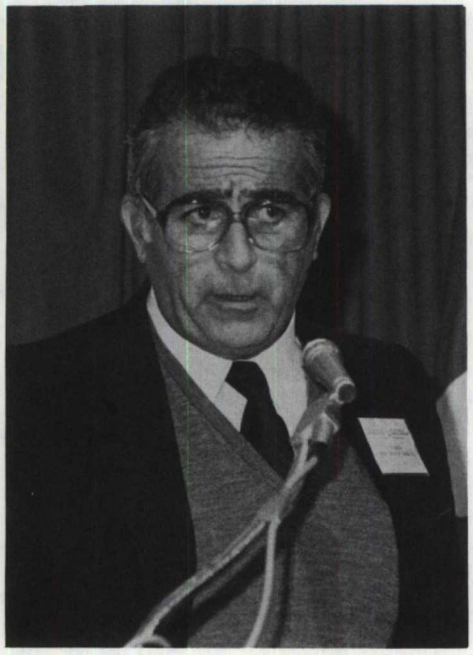
Mr. McGrath's paper also initiated discussion on the lack of formalized qualification requirements for key positions on board the drilling unit. For the uninitiated like me, the lack of such certification came as a shock. Much has been said about the hostile nature of the environment within which the industry must work and yet we lack an agreed standard of training for those that we send out into that environment. I detected here a unanimous view that certification by a single authority is essential and I do hope that our small "p" and capital "P" politics make that possible.

To come back to the man/machine interface, we have an opportunity in this country to use modern technology. For example, Canada is a leader in simulation

technology. We use it, of course, extensively for air crew training, and simulators are being developed now for small private planes to reduce the amount of time required in the air itself. I heard the argument presented that each drilling rig is different, but simulators can at least give you that 80 to 90% total feeling of being involved with the rig or being in the ballast room, and surely that is something we should strive for in our certification process.

One final observation on my panel discussion on the question about reporting systems for items such as accidents or incidents. Mr. McGrath's presentation stated that "reporting of incidents is in a transition stage and is subject to individual judgement due to the lack of a clear indication of what incidents must be reported. It is expected that it will be worked out over time." Compare that to the earlier admonition of Dr. Haakonson on the same panel when he said, "Pay attention to incidents, stop them from becoming accidents." Clearly, something must be done in this area. I must once again make a comparison to the nuclear industry where all incidents must be reported, where it is not left to the judgement of the individual concerned. They can be serious incidents or accidents, or they can be trivial ones; they can involve the nuclear component of the operation or the non-nuclear component, but they must be reported. This procedure provides a vital record of what is happening in that operation. I think the discussion has pointed out a clear need for action in this area.

Finally Mr. Chairman, to put my Natural Sciences and Engineering Research Council (NSERC) hat on, I must say my Council has active programs to promote research, and has increased the research effort involving industry and university. We have launched programs recently to which I have seen a significant response from the high tech industry, the forest industry and even the mining industry, but I have yet to see any significant response from the petroleum industry. I would have thought that I would have seen it from Memorial and other places where we do have significant engineering and advanced technology experience. I have seen nothing but a very fertile area for research and development, and I must disagree strongly with the comment that was made this morning, that the accidents we have heard about could not have been prevented by advanced technology, that it is more training that is required. It is not a case of one or the other, it is a case of both.



Dr. A.J. Mooradian
Senior Vice-President
Atomic Energy of Canada Limited
Chairman
Session Four
Emergencies

CONCLUDING REMARKS

I am going to comment on two areas: 1) the session I chaired very briefly, and 2) I would like to give you an overview of some of the important pieces of this Conference. You have heard from a body of experts that has a tremendous, mature and deep knowledge of the subject, and it might help to have some of their ideas fortified by someone from the outside. My background is in the nuclear development business, not in the nuclear regulation business, so you should keep that in mind as you hear my comments.

First, on the question of escape and survival, we have heard that there is plenty of room for improvement, and that it is a tremendously hostile environment which is likely to respond to concerted effort. We were given some good examples and good approaches on how to go at it and at the same time we were told about the institutional sorts of constraint possibilities and the competitive pressures, which operate on the motivation to proceed. However, I cannot really accept any of these as a real inhibition for action because what I detected is a uniform and sincere will to proceed to improve this area.

How can technology help? I would like to address the Commissioners specifically in an area that I know something about. You are not being addressed by the most brilliant technologist in Canada, but I can tell you that technology is hard. Our legal friends are very generous; they think we can do almost anything with science and engineering, that all we have to do is throw in the resources, throw in the effort and just release this tremendous intellectual capacity to get a result. There is an illusion that science proceeds very fast, that innovations proceed very fast. Science and technology, particularly in conservative areas, such as the ones that you are addressing, are a hard, tough business. My suspicion is that if we are going to get a new lifeboat system, it will take a significant effort, that this is no $100,000 sort of international game. This is a several million dollar, several year game that is going to require on-site proved demonstration, redemonstration, and qualification, all down the line, even if it is to be only an engineering type of solution. This area deserves attention, and it undoubtedly will respond, but it will not respond to a half-hearted effort that is based on a preconceived idea that it is a small job. It is a big job. It is as big a job as small reactors. It is easy to build a power plant, but it is a heck of a job to put one in an automobile.

On the rescue side we have also heard that this is more likely to respond to man-to-man interfaces than technology interfaces, that much of the technologies in place require organization. That is all I would like to say about the particular session I chaired.

I would like now to say a few words about my perception of the whole Conference. I have to start with our keynote speaker. I had some difficulty with two particular points that he brought out. The first was the indication that the private sector can handle this job alone. In my job I have interfaced with the private sector, the public sector, and the academic sector, and no one of them has a corner on responsibility, no one has a corner on the sense of motivation or of accountability, and no one has a corner on response capacity. It requires the marriage of all of these, and that is the most likely situation we are going to encounter. It is not helpful to isolate them.

The second point on which I disagreed is the treatment of accountability. I find that Chief Executive Officers fail with the same monotonous regularity as the rest of us. In fact, in some environments, they fail somewhat faster. Chief Executive Officers do not have a corner on perfection, so a fully accountable CEO can certainly lead to a fully accountable catastrophe, which is, nevertheless, a catastrophe. Accountability does work and it is an important aspect of management. It works when responsible people have something to respond to, or for which they can be held responsible. They need signals and part of the difficulty in developing a safety regime is developing the signal mechanisms.

I think this industry has a special problem because it brings two cultures together, the drilling culture and the maritime culture. The maritime culture is a thousand years old, with a tremendous tradition and conservatism in addressing catastrophic types of events where tens, twenties and possibly even hundreds of people are at stake from the given mistake. The drilling culture is not any less responsible, but it has been brought up in a different regime. It is a production type of regime, an industrial regime. In the nuclear industry we set up a regime which lets us look at every incident and we understand it. We do not shut our plant down, but we examine it until we understand it, and we work in a safety administrative zone. We are in a continual dialogue of safety in this safety administrative zone, and it allows us to concentrate on our safety within that area.

If you ignore the minor incidents, you do not get this kind of interesting dialogue throughout the whole of an operation. It is a continuing kind of dynamic thing, and everybody has a common aim; the operators, the owners, and the workers all want a safe plant. It is not that tough. In the development of regulations you have to make it easy, not punitive, for people to report.

In the nuclear industry, I think the most important attitude we bring to safety is humility. It is important to know what you know and even more important to know what you do not know. One can then address the minor incidents and extract from them the maximum benefit in attitudes.

Dr. J.E. Hodgetts
Professor Emeritus
University of Toronto
Chairman
Session Five
Regulatory Systems

CONCLUDING REMARKS

We were instructed as Chairmen to produce, on this last occasion, a kind of steely-eyed view of the proceedings. I can say that in every session I have had more fully confirmed an earlier previous impression that the particular arena of offshore exploratory drilling affords one of the most complicated venues in which public policy, as it relates to safety, has to be worked out. As a social scientist watching these proceedings, I observed the scientist interface with the engineer as the relationship between environment and design was confronted, and I found what seemed to me to be a fascinating tension between the literally inexhaustable appetite of the scientist for the accumulation of yet more accurate data, and the immediacy of the demand of the design engineer for hard facts.

With my particular concern with the regulatory side of this, I wonder about the relevance of this tension to the regulatory process. I suspect that the engineers feel that the scientists' demands for more research and more data may encourage overkill on the part of rather nervous regulators looking over their shoulders to the implications of what is the very significant feature, the 100-year wave, or the 100-year wind. That is one tension that was reflected in some of the concerns expressed this morning on the regulatory side.

In the discussion of the man/machine interface, I saw another sort of tension surfacing between two schools of engineering: one that emphasizes the separation of the man and the machine; and the other view, which views man as a machine with no interface at all. Again, the implications for public regulatory policy are still not clear to me, but perhaps there may be the root of the assertion that you cannot regulate against the frailties of human nature. Nevertheless, I suspect that it is not all that clear whether the regulation of the machine, the components of the machine and its requirements can help the human overcome his frailties. We in fact talk about that when we talk about the capacity of the machine to reduce the capability gap that one finds as a consequence of human limitations.

Similarly, as we move from concern for the individual human being to the human being acting as a system for productivity, attention shifts to organization management structures in which regulation imposes or insists upon standards of performance and qualifications for the key managerial personnel on the basis that such requirements can in turn improve the productivity of human beings. This is probably just an awkward way of raising the question of the relationship between training and regulation, and the further question of calculating whether compliance with regulations of any sort in this area can be achieved. Or indeed, the further question of who, in the end, should be responsible for imposing standards, the

operators, the industry, or governments acting in the name of the elusive "public interest", which I have not heard anyone refer to in this Conference.

The discussion in the third Session was really warming up toward the end, and a question was posed concerning the conflicting priority on a drill rig because of the different perceptions entertained by operator, contractor and regulator, and the effect of this conflict on the response of the crew. Now, I put that beside the rather interesting and spontaneous eruption when the apparently evil word of "union" was introduced this morning in conjunction with the question of whether the unions have had input into this Conference. A more mutual way of introducing that, without the presumed threat that is contained in the word "unions", would be to ask if there is any input by workers with respect to the regulatory process.

In Session Four, I perceived the tension or frustration created for the engineering designer facing regulators, particularly international regulators. Yet, as I understood that discussion about lifeboats and the introduction of more innovative techniques with respect to lifeboats, it sounded to me that, unless you did handle this through the international regulatory route with international agreement, there would be no disposition on the part of industry to incur the financial sacrifice required.

Finally, I want to come back to accountability. The word "accountability" was in fact seldom used in these Sessions, but a lot was said in terms of the word "responsibility". It is a loaded word that can be badly used, because it has quite a variety of meanings. I did hear, for example, nearly every participant claiming that they wanted more of this thing called responsibility. From our keynote speaker on through, industry was asking for more responsibility, the classification societies said they had a lot of it and the regulatory agencies took second place to no one in their claims for asserting this responsibility. All of these claimants are defining responsibility in one of two ways. The regulatory agencies are saying: we are responsible because this is our duty, and we are responsible for regulating legislative acts. And industry is saying: we are responsible people without being obliged by any regulation, and we are so at great personal expense; we have developed a unparallelled training program.

Throughout this Session I only twice heard a reference to responsibility in what I consider to be any gutsy sense of the term. One was an historic reference to that poor benighted engineer who died of shame because he was held personally accountable for the Tay Bridge collapse. That was the one key reference to accountability about which we should really be concerned. The other came from a drill rig owner/operator who, in referring to his being out on that rig on the high seas, said he really felt responsible for his people and for what was going on out there. Otherwise, anything less gets to be pure double talk and is falling into the same disrepute that seems to be developing for this notion of Ministerial responsibility. Yes, the Minister says, we are responsible in accordance with good constitutional doctrine. So what? Do they fall by the way? Do they resign? Indeed not. The Opposition goes back and licks its wounds and hopes that it can get in and apply the same interpretation of the doctrine of Ministerial responsibility.

So when you do accept responsibilty, is that being accountable in any real sense of the term? If responsibility viewed as accountability means anything, it means either that I am responsible to myself in the Shakespearian sense "to thine own self be true", or perhaps I would modify it to say "to thine own professional code of ethics be true"; or else that, yes, I have been assigned this duty and I am answerable, not in this instance to myself, but to someone out there, for the proper performance of that duty that has been imposed upon me and which I have accepted. I am prepared to take the consequences if it can be demonstrated that I have violated the commission of trust which has been imposed upon me.

Accountability or responsibility used in that sense is simply a matter of being

the discipline for the actors. This is what this whole exercise is about. People are not paying attention because nobody is accountable in that sense. Sure, all had responsibility, all had duties, but where was the payoff in terms of being genuinely accountable? Why would people be forced to report the incident if there was no pressure in the system on them?

I like to use my old colleague and mentor, Alec Cory's story which he used to tell to his freshman class when they came in. It is the best demonstration of what I mean by accountability and I will leave you with this thought because I think one cannot dispense this notion of accountability as I am giving it. A mule trainer was brought in by the farmer to train a mule and his first action was to go over and take a board off the fence and proceed to beat the poor beast about the head. The farmer protested, "What sort of mule trainer are you?" The mule trainer replied, "The first principle of mule training is that you have got to get their attention." Now that is what accountability is all about. Get their attention and that applies from top to bottom of the system and if there is any break in that linkage, in that long chain of accountability, then all hell can break loose.

Summary of General Discussion

Dr. R.B. Wardlaw (NRC) opened discussions by noting that the Conference's Technical Sessions identified numerous gaps in the technological data base being used by the offshore industry, and that it also became evident that the industry has very little ongoing scientific research. This is so despite efforts of the National Research Council to establish an environment which encourages research either through funding or the provision of technical support. Dr. Wardlaw felt that regulatory or codewriting bodies should play a leadership role in encouraging this necessary research, since these bodies interact positively with the scientific community in both industry and academia.

He advised the Conference that Canada already has a precedent for such an approach in its National Building Code which is thought to be one of the most progressive and responsive building codes in the world. It was suggested that this Code and the methods and procedures used to keep it current and accurate would be a suitable model for the establishment of a progressive and dynamic code for the offshore industry.

Session Chairman Mr. R.A. Hemstock emphasized, however, that initiative for research must originate with the industry, and not with government, in order to achieve satisfactory results. Nevertheless, industry should take advantage of the research opportunities, funds and support made available, and the offshore industry has not done so in the past.

The question of achieving accountability, whether in government, in industry, or on rigs, generated much discussion. Session Chairman A.J. Mooradian, citing the experiences of the nuclear industry, described the use of a "signal system", first to identify and then to resolve problems. The nuclear industry treats all incidents as serious and, therefore, worthy of recording and investigating. That includes events which are well within the non-catastrophic range. This reporting system spreads levels of accountability throughout the whole infrastructure of an organization, from the chief executive officer to the worker in the field, and provides data to be used towards the prevention of incidents which may be catastrophic. In the offshore industry, with its mating of marine and industrial cultures, it is imperative to make accountability a state of continuing operation. This may be achieved by setting up the criteria based on figures which are already available, and by developing an information system that allows everybody to participate in improvement of the industry.

Session Chairman Dr. J.E. Hodgetts disagreed with the establishment of a "system" of accountability and preferred an approach which makes accountability a collaborative venture between industry and regulatory authorities, with both groups having a precise perception of what each is supposed to be doing for which it is to be accountable. The flow of information would be an important aspect of this approach. In addition, no method of assuring accountability is workable without the attention and awareness of the legislative body which, in our parliamentary system, has the ultimate authority.

Mr. Norman Letalik (Dalhousie Ocean Studies Program) suggested that, because politicians have created great expectations in the general public from the oil industry, the public tends to confer accountability on government. Consequently, government aims at complete control over all facets of the offshore industry, since they feel that the public will hold them accountable.

Session Chairman Dr. J.E. Hodgetts responded to this suggestion with the comment that government creates policies on energy and establishes crown corporations to manage and administer them, and that this places them squarely in a

position which makes it difficult for the public mind to dissociate government from the question of accountability.

Dr. E. Gold (Dalhousie Ocean Studies Program) felt that accountability should not be confined to events following an incident; there should be more emphasis on accountability for the prevention of incidents. In this light, it does not seem proper from an accountability point of view to allow rigs similar to the *Ocean Ranger* to continue operation. And yet, no one in the offshore industry, either on the government or the industry side, has taken the responsibility to recall such rigs. This is often done in the aviation industry, where at times whole series of aircraft are grounded until safety conditions are restored.

Dr. T.D. Petty (ODECO Engineers, Inc.) made lengthy comment about the role of rules and compliance with them in the achievement of safe design. He referred to the *Ocean Ranger* which was built to compliance with existing rules but which sank in conditions far less than those for which it was designed. That such an event could happen indicates that design and construction rules are an inadequate assurance of safety, despite the other weaknesses (such as lack of documentation and improper training) which are said to have contributed to the loss of the *Ocean Ranger*.

Dr. Petty was specific in his criticism of the rules which permitted the design of the *Ocean Ranger* as an unsafe rig. In 1973, classification societies, at insistence from industry, relaxed stability criteria for semisubmersibles and thereby decreased the inherent margin of safety which had been in existence up to that time. This resulted in too much dependence on gadgetry, procedures, and people for adequate safety. Furthermore, present rules allow a semisubmersible to be designed so that when the allowable KG is being determined, it may heel to its angle of downflooding in an assumed calm water condition. Calm water is an unrealistic condition in 70 or 100 knot winds.

The angle of downflooding under the calm conditions assumed is normally found to be in excess of 20 degrees. Dr. Petty also stressed that when a rig is heeled to 20 degrees, a condition allowed by the rules, it is highly unlikely that a crew could perform any effective work, regardless of the positive attributes of training in overcoming stress under emergency conditions. Useful work is not likely to be effective beyond 12 degrees.

The rules in effect today allow a designer to assume various cases of damage with only a 50 knot wind load (again in the unrealistic calm water), and this may be applied to the U.S. Outer Continental Shelf, the U.K. North Sea, and to offshore Canada. In addition, a designer is permitted to allow the deck to become submersed and awash at the angle of downflooding, without being required to ensure that the deck is structurally able to withstand the forces imposed by sea waves driven by 100, 70, or even 50 knot winds. A design which allows this to be acceptable has severe implications for the major problems already encountered in the launching of lifeboats and with evacuation systems generally.

In a plea to re-address the fundamentals, Dr. Petty urged the Royal Commission to regain the pre-1973 margin of safety in rig design and to limit, by design, allowable heel and list angles in the various cases of damage which are assumed in the stability calculations. He emphasized that these calculations should require the consideration of reasonable wind speeds and the resultant forces that can be expected in the environment. These measures would increase the probability of rig survival and, in turn, would increase the resiliency of the rig to absorb human error.

The suggestions made by Dr. Petty were endorsed by Mr. J. Hornsby (CCG

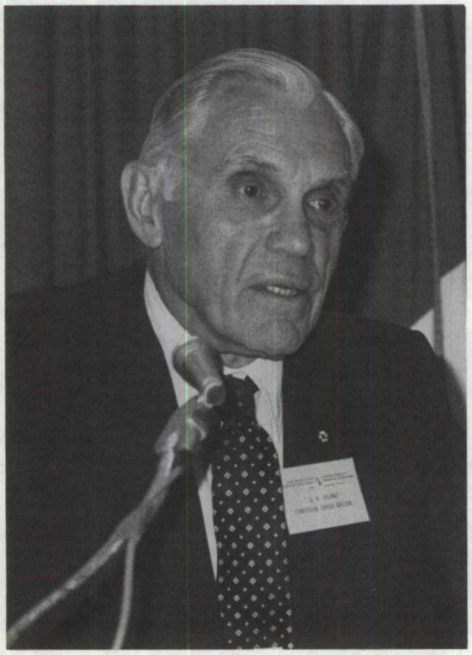
Ship Safety Branch) but Mr. Hornsby reminded the Conference that to follow them would result in the "grandfathering" of nearly all existing rigs because they would not meet these revised standards. Mr. Hornsby advocated that, all things considered, it is the flag state and those who permit the drilling operations who are responsible and accountable.

Dr. Gold noted with interest the hostile reaction to the suggestion that the offshore industry should be unionized, and commented that the cited example of experiences in Australia was not one of good management and labour relations. He said that there is a role for labour, whether organized or not, and there are many examples worldwide where organized labour has had a responsible and effective input, particularly on the safety side of the industry. This is an aspect which requires further development because the industry as a rule tolerates little criticism from its employees.

Mr. J. Hielm (Elf Aquitaine Norge) stated that in Norway the law requires that employees elect a representative to the safety committee of a rig, and, of course, where there is a union, this representative would obviously be a union member. It is important to stress, however, that he acts as the representative of the employees and not of the union. This representative is required to be thoroughly familiar with employee responsibilities and obligations under the law. Also, inspections by the regulatory authorities include private interviews with employees, which provide the opportunity for both structured questions on safety and free discussion on matters of concern to the employee.

Mr. R. Fodchuk (Shell Canada) reported that at Shell Canada the safety representative does not come from the ranks of the employees but is someone independent of the rig's management. This person also interviews employees following any incident (such as was done following the *Vinland* blowout at Uniacke G-72) in order to obtain useful feedback on emergency procedures from the employees' point of view. Each rig also holds a weekly safety meeting which all employees are requested to attend, and this provides another form of communication. Mr. Fodchuk also stated that Shell Canada has very formalized procedures for the reporting of all incidents, even when the incidents fall under the control of a sub-contractor. Furthermore, industry is attempting to avoid variances in reporting between the operators and the drilling contractors by standardized reporting to the Offshore Operators Division of the Canadian Petroleum Association in Calgary.

Mr. J. Gow (Mobil Oil Canada) described Mobil's safety committees which comprise three management people and three workers, with all workers being given the opportunity to serve on the safety committee at some point. These committees examine their respective rigs for safety deficiencies, have a follow-up mechanism to control the deficiencies, and report, in Newfoundland to Occupational Health and Safety, what deficiencies are found, how they are rectified and when. Mobil is proud that these committees have been established prior to any regulatory requirement.



Dr. O.M. Solandt
Conference Chairman

CLOSING REMARKS

By way of introduction I will recite a little notice that a friend of mine used to have over the desk in his office. In large letters, it said, "If I seem to be confused, it is only because I am." I knew that making these concluding remarks would be a difficult task, but I had not appreciated until today how difficult it was going to be. I prepared my notes last night and now almost everything that I wrote has been said during the morning. The few remaining *bon mots* that I had up my sleeve have been stolen by this final panel. I will still attempt to give some concluding remarks. I am not going to try to make a systematic overview of the whole meeting; I will just try to touch on a few highlights and especially on areas where it seems to me the Commission may wish to give further consideration with the possibility of finding material for recommendations.

In general, it seems to me that the Conference has been a success. The Chief Justice will tell you more in his concluding remarks as to the views of the Commission, which are the ones that really matter. The purpose of the Conference was to expose the Commission to the opinions of experts and they have certainly been exposed. It has on the whole been an open discussion. If we could go on for a few more days it would become even more open and more lively. There is every indication that people are beginning to feel more relaxed with each other and are ready to say what they think. There has been a fair amount of repetition of the conventional wisdom and an occasional covering of positions, but for a Conference in which there have been so many diverse interests represented, it has gone extremely well.

Gordon Harrison's keynote address found very little response in the earlier parts of the Conference but has been mentioned several times recently. It is a great pity that he is not still here to try to tell us exactly what he did mean, because there have been many interpretations of what he did say. The general message that I got out of it was that there have to be absolutely clear lines of command, responsibility and authority at every level in such a complex system, so that no one is ever in any doubt as to where the orders come from, and nobody who gives orders is in any doubt as to whether he is responsible for the result.

Turning now to some of the specific sessions, the one on the environment was interesting and useful. It highlighted the fact that we badly need more data, that we certainly need more measurement of wind, waves, and current at the same time and in the same place, and that the forecasting, particularly on the Grand Banks, would probably be substantially improved by the use of buoys to give more weather observations. It was not mentioned in the session, but I think it is worth

underlining here that while the forecasting and weather information seem adequate in the exploration phase, it will be very important and valuable to have much better forecasting during the production phase. Clearly, the greatest need from the environmental point of view is for somebody to turn up reliable records of wave heights dating back to 1880, but that is unlikely to happen; that might give some real clues as to the size of the 100-year wave!

We heard in some admirable papers on structure and design about analytical methods both for general structural strength and fatigue life. It was clear that the designers need from the environmentalists far more than just the height of the 100-year wave. They need wave spectra, and information about wind directions and wind effects on the structure in much more complex ways. It was particularly interesting to find that the experts on structure disagreed quite sharply on many important points, illustrating again that this is an art and not entirely a science.

Offshore safety, as evidenced by the interaction between the environmental information and structural design, is a classic example of the interface between science and engineering. A conservative scientist, if asked, "Do we really know enough about the environment offshore on the Grand Banks to design a completely safe and reliable drill rig?", if he were frank about it, would reply, "No, we do not really have enough information. Give us another thirty or forty years' observations and come back and we will tell you exactly for what conditions you ought to design." The engineer says, "Fine, but we want to drill today. So, we will cautiously begin drilling first in sheltered waters, using all the scientific knowledge that we can get. As we advance into deeper and more difficult situations, we will try to spur the scientists into giving us a little more help, and gradually we will be able to conquer the most difficult areas."

This approach has worked remarkably well, as it traditionally has with engineering, and it should not be either belittled or mistrusted. What we need is an increasing cooperation between the scientist and the engineer so that the scientist can focus his research more directly toward the things that the engineer needs to know for the future. And again let us not think that we have come to the end of the evolution of offshore drilling structures. We only have to think of the challenges that face the engineering community for the production structures that will be needed offshore on the Grand Banks and even more in Labrador. So, this process of evolution, the interaction between science and engineering must be pushed ahead as rapidly as we can afford. But in spite of what I have said, it is necessary to underline the fact that, even off Newfoundland and Labrador, offshore drilling is by no means one of man's most hazardous occupations. It is relatively safe, but can be made safer.

We had very interesting presentations on man/machine interfaces and discussions about the importance of adapting the job to the operator, not trying to adapt the operator to the job. This is clearly something that was needed in the case of the *Ocean Ranger*. I am not sure that it is needed now, as I have not been on any drill rigs recently or seen the latest in ballast control systems, but there is clearly no great problem in designing a ballast control system that will suit the general run of operators that are available. The same is true of most of the jobs on drill rigs. They are not at the limit of human capability, but they are ones where performance can be substantially improved by better attention to the man/machine interface, probably even more at the level of the interplay of the crew with the rig as a whole, and particularly in some specific fields like evacuation. The problems of providing not only the lifeboat or other improved mechanism for leaving the rig, but ensuring access to the embarkation points and ease of embarkation, of deciding in advance who will be in charge of the lifeboats, who will be responsible for giving the warnings? All this is part of the organization of what I would call the man/machine interface at this higher level.

Nearly all seemed to agree, and this was remarkable, on the need for a single commander, to have the same person in charge all the time. At many times it is obvious that whoever is in charge of the drilling side, is the dominant one. There was a difference of opinion as to whether it is easier to train an experienced toolpush to be a master mariner or whether it is easier to train a master mariner to be a toolpush. This is an argument that I am sure will go on for a long time, but in the meantime, it seems quite possible that some way can be found of ensuring that the man who is in charge is well qualified and can become the visible leader to the whole team at all times. It is particularly important not to have a transition in times of emergency.

On the hardware side of escape and survival, the discussion was extremely interesting and on the whole reassuring. The discussion indicated that, if enough effort is put into the problem and the effort must be substantial, as Dr. Mooradian pointed out, but not astronomical, not at all outside the limits of what should be available, it should be possible to come up with a satisfactory solution that could be widely adopted within a few years. What is needed is to make a systematic approach to this problem: writing down the objectives and characteristics of an effective escape system, thinking of all the solutions, having them developed by those who support them to the point for proposal, choosing a few, and funding, probably through a competition, people to get them busy working at it. These sorts of escape mechanisms should never be needed on oil rigs but they have got to be there and they have got to be things which are known to work and in which everybody has confidence. I, myself have a weakness for Colonel Brooks' ejection mechanism. I think it might be very effective and really rather pleasant, more pleasant probably than any of the free fall lifeboats, but, of course, pleasure is not what one is seeking in an escape device.

It was interesting to hear the unanimity about the problems of immersion suits. That is another one that should be attacked very quickly and solved. It will never be totally solved, but at least a better solution should be found fairly quickly.

The discussions on operations research, in relation to search and rescue, were very interesting, and came to a pretty straightforward conclusion which is about the same conclusion that both the U.K. and Norway reached some time ago. The conclusion is that the rescue system needed for offshore drill rigs is specialized and that an ordinary national search and rescue system is not designed to respond to their needs, nor would it be wise to try to distort the system in order to meet their needs. It is far better to add to the search and rescue system an element that is specially tailored for meeting the needs of the offshore rigs. This element should be integrated into the main system so that it can be used for other incidents in the area and can help to support rescue efforts in other areas. The lines along which it should be designed were well outlined. There was, I thought at one time, a little argument as to who was going to pay for it, but it sounds as if industry is willing to, if not pay, at least contribute quite substantially. So, that again, would seem to me to be a soluble problem.

In many ways the most important general lesson that has come out of the Conference is that Canada is just now in a great position to make its handling of offshore activities and their regulation a model for the world. In saying this, I do not mean that we are a lot smarter than other people; I just mean that we are coming along at a time when other people have wrestled with and successfully solved a good many of the worst problems, so that we, if we are smart, can pick up where they're at and add the necessary improvements to meet our own peculiar conditions, both political and climatic. With any reasonably good handling of our opportunity, we can really have an excellent system in operation quite soon.

You have heard about the present situation, about the complexities of the organizational structure, about the problems between Federal and Provincial Gov-

ernments, the relationship between COGLA and the Coast Guard and so on, but as you have also heard, these relationships are pretty good. Everybody is poised and ready to try to step in and do a good job. I will not attempt to outline a solution which would seem to me to be appropriate, except to suggest that the experience of Britain with OFINTAC, the Offshore Installations Technical Advisory Committee, seems to have been extremely good. It could be adapted as a model for an institutional structure in Canada. One of the important features of OFINTAC is that it brought together the combined technical expertise within government to interact with industry, and then presented its recommendations for public debate. I see an organization of this kind being set up not just to get a good regulatory mechanism in position now, but to keep the actions of the regulatory mechanism continually adapted to the needs of the time and even be looking ahead to see what is coming so that it can be prepared. To help achieve this, there should be an input from research so that research people can tell the regulators what they think is likely to happen and can also try to find the answers that appear to be needed by practical developments.

The most important thing that can happen in the near future is a rationalization of our institutions for regulation offshore along the lines I have roughly outlined, so that Canada can take advantage of this magnificant opportunity that is presented now. I use the term "regulation" here very loosely to indicate control. I was much impressed that when the two sides argued about regulation and about how much or how little there should be, that really they were not very far apart. They are both talking about the same kind of thing; you should not attempt to regulate every detail but some things just must be regulated very firmly and very strictly, and some of them in great detail, whereas others should be flexible. I think that common sense will prevail and that we can reach a good conclusion.

We should not overlook in this process the fact that we are seeking to bring together two different subcultures, the maritime subculture and the offshore drilling subculture. They really are very different. The maritime side, with its long history is still somewhat affected by tradition, and I say somewhat, because the people you meet nowadays in the Coast Guard are not the old-fashioned master mariner of the stereotype of 50 years ago. They are pretty sharp young guys who know what is going on, and the possibility of getting the two sides to see each other's point of view has never been better. I am just mentioning it to point out that when an oil man starts to talk to a master mariner and he does not understand him immediately, you should not think that either of them is stupid. Just keep talking for a little while, and you will begin to understand that each probably knows much about the other's job.

I will stop at this point on a happy note. Canada is at the beginning of a great stage in offshore activity. I hope that we will continue to keep an international outlook in this field as exemplified by this Conference, and that we should feel that our colleagues in Norway, Britain, the United States and many other parts of the world are friends who are pushing ahead in a joint international effort; that we will not specialize our regulations or other activities in Canada any more than is needed to solve our own special problems such as ice. Offshore oil exploration and production can be one of the most exciting and successful areas of scientific, professional and especially economic activity in eastern Canada and, in fact, throughout Canada.

Chief Justice
The Honourable T. Alexander Hickman
Commission Chairman

CLOSING REMARKS

When I opened this International Conference on Safety Offshore Eastern Canada, I expressed the hope there would be uninhibited dialogue between those in attendance. I have no hesitancy in saying that my hopes and expectations have been far exceeded by the obviously expert and responsible contribution of those who have participated during the past three days. You were invited to this Conference, not as representatives of particular segments of society, but rather because of your experience or expertise in the vital question of safety particularly as it relates to offshore eastern Canada. The comments and questions put by knowledgeable persons from many parts of the world have been frank, often provocative, but made in an atmosphere of genuine concern rather than irresponsible confrontation, which is precisely what the Commission asked of all of you.

It was recognized by the Commission, very early in our deliberations, that to discharge our mandate properly we would have to look to the world community for help, as the offshore oil and gas industry, while somewhat young when measured against the history of industrial development generally, had far more experience in other parts of the world than could be found in Canada where, comparatively speaking, the industry is still in its infancy. It is equally clear that recommendations which fail to take into account the international flavour of this particular industry will not be credible. As a consequence, we consider it most helpful to our task to have been able to listen to such open international dialogue between persons who possess detailed knowledge and experience in the offshore oil and gas industry. I have been encouraged by the many comments and suggestions from those in attendance that every two years there should be a conference of this kind in one of the countries represented here. While the Commission's work will be finished long before that time we may, in the future, be able to look back on this International Symposium as a small but significant step along the desirable path of world co-operation in this area of industrial development.

The excellent papers which have been presented and the learned discussions which have taken place will, over the next few months, be carefully scrutinized by the Commission as an integral part of our public consultation process. In that context, I repeat what was said earlier today, that anyone wishing to make further observations or comment on all or any of the matters discussed at this conference or indeed other areas of concern, which you may deem relevant to the Commission's mandate, please do not hesitate to write and let us have the benefit of your opinion.

This Royal Commission stands very much indebted to those who prepared

and presented such excellent papers. We are equally grateful to those who chaired the sessions and those who acted as discussants; we have been treated to a world-class performance by all of these people. I thank, as well, all of you who accepted our invitation to attend and who came from various parts of the world as well as from other parts of Canada to participate; your comments and often provocative interventions contributed a great deal to what I modestly believe has been a successful gathering.

The work of Dr. Omond Solandt, as general Conference Chairman, has been most effective indeed and I thank him for a job well done. The Conference Vice-Chairman, Dr. Ross Peters, has discharged his responsibilities with the kind of efficiency and zeal that we have grown to expect from our Dean of Engineering and I know I voice your sentiments, as well as those of the Commission, when I express to him our sincere gratitude for his efforts and co-operation. I extend to Dr. Leslie Harris, President of Memorial University of Newfoundland, and the faculty and staff of the University, including the competent staff of the R. Gushue Dining Hall, our thanks for their co-operation in making this Conference facility as well as other University facilities available to us.

I would be remiss indeed if I failed to express the gratitude of all members of the Commission to our Commission Staff, all of whom have worked long hours preparing for and seeing to it that the Conference ran smoothly and efficiently. They are a super group of persons.

On Tuesday, I commended the Honourable Gordon Winter and his Conference Committee for their efforts in organizing this event. Their choice of speakers and participants has vindicated the trust we placed in them and I sincerely thank them, once again, for their efforts.

The Commission concluded some time ago that a responsible and knowledgeable press was essential to public involvement, at appropriate times and places in our work. In that regard, we have not been disappointed. I thank all members of the press for the responsible coverage they have given our deliberations.

Once again, thank you all for coming. I declare this Safety Offshore Eastern Canada Conference closed.

APPENDICES

APPENDIX A

WELDING WITH WISDOM;
GAUGING THE RISKS OF ENTERPRISES

Dr. L. Kerwin
President
National Research Council of Canada

It is a pleasure and an honour to meet with this distinguished group which is hard at work on one of humanity's most difficult problems: human safety in complex endeavours. The problem is complex, comprising a multitude of disparate factors. The resulting solution is necessarily a tradeoff, requiring niceties of judgement and intuition. I am not intimately familiar with your specific field, but I do appreciate your difficulties from my work on the Atomic Energy Control Board, where we must license only those nuclear reactors we consider safe; and from work at NRC, where our Building Research Division does research on the safety of buildings. From this background I view your competence and your Conference here in St. John's with both respect and gratitude.

New nuclear reactors, buildings, and drilling rigs will inevitably be constructed, and this means that solutions to the safety problem will certainly be proposed and accepted. But how are these solutions arrived at? First, the experts require facts: solid scientific and engineering data on strength of materials, applicability of construction techniques, environmental parameters, and a host of other things. These facts come from basic research in the sciences. Secondly, come calculations on various component sets, assembled into tentative models. Thirdly, come the non-quantifiable considerations from the realms of sociology, psychology, and (alas!) today's economics. Fourthly, come the intuitive solutions grouping all of these, from which we select, again intuitively, that which best fits the basic facts and the calculated models which we have produced. This intuition which fashions the solution from so many variables is itself an ensemble: we call it wisdom. It is wise men and women who by a complex process find solutions to our most important technical difficulties.

During this Conference, you have been considering many factors which enter into your solutions. Permit me to take an admiring outsider's look at some of them, to illustrate the process by which they are finally welded by wisdom into a safe design solution: a safe reactor, a safe building, a safe offshore drilling rig.

One of these initial factors is risk. Men "that go down to the sea in ships" are generally considered to have a traditional fatalism, to accept risk. But what 'risk' really means is not always clear, particularly to the general public, who sometimes equates it with probability or statistics.

Statistics, or classical probability, is actually quite different from risk. It includes the set of consistent behaviour patterns that we call physical laws. It is inferential and reliable. We use it to predict the future with uncanny accuracy,

because it is founded on a large number of facts about the past. We see; we summarize; we assume the world will keep on working as it has. So far, we have been right.

Classical probability underlies the success of most modern physics and chemistry – its powerful techniques permit it to discern pattern where an unassisted human understanding would bog down in sheer quantity of data. Its subject material is, properly, vast numbers of interchangeable items: atoms, molecules, electrons. The resultant scientific laws are completely dependable. The facts of conductivity of a given copper alloy, or the tensile strength of a given steel, are reliable because the copper and steel artifacts we test comprise myriads of atoms; thus the statistics are excellent. However, what works for the exact sciences does not work for complete offshore structures. If we applied this classical approach, we would build and operate thousands of offshore platforms, then coldly record which sink and which survive. Eventually we could accumulate sufficient correlations to make confident predictions about future platforms. We should also have criminally squandered dollars, years, and lives. Statistical brute force, which works so well for subatomic particles, fails us for units that are neither unmanned nor interchangeable. This is where we switch from probability to risk. We make use of our astonishing human capacity for imagining situations that have never been, for creating a virtual universe of scenarios, and then selecting from this virtual universe the one course that we proceed to make real. To put it another way, the calculation of risk before the event permits us to perform end-runs around the impossibility of using statistics.

It is just this talent, unique to our species, that once won us the moon. No one had been there when President Kennedy announced his goal: there were no classical data. Yet, in July 1969, Neil Armstrong sunk his foot in lunar soil. If this proved possible, may we not dream of ocean platforms of perfect safety? Yes, of course we may; it is why we are here at this Conference.

A second factor is that of cost/benefit, which in turn uses the calculated risk factor as one of its components. In forecasting benefits and costs, it is usual to state relevant factors in identical units, usually fixed-year dollars. In this way we can see more clearly how to tip the scales towards the best solution. Here is how this was done by the United States Food and Drug Administration when it recently set a tolerance for polychlorinated biphenyls (PCBs) in fish for human consumption. It laid out its data in the form of a table, given below.

An Example of Balancing Risk Against Revenue Loss:
The U.S. Food & Drug Administration's Setting of a Tolerance for PCB's in Edible Fish

1	2	3	(3 ÷ 2)
Proposed PCB Tolerance in Parts per Million	Projected Number of New Cancer Cases per Year	Loss of Revenue (Estimated Millions of U.S. dollars)	Dollar Cost of One New Cancer Case (Thousands of U.S. dollars)
5	46.8	0.6	12.8
2	34.3	5.7	166.0
1	21.0	16.0	762.0

Source: U.S. Office of Technology Assessment
(After O'Brien & Marchand, 1982)

Each proposed parts-per-million maximum of PCBs has associated with it an expected yearly number of consequent cancer cases, and a dollar cost due in part to administration costs and to the value of the food jettisoned. By comparing the data sets, which lie in horizontal rows in the above table, we may infer dynamic

data: that is, what happens to one (dependent) variable when another (independent) variable is changed. You can see that as the proposed tolerance rises, the expected yearly number of new cancer cases rises too; and as the proposed tolerance drops, so do new cancer cases we expect. There is a similar direct variation between cancer cases and total cost. In this case, the FDA opted for a PCB tolerance of 2 ppm. This was expected to result in 34.3 new cancer cases per year, and to have a yearly cost (in constant dollars) of $5.7 million U.S.

Why this option? One may possibly infer the answer from dividing each element in the second column into its paired element in the third, deriving a cost per cancer case – a pricetag on life. In the first row, 5 ppm, we are valuing each risked life at about $13,000. Clearly, this is too little. In the other extreme, 1 ppm, the value of each life newly afflicted is almost eight hundred thousand dollars, or more than sixty times as great. The middle way provides a compromise life-worth of about $166,000.

Distasteful as it may seem, the planner must often judge lives in this way. There are extenuations, however, that make this task less ghoulish than it appears. He does not judge ethically, morally, or theologically; the lives he weighs are abstract. To use again the language of physics, they are "virtual" lives rather than real ones. Virtual lives acquire a face only at an actual fatality, an occurrence which the planner bends every effort to avoid. And when a low-risk estimated accident does occur, such as a child falling down a well or a miner being trapped underground, the fact is not accepted just because it was predicted. On the contrary, society then bends every effort and expense, far beyond the original cost/benefit estimate, to get the child out of the well, or the miner out of the cave-in.

Mathematically we call such exercises multivariate analyses or "mini-max solutions"; in every day speech, tradeoffs. Generally, increased safety is purchased by increased cost.

A third factor may be termed "necessary paranoia". This is simply an acknowledgement of the tenuous nature of some of the elements in the process of cost/benefit analysis. Because they deal in numbers and units, these calculations can give us a false sense of security, as if everything they discuss were known to five significant figures. But there are numbers and numbers; not all are equally reliable. Quantum electrodynamics may accurately predict events in the subatomic world to one part in a hundred million billion; but woe betide us if we believe our planner's approximations have the same dependability! In the PCB tolerance table, the route from column 1 to column 2 is tortuous. Going from a given level of tolerances to an end of projected cancer cases involves interbraiding laboratory, epidemiological, and demographic data in a staggeringly complex way. In any quantified risk assessment, then, we must always bear in mind that nothing we produce can be more solid than our assumption set. Data billed as 'hard facts' all too often conceal the wildest guesstimates. Most of the time we simply do not know all the answers necessary for ironclad predictions, and to forget this can invite the very disasters we seek to avoid. When in doubt, then, planners of any large-scale human enterprise must err on the side of safety. Here, if nowhere else, a little paranoia is an eminently desirable thing.

Carrying overdesign too far, however, – "over-overdesigning" – brings us into a situation at once unnecessary and cost-ineffective. If statistical brute force, the mere crunching of vast tracts of data, is an unacceptable way of approaching offshore planning, then the brute force of inelegant overdesign must be unacceptable as well. Paranoia is like spice: a dash of it is salutary, too much ruins the meal. Certainly, there are occasions when the consequences of failure are extreme; and unless we can undertake to trim those risks to acceptable levels, we have no business in the project at hand.

This brings us to a fourth factor affecting our solution: the non-linearity of equivalent probabilities. In classical theory, a one-in-ten chance of winning a dollar is equivalent to a one-in-twenty chance of winning two; a one per cent risk of losing half my bank account is equivalent to a one-half per cent risk of losing it all. Thus, in classical theory, a slight risk of a grave consequence is mathematically the same as a graver risk of a proportionately slighter consequence. For simple cases, things are linear. In the real world, however, such functions cease to be linear for extreme values. If I run one chance in a thousand of losing my life, I most certainly do not run one chance in two thousand of losing two – I have not got the stakes!

Similarly, some eventualities are too terrible not to take every conceivable precaution against, even to a degree not strictly justifiable in mathematics. Let us consider an example. To our knowledge, there has never been a life lost as a direct result of radiation unexpectedly released at a fission powerplant. Hence, based on these data, one could assert the classical probability of death from atomicly-derived electricity is zero. Experience has taught us, however (would that it had not!), that radioactive substances do indeed pack risk, one that often goes unnoticed before it is too late.

Nuclear power plants have therefore been designed with elaborate and redundant safeguards in the form of hardware, controls, and operation techniques. The safeguards, in fact, are more stringent than the probabilities warrant, simply because of the gravity of a worst-case situation. Despite reactor-centuries of use, a core meltdown has never yet occurred in the world. However, even granted that the likelihood of a meltdown is vanishingly small, its consequences, at least for a densely-populated urban area, would be too terrible to utter. Planners of nuclear installations must decide beforehand, in a kind of Hippocratic Oath for their profession, that such a scenario must not occur.

I have selected a deliberately extreme example. A worst-case scenario for an offshore drilling platform has already occurred; leading, among many other things, to our presence here tonight. Yet although we may be speaking of deaths in the tens rather than in the tens of thousands, the principles remain. In a sense, the designers and operators of equipment on the continental shelves must overpower the odds. They must begin with the idée fixe that certain situations must categorically not happen. One might say, paraphrasing Louis St-Laurent (who uttered it of the law), that statistics may also be a humanity; that the non-linearity of equivalent probability must be made to fall on our side.

Seen in this light, even the quantitative exercises of the actuary take on a qualitative, human aspect, and statistics, like pity "bears a human face". Unfortunately, there is more to people than the admirable. If risk statistics is a humanity, it must reflect the bad in people as well as the good. It is probably more cost-efficient to seek out and safely cap all land-based water-wells than to mobilize hundreds of person-days and thousands of dollars in often-futile attempts to rescue a child who has tumbled into one. People do not take such wise precautions: most of us seem to need an actual crisis before we can mobilize and act. Yet such ad hoc heroism is often less truly heroic, i.e. effective, than unglamorous prevention. In a sense, then, the wise designer will save people from themselves, 'idiot-proofing' his or her solutions as much as possible.

A fifth factor in our solution concerns the amplification of corporate responsibility. As we have seen, human nature intrudes into, and places coefficients upon, risk assessment. Most healthy adults, considered as individuals, routinely take risks that no corporation would dare duplicate. Consider what the bulk of us private citizens do daily. We sleep in houses laced with electrified cables, which we seldom bother to check. We use poison-gas generators to drive to work, heat our houses, and barbeque our food. We walk blindly in that deadliest of hazards, the slippery bathtub. We operate power tools with nothing protecting our irreplaceable

Dr. Kerwin earned his Doctor of Science degree from Laval University in 1949 after obtaining a M.Sc. from the Massachusetts Institute of Technology in 1946. He has received numerous awards and honorary degrees. In 1980 Dr. Kerwin was appointed to a five-year term as President of the National Research Council of Canada where he contributed to building a national awareness of the importance of research and development to the well being of the nation. In 1982 he was appointed Canada's representative on a working group set up as a result of the June 1982 Economic Summit, to study how research and development can be used to create jobs and help the world economy to recover. The working group is made up of representatives of the seven Economic Summit nations and one from the European Economic Community.

eyes. But we do not condone such cavalier behaviour when we work as a group; for corporately, we humans are far more conservative. The same people who mow their own lawns wearing tennis shoes are forced by law to wear steel-toed shoes on a public grounds crew.

Clearly, we must eschew all individual flippancy when we go to face the northern seas. For one thing, those who make the plans are usually not those who face the risks. If I mow my toe off, it is my own fault; if my inattention results in the injury or death of my fellows, then they have reaped the consequences I myself deserve but have escaped. The very size of our enterprise makes this more critical, for sufficient quantitative change creates qualitative change. Lawn-mowing and offshore exploration are so different in hours, dollars, and person-years that they become different in essence as well.

There is a vital sixth factor which must enter our solution. There is yet another way in which human nature intervenes to modify the chaste numerical predictions of risk assessment. Risk itself may form part of what attracts workers to the danger and discomfort of an offshore platform. Risk confers status, both directly and by means of pay and benefits. Is a rig that seems as safe as one's living room not liable to have difficulty recruiting the best workers? Further, a paradoxically greater danger may lurk in an environment that is too obviously safe. With the removal of apparent threat, people get careless. Crew quarters with wall-to-wall broadloom, pools, and video arcades are still perched a few metres above disaster on an unforgiving ocean. Designers may forget this; workers may forget this; but the sea never will.

As is true in so many other areas, the appropriate response to this threat is awareness. 'Raw' high risk need not lead to accident so long as those at risk recognize the fact and govern themselves accordingly. Ask yourself what would happen if summertime drivers stopped taking the road for granted, and drove as if it were winter, accelerating slowly, braking smoothly, behaving as gingerly as if the roads were ice. And while the absolute prevention of risk may not be within our grasp – risk, after all, being part of life – we may be able to go along indefinitely without a major accident. A situation where accidents cannot happen, where the simple operation of natural law forbids them, is doubtless unattainable. A situation where accidents do not happen, may well be within our grasp. In that sense, our human consciousness can become part of natural law. A judicious blend of good design, good operations methods, and training may keep tragedy forever from the door.

I have mentioned six factors which enter into the process of determining a solution to the complex problem of human safety in a major endeavour. Each of the six is important; the expert sees them standing in a row, waiting to be combined, somehow, into a solution. First the risk assessment, that end-run around the statistics; second the cost/benefit figures, which must lie in the realm of the possible; third, that nice dosage of paranoia, which often makes a solution more acceptable; fourth, the non-linearity of equivalent probabilities, which categorically excludes the worst-case solution; fifth, the amplification of corporate responsibility; sixth, the leavening of awareness.

To the judicious and acceptable melding of these, the expert must himself bring the ultimate factor: wisdom. I have discussed the nature of excellence on other occasions, and the nature of wisdom is akin to it. Its recognition is, ultimately, the fruit of generations of honed experience.

In their wisdom, then, the experts judge the optimum solution from the numerous virtual solutions which they can assemble in their imaginations out of all the basic components. For problems of human safety, the cardinal virtue which their wisdom brings to bear is charity, or disinterested love. In facing the question "How safe can we afford to make our offshore installations?" we must really ask

ourselves: "How much do we care about the people on them?" This will modulate our strict cost/benefit equations, and further make our statistics into a humanity. The human lives we deal with, however virtual or theoretical, will then appear more real as we remember that every individual on Earth is fundamentally priceless. Indeed, if we regard the lives of those who venture into stormy seas as themselves of greater worth than anything they may obtain, we will be physically unable to create an offshore enterprise prone to disaster. Such will be the solutions of wise people, fashioning from carefully-prepared factors, and with love, a solution that will be equally acceptable in its engineering, economic, and human aspects. There may yet be other disasters, borne of solutions which were not thus fashioned by wisdom or animated by charity; these are statistics that the future will provide. But I sense already that the efforts of the Commission, and of the wise people at this Conference, will render such disasters vanishingly rare.

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