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MAN/MACHINE INTERFACE


Royal Commission on the
Ocean Ranger Marine Disaster
Canada
Commission Royale sur le
Désastre Marin de l'Ocean Ranger
Newfoundland / Terre-Neuve
Safety Offshore Eastern Canada

MAN/MACHINE INTERFACE

INTRODUCTION

In this area the major aspects studied were personnel training and equipment design with a view to reducing operator errors. This examination included consideration of current feedback mechanisms which provide equipment manufacturers with information from equipment operators and users which can be incorporated to improve equipment redesign. Personnel selection was also reviewed in order to identify the basic minimum qualifications for key positions on MODUs which require the operator to perform ancillary and/or emergency control functions.

This Technical Session was chaired by Dr. G.M. MacNabb, who holds a degree in Civil Engineering from Queen's University, as well as six honourary doctorates from Canadian universities. He spent his earlier professional years with the Federal Government, most notably as Senior Assistant Deputy Minister of Energy, Mines and Resources Canada to which he was appointed in 1975. Dr. MacNabb has been President of the Natural Sciences and Engineering Research Council since 1978, and is also President of Uranium Canada Limited, honourary Vice-President of the World Energy Conference, and Director of Atomic Energy of Canada Limited.

Dr. P. FOLEY
Head, Dept. of Industrial Engineering
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Dr. Foley has broad experience in human factors problems, and in 1966 he instituted the Human Factors Program at the University of Toronto, where he is currently the Head of the Department of Industrial Engineering. He has represented Canada on numerous international committees and is also member at present of a number of Canadian research and development committees.

PAPER D

Operator Competence in Relation to Critical Systems Technology

Given the time constraints placed upon me in the preparation of this paper, and the consequent lack of opportunity to familiarize myself with the specifics of the offshore drilling problem, I have decided to concentrate upon an examination of the general problem of the design of man-machine systems and the role of Human Factors Engineering in this context. There may therefore be some overlap between my remarks and those of other speakers. Any such repetition should be taken as emphasis rather than redundancy.

The design of a man-machine system is an attempt optimally to integrate the basic elements of such a system, namely, human, physical and informational resources, to achieve some clearly-defined goal. However, these elements are not independent and the design problem becomes one of decision taking where one has to consider not simple tradeoffs, but the possible effects of very complex interactions among the basic elements. Further, the decision taking process itself may be affected by possible implicit assumptions. Consider the design implications of the following assumptions, for example:

1. "If I design my equipment this way, what can I expect of the human operator, and what will the effectiveness of my system be?"
2. "If the human operator is to use his capabilities this way, how must I design my equipment so as to optimize system effectiveness?"

The difference between one and two may at first sight seem to be rather subtle, but it is, in fact, critical. The design implications are extremely profound, and the importance of making explicit what is implicit, cannot be overstressed.

Let us then examine the design problem in detail. Figure 1 shows the basic components of the system, the human element, the machine element and the information element. It also emphasizes that no system exists in isolation, but within an environment which subjects it, in both the design phase and the operational phase, to critical forces. I have listed the most obvious of these. Note that the order is simply alphabetical and consequently avoids the problem of deciding their relative importance. This is not an attempt to evade a difficult task, but a recognition that, for any given system, relative importance is itself one of the decisions to be made. The diagram also emphasizes that no element exists in isolation within the system. The human element affects and is affected by the machine element. The human element affects and is affected by the information element. The information element affects and is affected by the machine element. Most importantly, the design process affects and is affected by all three, and their interactions, both first and second order. These complexities require a highly structured approach and one such structure (Wulfeck and Zeitlin, 1962), is illustrative and still relevant. The layout is necessarily sequential, but some of the activities will of course be concomitant:

1. Establishing system goals;
2. Determining system requirements;
3. Allocating system functions between men and machines by:
   - determining information requirements
   - determining transfer requirements
   - determining control requirements
   - establishing a maintenance and logistics philosophy;
4. Equipment design and workplace layout;
5. Establishing manning requirements;
6. Determining training requirements;
7. Training;
8. System test and evaluation.

If this all seems like common sense, let me assure you, in the words of one of my former Professors, that "common sense is the scarcest economic commodity," a statement I have never found it necessary to qualify.

The point in which human factors input is required will, of course, depend upon the system goals. For example, if the system goal is to put a man on the moon to sort and gather geological specimens, then knowledge of human capabilities and limitations in a lunar environment will be required, to decide whether or not such a goal is realistic. If on the other hand, to continue the standard example, the goal is to develop a fully-automated system for geological exploration of the lunar surface, then knowledge of human capabilities will not be required until the point at which establishing a maintenance and logistics philosophy is reached. Parenthetically, it is interesting to speculate on the role of social and political environmental factors in influencing the determination of the goal of the Apollo missions, culminating in the achievement of *Apollo II* in 1969; given Sputnik in 1957, the Luna missions in 1959, and the formal inauguration of NASA in 1958.

In any event, although human factors input will be required in steps one and two, it is at stage three, allocating system functions between men and machines, that such input

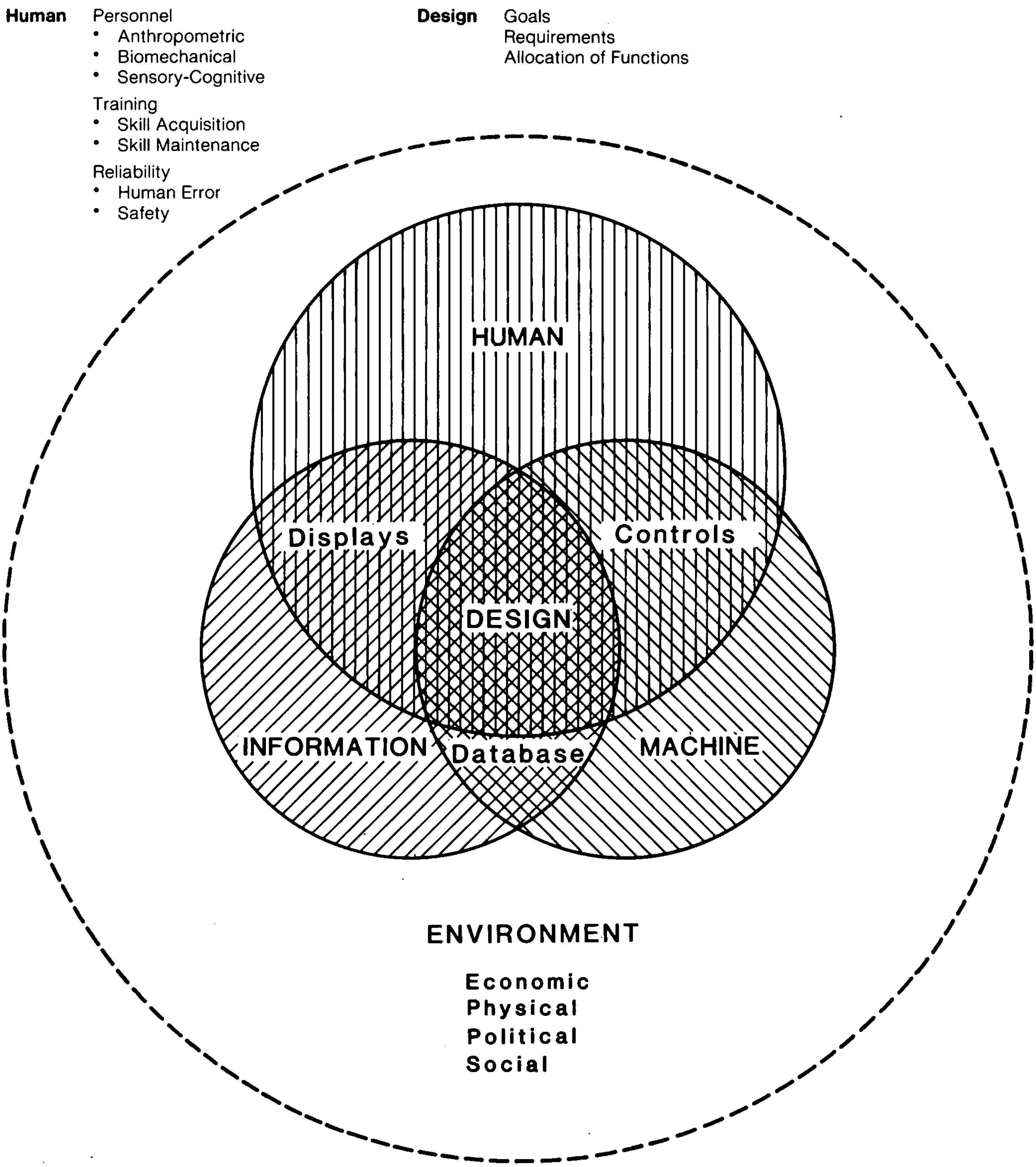

FIGURE 1 Human factors in the design of a man-machine system

is of vital importance. Here considerably more than superficial understanding of the relative capabilities and limitations of both men and machines is required. Much effort has, in the past, been expended by human factors specialists in investigating, codifying and tabulating human performance characteristics culminating in the "Fitts" list and the more sophisticated modern version proposed by Geer, (1981). However, this approach is limited, concentrating as it does on the relative efficiencies of men and machines. The issue is never quite so clear. The question is not simply whether a man or a machine, but rather how they should interact. The rapid developments in the computer field have posed new questions, the answers to which are not intuitively obvious. Consider for example, the following description of interaction[1]:

1. The human does the whole job up to the point of turning it over to the computer to implement.
2. The computer helps by determining the options.
3. The computer helps determine the options and suggests one, which the human need not follow.
4. The computer selects action and the human may or may not carry it out.
5. The computer selects action and implements it, subject to human approval.
6. The computer selects action, informs human in plenty of time to stop it.
7. The computer does whole job and necessarily tells human what it did.
8. The computer does whole job and tells the human what it did only if the human explicitly asks.
9. The computer does whole job and tells the human what it did, and it, the computer, decides the human should be told.
10. The computer does the whole job, if it decides it should be done, and if so tells human, if it decides he should be told.

The ten possibilities listed are not by any means exhaustive. In each of the ten cases, the original human request may either not be necessary or be ignored by the computer. Step ten alone can have several variations, where the computer tells the human necessarily, or on his request. The ultimate condition is the dynamic case, where one does not decide initially exactly what the interaction will be, and that interaction is then built into the system and fixed, but rather that the form the interaction takes will vary from time to time, depending on the state and needs of the system, and this adaptability will be built into the system. In summary, allocation of function is critical in system design and development. Functions, having been defined earlier must now be given specific form; how, precisely, will they be implemented? It is obvious that the problem must be tackled in a systematic way. Each possibility must be examined and defined with respect to its information, transfer, and control requirements and of course to the system requirements. Only then can rational choices be made among alternative configurations. It should also be obvious that this is not a task for amateurs, nor is it something that can be tacked on to other responsibilities, nor can it be allowed to evolve. Human factors expertise at this stage is mandatory, and the human factors specialist should be a member of the design team. This should become clear as we examine the information, transfer, and control requirements in more detail.

Determining information requirements is not as simple as it may at first sight appear. Too much information is obviously as bad as too little. What then constitutes just enough? How much pre-processing of information can be entrusted to the machine to reduce information overload and simultaneously take advantage of the human's powerful pattern recognition abilities? The answers to these and similar questions will depend upon what role the operator is expected to play. Bainbridge (1984) reviewing studies of the performance of the human operator in process control, emphasises the need to "obtain information on the operators' understanding of the situation, intentions and expectations." Displays should show the structure of the process and focus on the level of process variables rather than the stage of plant components. The displays should use a format which supports the flexibility of the operators' thinking. It should be pointed out perhaps, that Bainbridge bases her recommendations on a detailed analysis of six nuclear power plant incidents, including Three Mile Island, using reports giving detailed post-event analyses, made with the operators, of what happened during each incident. Her report emphasises the need for a thorough understanding of human cognitive capacities and limitations before rational decisions about the information interface can be taken. As she rather wryly comments, and in this context it is worth quoting her in full; "Engineers looking for advice from ergonomists tend to ask for absolute numbers for performance levels. 'We don't want to know about cognitive processes, just tell us what is the human: error-rate/information transmission capacity, memory capacity, perception capacity, and we will design the system accordingly'."

Unfortunately, the task categories used as a basis for asking for such numbers are too simple. Suppose for example one asks for human failure rates in 'deductive reasoning'. Hunter (1959) found that the number of people who can say which is the biggest item in a '3-term series' problem, within a time limit, depends on the way the task is presented. For example:

$a > b$,	$b > c$	70%
$a > b$,	$c < b$	59%
$b < a$,	$c < b$	43%
$b < a$,	$b > c$	27%

If changing the order of the information can more than double the failure rate, then the detailed transformations that the person has to carry out to do the task have more effect on failure rate than the overall task of deductive reasoning. Detailed knowledge of the cognitive processes involved in a task may be necessary before performance predictions can be made with any accuracy. Since this knowledge precedes display design, I again, emphasize that this is not a task for amateurs.

Determining transfer requirements calls for similar understanding and a similar approach. Here the emphasis is on mathematical modelling of the performance characteristics of the human operator, and the potential ability to match operator characteristics with machine characteristics to arrive at a quantitative expression of the system dynamics. This approach has many advantages; the ability to make precise design comparisons, to predict performance, and to evaluate the adequacy of the design chosen. It does, on the other hand, call for fairly sophisticated techniques and considerable quantities of data, the human operator not being a simple linear system. The approach is, however, showing considerable promise, particularly in the estimation of mental workload, a notoriously difficult problem, and a very important problem. Standard physiological measures have so far proved to be not very helpful, in spite of considerable research effort. The approach taken by, for example, Moray (1979), is indicative of present trends. The area is becoming more and more popular, given indications that excessive mental workload may be the primary factor in operator error, and useful principles are emerging.

Control requirements can be tackled in a similar way, that is, by using mathematical models of the human operator, and the general principles outlined above, apply.

In summary then, the "allocation of function" is critical to system development, calls for highly specialised knowledge and understanding of operator characteristics, and demands that such expertise be given equal weight at the design level. Retrofit is inefficient and very expensive.

Equipment design and workplace layout is an area where the problem is not one of complexity or insufficient research or lack of relevant data, but rather one of what might be called "information transfer". The data exist in abundance, in handbooks, textbooks, reports, giving all the recommendations one could ask for with respect to body sizes and dimensions for different populations; the dynamics of body movement; forces that can be applied in different configurations; sensory sensitivities and discrimination capabilities as they affect legibility, intelligibility, and so on. Perhaps there is too much information available, so that many designers simply give up and design for themselves. Examples of this are numerous and can best be demonstrated by a few pictures. The answer lies in the systematic approach to the design process, ensuring that at least the data required can be identified at an early stage. Even here one has to be cautious, as the recent Swedish-Finnish Saab incident demonstrates. Ergonomic design of work places was considered very important and the design was carefully tailored to the population characteristics. Unfortunately, the data were Swedish and the operator population was Finnish, quite different. Constant vigilance is required.

I shall deal with the problems of manning and training together, within the context of error and reliability, since they are intimately related. Here I would emphasize that the system development procedure I have delineated earlier, is only linear because of the constraints imposed by the print mode. I repeat that we are dealing with a highly interactive process. I would also emphasize that the design of a training sub-system is subject to the same process and constraints as the design of the overall system itself. What then is error? Senders (1982), discussing human error and human reliability, within the context of process control, distinguishes between those errors which arise from factors internal to the operator, endogenous errors, and those errors which arise from factors external to the operator, exogenous errors. Endogenous errors we attempt to reduce by selection, training, and practice, and exogenous errors by "good design". The point here is that although we do not as yet fully understand the fundamental nature of error, we can still tackle the problem of error reduction. As Senders points out, "it is clearly beneficial to select people who can grasp the controls, see the displays, read the numbers, understand the language, and so on. It is clearly beneficial to tell these people what to do, i.e., train them in the system. It is clearly beneficial to design the displays and controls and the panel layout in such a way that they are within the grasp of one or a team of human beings. Beyond that, however, the simplistic assumption of linearity that tells us if we made all parts good, the whole will be good, is unproven." Since training can reduce endogenous errors, then let us give careful attention to training, even though our imperfect understanding of the genesis of error does not allow us yet to decide what is the optimal training system, having regard to efficiency. Remember that process control is no different from any other kind of skilled performance; to become adept we must practice, practice, practice, until performance becomes essentially automatic, "open-loop". This surely is the essence of all skilled behaviour, that we do not have to consider the individual components; in fact to do so is counter-productive. As Schrodinger once said, "consciousness is becoming, unconsciousness is being." We may not indeed be able yet to optimize, but we can at least meliorize. And we can improve performance by logging and analyzing all transactions between the operator and the system to help us identify those areas where practice and improvement are necessary.

Given this approach, this statement of the U.S. Maritime Transportation Research Board (1981) may be unduly pessimistic:

> The causes of maritime casualties are seldom technologically sophisticated and obscure. Almost without exception, the proximate or probable causes of collisions, rammings and groundings are well known and widely recognised as some form of human failing. Yet there is little recognition or understanding of the underlying causes of human error.

On the other hand, their statement is worth pondering that:

> There is an inverse relationship between the known causes of maritime accidents and the areas in which research is conducted. Most major maritime casualties are due to some form of human failing, whereas most maritime research resources are expended on hardware.

In conclusion, I have attempted, without being exhaustive, to outline a plan, and stress the need for a systematic approach to the design of man-machine systems. Such a plan does not guarantee zero probability of failure, but it, at the very least, reduces that probability: surely attainable meliorization is worth it. A camel may be a horse designed by a committee, but why not give the committee credit for having at least clearly defined its needs.

References

(1) Bainbridge, Lisanne. "Diagnostic Skill in Process Operation." Proceedings of the 1984 International Conference on Occupational Ergonomics, Vol. 2: Reviews, H.F.A.C., Toronto, 1984.

(2) Hunter, I.M.L. "The Solving of 3-Term Series Problems." *British Journal of Psychology*, 1957, 48: 286-298.

(3) Moray, N.P. (Ed.). *Mental Workload, Its Theory and Measurement*. New York, Plenum Press, 1979.

(4) Senders, J.W. "Human Error and Human Reliability in Process Control." In Edgar, T.F. and D.E. Seborg (Ed.) Chemical Process Control 2, Proceedings of the Engineering Foundation Conference. New York: American Institute of Chemical Engineers, 1982.

(5) Sheridan, T.B., and Verplank, W. L. "Human and Computer Control of Undersea Teleoperators." Man-Machine Systems Laboratory, M.I.T., Project NR 196-152. 1978.

(6) Wulfeck, J.W., and Zeitlin, L.R. "Human Capabilities and Limitations." In Gagne, R.M. (Ed.), *Psychological Principles in System Development*. New York, Holt, Rinehart and Winston, 1962.

(7) Maritime Transportation Research Board Commission on Sociotechnical Systems. "Research Needs to Reduce Maritime Collisions, Rammings and Groundings." National Academy Press, Washington, D.C., 1981.

[1]Source: Levels of Automation in Man-Computer Decision Making, for a single elemental decisive step, (after Sheridan and Verplank, 1978).

[EDITOR'S NOTE ON PAPER D]

Dr. Foley did not read his paper to Conference participants but instead enlarged on the principles and the elements of human engineering discussed in it. He provided specific examples of instances where a system design failed to recognize or take into account the requirements and capabilities of the system operator.

He referred to the North American car of the 1970s, the design of which did not permit easy operation by the average American male and female, even though it complied with the established and required standards. For example, the location of the foot pedals and the handbrake release lever, and the force required to operate the brake pedal all exceeded the physical capabilities of most American females. Similarly, the operation of the foot pedals and the degree of visibility afforded to the average American male operator also caused difficulties because little allowance had been made by designers for the physical dimensions of the majority of the potential operators. Dr. Foley also cited architectural design at one of the buildings at the University of Toronto as being inadequate for the purpose it was intended to fulfill. Drinking fountains at this particular building were designed specifically for use by handicapped people, but were, in actual fact, not accessible from a wheelchair. These fountains turned out to be equally difficult when used by the non-handicapped.

Dr. Foley also reviewed each of the three elements of human engineering: the human element, the machine element, and the information element, and emphasized that none of these should be considered independently of the others. The way an operator deals with information, the way information is presented to him, how he processes the information and controls or operates the system are all at the centre of the man-machine interface. He felt that the design of a system requiring human interaction is best accomplished by a committee, rather than by one individual, and that the expert in human factors should have input from the beginning of the design process when the specifications are being written. A sophisticated understanding of human factors is crucial to establishing the goal and requirements of a man-machine system; it is counter-productive to design a system without regard to human factors and then to select personnel to operate it. The design of a system must be conditional upon the capabilities which can be reasonably expected of the average human operator.

Dr. Foley gave two examples where design had proceeded without sufficient regard for human factors and where system goals had not been identified. One was a concrete mixer which was so awkward to load and unload that severe accidents during operation were a high probability. The other was a vehicle intended for use by the Canadian Armed Forces in the Arctic. The heavy and bulky protective Arctic clothing of operators made operation of the vehicles extremely difficult because the controls and the entry/exit hatch were all too small.

Another problem pointed out by Dr. Foley was that of determining what information is required to operate a system and how that information is best presented to the operator. The display of information should not be confusing, should not contravene population stereotypes, and should be instantly readable with a minimum of error in interpretation, regardless of the degree of stress being experienced by the operator in either a normal or emergency situation. Changes made in the design of an information display which are intended to be improvements should not be incremental and should be based on a re-assessment of original information requirements.

The need for engineering continuity was another element of the design process which was illustrated by Dr. Foley with an example. The procedural steps for emergency ejection from a particular aircraft were listed on a plaque which was mounted on the canopy of the aircraft. Unfortunately, the first step in the procedure told the operator to jettison the canopy, thus leaving him without any further directions for ejection.

Dr. Foley indicated that his paper dealt with the fundamental principles of human factors engineering only, but that his examples helped emphasize the importance of integrating human factors engineering into the design process.

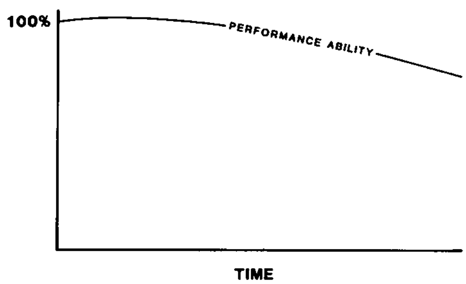

FIGURE 1

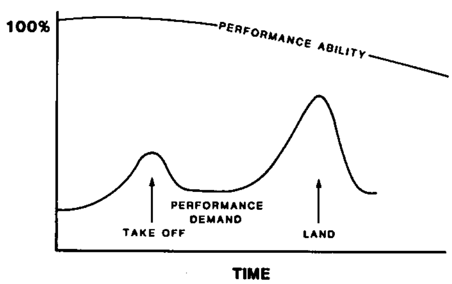

FIGURE 2

COMMENTARY ON PAPER D

Dr. H. Haakonson
Corporate Medical Director
Petro-Canada Resources

In responding to Dr. Foley's paper the only thing I can say is "Amen". I think that his coming from a position of academia, if you will, is absolutely vital. To think of designing a machine in 1984 without including human factors would, in my opinion, be gross negligence and to think of including human factors without doing so from the principles of an academic base would also be gross negligence. His paper has a great deal of relevance to the kinds of practical things that I and our other discussant will say. Dr. Foley has talked about the first step in a whole sequence of things that we try to do, or perhaps we should try to do, to reduce risk and in doing so, to increase the operator reliability in performing critical tasks.

I would like to deal with three specific issues from medicine, my area of expertise. The first issue is unexpected behaviour, or why do people not do what we expect they should do in the circumstances dictated? The second issue deals with the stress associated with significant events or incidents and the third is about leadership.

UNEXPECTED BEHAVIOUR

In discussing unexpected behaviour, for illustration, let us consider a crane operator, because I know there are some on offshore rigs. Let us suppose that a crane was so designed that when the operator wants the crane to lower, he lifts his lever up. That action goes against the stereotype which Dr. Foley talked about. Logic would tell us that eventually the operator is going to do it wrong because his mental processes, his stereotype, is going to tell him that for the thing to go down, he should push down. When is he going to do it wrong? Probably when you least want him to do it wrong, when the heat is on. So, it is fundamental that, in the design of whatever we are talking about, we factor out that human element.

Once we have done that, the next step is proper and adequate training of the individual to be capable of doing whatever is required of him and to carry out that action under whatever circumstances may prevail. But we cannot stop there. The training has to be followed by exercising, followed by training, followed by exercising, ad infinitum. There is no point in just training to a task if you do not exercise to see what is going to happen when the real situation arrives.

STRESS

Then we must not forget those things that we, in lay language, tend to call stress. At one point in his paper, Dr. Foley makes the point that ". . . mental work load may be the primary factor in operator error . . ." and nowhere is that better demonstrated today than in the current generation of aircraft fighters where we really have reached the border of absolute overload for mental workload. That is not the only place.

In order to illustrate, refer to the plot of performance against time (Figure 1) and consider a hypothetical situation. Let us say that for each of us we have a performance ability which starts off at some 100% value and over time, whether that be the duration of a day as we become fatigued, or the duration of a lifetime as our body becomes less and less capable, the performance ability drops off.

Let us compare that against the performance demand which exists in a given situation. Dr. Foley provided an appropriate illustration of the commercial aircraft pilot for whom the performance demand increase upon landing was reflected in his heart rate increase. In his case, the performance graph would have looked something like that in Figure 2. The difference between performance ability and performance demand is referred to as coping capacity: the ability which is in excess of what is required. It is a capacity to deal with things over and above that which you may be facing at the very moment.

Let us now factor in some other demands, stress, if you will. Let us suppose an individual is on his second or third day back on the rig after his three weeks off, and he is a little hung over, because we have a perception of what people tend to do when they are on their time off. So, one would have to guess that, whatever ability he might have had under other circumstances, that ability is somewhat decreased under this situation. Let us suppose that there is some marital strife going on, and further, let us suppose that he is quite physically unfit. All very real possibilities in an individual situation and all to some degree decreasing his performance ability (Figure 3).

I had a professor of obstetrics who used to describe his profession as being one of long periods of boredom interspersed with short periods of absolute terror. When a complication of delivery occurs, it is a moment of absolute terror. You have only very short moments to make very critical decisions and get them right. That, I think, describes some of the critical tasks in the offshore industry where a very long boring job of surveillance may be interspersed with a critical task related to an emergency, and so the

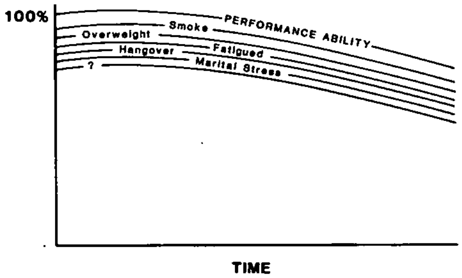

FIGURE 3

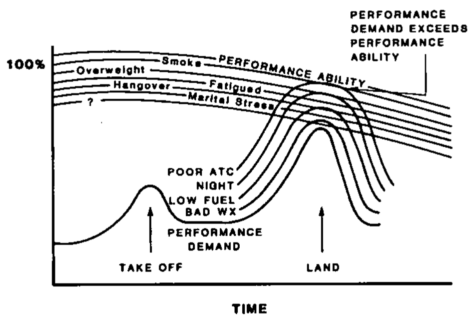

FIGURE 4

demand goes up appreciably at that particular moment. You can pick whatever emergency you like. Have it happen at night and you have just increased the demand a little bit further. Have it happen when the sea state is as it was when the *Ocean Ranger* went down, and you have really pushed the demand right out of proportion. Indeed, you run the risk of having the demand exceed the ability. I propose that a good number of critical tasks occur in circumstances where the performance demand exceeds the expected performance ability (Figure 4). The difference between having an accident under this situation, and only having an incident, is a result of training, experience and, I suppose we should add, good luck.

In order that the operator performance ability be maximized, we must ensure that the operator is fit medically, physically, emotionally, and spiritually. There is a critical place here for the operator to be fit through his own assessment, not just external assessments such as a medical person might provide. When we talk about significant events, we have to be very clear as to the difference between an incident and an accident. If the difference between the two is based on experience and training and luck, then we have to pay attention to those factors of the three that we can control. We can improve upon our situation by paying attention to the incidents and preventing them from becoming accidents and that is the pitch I wanted to make at this point.

I would like to conjecture for a minute – what do you suppose would have happened if the *Ocean Ranger* had not gone down? I do not think there is any doubt that there have been a number of advances and much progress made in offshore safety because the *Ocean Ranger* went down. What if it had not gone down? None of this attention, nor a whole lot of other attention, would have been focussed. Most likely the people who were aboard the drill rig throughout that period of terror would have come away from it saying, "That was a close call." Maybe they would not have even recognized quite that much.

It is only through paying attention to the ongoing close calls that action can be taken to prevent disasters. Why wait for the crane operator to drop a pallet on somebody because he moved his lever the wrong way? Why not have a system that regards every occasion when the crane operator goes to move the lever the wrong way as an incident, so that it is brought to attention of supervision. After it has been brought to attention enough times, it is going to click, "Hey, there is something wrong with the way that system operates."

LEADERSHIP

Leadership is critically important in the whole business. There is no point in our telling people what to do if we do not show them by way of our own example. I would remind you in closing that the single greatest risk to safety is human performance. There is a closing sentence in Dr. Foley's paper that says, "Most maritime casualties are due to some form of human failure whereas most maritime research resources are expended on hardware." Ladies and gentlemen, I think it is time to strike a balance.

COMMENTARY ON PAPER D

H.L. Zinkgraf
Vice-President
SEDCO, Inc.

First let me say that "operator competence" is a subjective statement that requires definition: what is the level of competence required? On what system operation? Under what condition? A man's capability and competence to control a machine or systems are dependent on so many factors, including, but not limited to:

1. Basic skills, education, and most important, common sense;
2. Training, on the same or similar machine/system;
3. Experience;
4. Information and operational data presented to him;
5. The physical control elements required for correct operation of the machine/system.

We must assume that the physical functions required to successfully control the machine or system are within the capability of the operator and that no unusual physical attributes are required. It also must be assumed that the machine or system has been designed correctly and is fully capable of proper operation. A man, as viewed by an engineer, is a complete servo-system. He comes complete with a computer (brain) that can rationalize (i.e., store data, reach conclusions, issue commands) and execute with arms, legs, hands, feet, and fingers. He receives "feedback" from sight, sound, touch, smell, and sometimes taste. He is equipped with the same capacity as a P.I.D. controller; he can and does function as a three mode control system.

As an example, let us consider a man driving a car. His computer is receiving information continuously from eyes, ears, and touch. He is steering the car, travelling in the correct direction, along the correct path, at a reasonably accepted speed, and all the while carrying on a conversation with the girl alongside him. He is constantly compensating for ever-changing variables on a micro second basis and is not even conscious that he is doing so. He is using all of the computation capability, sensor inputs and servomechanisms, as a "closed loop" control system. Now comes the most important capability. A child rides his bicycle out into the street. His sensors (eyes) provide an interrupt or alarm message to his computer (brain). It instantly analyzes the alarms, decides what action is required to prevent hitting the child, issues the command (in this case let us assume it is to put on the brakes), sends the command to the leg, applies what brake pressure it has calculated, integrates the response by sight and feel, and compensates for the action by more or less pressure. He perhaps sees the action is useless and reverts to a swerving of the path of the car using a new group of devices (arms and hands) and the process again repeats itself. What a wonderful machine, as long as the sensors are in working order, the computer is functional, and the servo-mechanisms respond to commands. It can work, it can compute, it can respond, as long as the machine has been programmed correctly. In this case the program is extremely simple – Do Not Run Over The Child.

With this kind of machine to start with, let us now examine how we utilize it in the real world that is the subject of this Conference: operational safety of an offshore drilling unit. A modern mobile offshore drilling unit is a complicated machine, composed of a large number of other machines and complex systems. If the designer, owner, and operator have done their job, there are no unimportant machines or systems onboard. The entire system was designed and equipped to perform only one function: to safely and efficiently explore for hydrocarbons by drilling a hole in the ground under hundreds or even thousands of feet of water. There is not enough time to adequately cover even a small percentage of the systems that require the man/machine interface so I will concentrate on one of those that is critical in the context of this Conference, the ballast control system.

The man/machine interface in this system is focussed at a control console. These consoles may take on many configurations and can be as simple or complex as the designer chooses. The control functions to be accommodated are the opening and closing of valves and the starting and stopping of pumps. The display of liquid levels, the draft at corner columns, the inclination of the vessel in both axes, and the status of valves and pumps are the minimum "feedback" or information required.

Now that does not seem to be all that complicated, but it is. The first simple consideration is to present the information and control elements in a logical and understandable way.

1. The control panel layout should be graphical; the graphic displays of tanks, valves, pumps, and piping should be aligned with the orientation of the vessel, that is the bow of the display should be oriented with the bow of the vessel, portside to port, etc.
2. The valves, tanks and pumps should have identities that make them unique.
3. The indicators for valves should be unambiguous: "Open" one color, "Closed"

another. There should be some indication that the valves are moving by using, for example, blinking lamps, or a moving dial. Such displays should also indicate the direction of movement.

4. The pump control should have the same logical presentation of condition (running or stopped) with an indication of operating dynamics (motorload, flow).

5. The liquid levels should be presented in a continuous method in either measured height or in tons and with the ability to assess the rate of change and the direction of change.

6. The draft should be displayed in a continuous manner with enough damping (or averaging) such that action of waves does not make readings useless.

7. The display of the inclination of a vessel should be presented in a straight forward non-ambigious manner oriented in the correct vessel coordinates.

The above comprises the absolute minimum of control indicators required. The more straight forward and simple these are, the better. When man is operating the machine he should become part of the system. He should instinctively look for an indicator in the proper orientation of the vessel, he should be sensitive to the rate of change of the vessel attitude by knowledge of the rate of flow or change in the fluid height or weight of the tanks. This can only be successfully accomplished when:

1. The operator has been properly trained and has experience in the operation of the equipment. The training must include fundamentals in the stability theory for the vessel he is attempting to control.

2. There must be a ballast procedure plan designed for the particular vessel, that is, designed to safely control the heel and trim of the vessel with only minor corrections being made to accommodate variables in vessel loading. This applies to ballasting up or down. Concise and unambiguous instructions should be in place.

3. The operator should be trained and drilled to perform the functions required to accomplish the plan, almost without consciously being aware of it.

4. Alarms for out-of-trim condition beyond a fixed limit should be presented to the operator both visually and audibly.

The designer must be careful to present the operator with those items of information that are obligatory to safely perform the ballasting function. He must not clutter the control panel with unimportant indicators or controls which would only tend to confuse the operator. We have found it extremely useful for the ballast operator to be trained on a computer, programmed to calculate his stability margin, heel and trim with any condition of vessel loading, and with the ability to damage any compartment, voids or tanks. This teaching aid allows the operator to plan in advance actions to be taken under emergency conditions. We have implemented these systems on-line where the tank loads are continuously input to the computer and the stability is calculated once per second. We have also implemented these off-line where all information is manually input. I mention this type installation not in the light of being necessary but as being useful from an operational and training standpoint. It does not relieve the requirement for the operator to manually perform his stability calculation.

I would like to conclude with this comment: a man, properly trained and provided the correct tools, can perform complex functions with competence. He is indispensable and also irreplacable.

Summary of General Discussion Following Paper D

Mr. G.L. Hargreaves (Consultant, U.K.) cited alleged practices during World War I with regard to training: that complex tasks were broken into a series of simple tasks so that very little training was required to perform them. They resulted in operator boredom and a high accident frequency. He indicated that research in Sweden has shown that it is probably preferable to train operators to a more competent level which allows them to exercise discretion and initiative and results in more efficient performance.

Dr. P. Foley (University of Toronto, Dept. of Industrial Engineering) agreed that training, as an integral part of any system, aims to achieve greater reliability of the system by reducing operator error. One approach is to provide the operator with an internal model or understanding of the systems that he is to operate and to train him to control activities which deviate from that model. Another approach is to teach the operator a set of operating rules, without imparting to him a knowledge of the entire system. Dr. Foley believed that a synthesis of these training approaches would be most effective, and that all training should include an element of internal modelling which, in combination with an optimum information display, will allow the average person to perform the task. Operator errors may also be reduced by the selection process for personnel, as qualifications are an indication of a person's potential and existing internal modelling. Those errors resulting from the machine's design inadequacies, such as failure to accommodate population stereotypes, must be rectified through design modifications.

Dr. A.E. Collin (Energy, Mines & Resources Canada) pointed to three differences between land and offshore drilling which must be considered in the management and training of persons to work on an offshore drilling rig: 1) a worker must become accustomed to the constant motion of the rig while work is being performed; 2) the external environment in the offshore does not afford the worker the same psychological support experienced in land-based operations; and 3) the MODU must provide adequate defence against a potentially hostile environment. Designers must be cautious in viewing an offshore rig as an island and must carefully consider the situations where the rig is not a self sufficient island and must defend itself against an unforgiving environment which does not offer the same dimension of escape available on land.

Mr. H.L. Zinkgraf (SEDCO, Inc.) verified that these considerations are not new to industry and that all available resources are being applied to make drilling offshore more efficient and safer for the worker.

Dr. O.M. Solandt pointed out that it is important to consider the limits of human capabilities in the design of equipment and that an operator should not be deluged with complex or irrelevant data which does not add to his operation of a system. In summary Dr. Solandt indicated that, although the Conference had dealt with the level of human factors involving an operator and a subsystem on a rig, it is important to consider yet another level of man/machine interface: that of an entire crew operating as part of the complex system of the rig as a single entity.

Mr. R. McGrath
Vice-President, Drilling
Petro-Canada

Mr. McGrath has a B.Sc. in Mechanical Engineering and worked with Mobil Oil Canada from 1966 to 1977 in various engineering positions. From 1977 to 1980 he joined Gulf Oil as co-ordinator for Offshore Drilling and as Manager of the Drilling Division. Since 1980 he has been with Petro-Canada where he is currently Vice-President, Drilling, and responsible for Petro-Canada's land and offshore drilling activities, including the company's Atlantic Region.

PAPER E

Organization and Management

ABSTRACT

This paper addresses the effectiveness of management and human organization for eastern Canada offshore operations during both normal operations and unplanned events. The paper develops a perspective of the organizational and command structures and communication methods in place for exploration programs offshore in relationship to the historic aspects of offshore drilling, the sinking of the *Ocean Ranger*, the environment, and the nature of marine and drilling operations. This paper discusses recent Government and industry initiatives which attempt to make the offshore a safer work place, organizational and command structures, and the elements of emergency response. Conclusions are presented based on current practice. It is a conclusion of the paper that existing management organizations are generally effective. Several outstanding issues are presented which are relevant to the topic and, we believe, need to be addressed by industry and Government for enhanced safety offshore.

BACKGROUND

The sinking of the *Ocean Ranger* was an unfortunate incident that, based on rig design and industry experience, should never have happened. However, it did happen and, as a result, this Commission, the industry, and government are focusing their resources and attention on determining what caused the incident and, secondly, are contemplating and, in some cases, implementing new guidelines, standards, and procedures in an effort to make the offshore safer for all drilling units, support systems, and personnel who derive their livelihood from the oil and gas industry offshore Canada.

Exploration for oil and gas offshore goes back to the early 1900's and, since that time, some 45,000 offshore wells have been drilled worldwide. As the demand for oil increased, exploration activities moved into deeper waters and more severe environmental areas. Technology has had to advance at a rapid pace to meet the challenge. Offshore drilling has progressed from using a conventional land drilling rig mounted on a wooden platform over the water to submerged barge-mounted drilling units, submersible drilling units, jackups, anchored floating barges, anchored drillships, anchored semi-submersibles, dynamically positioned drillships and, finally, dynamically positioned semi-submersibles. Each advancement required the development of innovative procedures, equipment, tools, and improved training and skills for crews to ensure safe and efficient drilling operations in the new frontier areas.

Progress has not been without incident. Between the years 1955 and 1981, a total of 140 mobile unit mishaps were recorded, 47 of which resulted in a mobile drilling unit being lost at sea or taken out of service.

Offshore operations on Canada's East Coast commenced in 1966 on the Grand Banks with the anchored drillship *Glomar Sirte*. Since that time, approximately 200 wells have been drilled offshore Canada's East Coast from the Scotian Shelf to Davis Strait. Drilling units operating on the East Coast of Canada have included 15 drillships, 7 jackups, and 16 semi-submersibles. The drilling units were selected based on water depth, environmental considerations, the well program, timing, and, in some instances, availability. Recently, there have been two incidents of significance which marred industry's safety and performance record on the East Coast of Canada, the sinking of the *Ocean Ranger* and the Uniacke well blowout. These events put the industry and Government on notice that mishaps could also become part of the Canadian experience.

This does not mean to imply that prior to either of these two incidents Government did not require offshore operators to prove the existence of an adequate management system or that the operators did not meet and, in most cases, exceed regulatory requirements. Quite the opposite, we believe the industry has been acutely aware of the necessity for advancing the management systems consistent with the technological marine and drilling advancements. The successful response to the Uniacke well blowout may, in part, be due to the recent attention paid to emergency response planning as a direct result of the *Ocean Ranger* incident, primarily in the co-ordination of operator, contractor, support services, and regulatory plans and resources that has taken place since February 1982.

However, even with these co-ordinated plans in place, there are still factors such as equipment limitation and the marine environment which affect our ability to respond to an offshore situation. Considering the marine component of offshore drilling, it is well accepted that personnel and equipment experience an element of risk while operating offshore. As offshore operations moved to more severe environments, increased attention was paid to the support and backup systems necessary for safe and efficient operations. Current examples are training and prevention programs targeted at specific activities for all offshore crews, design and selection of equipment consistent with the working environment, state-of-the-art survival equipment and emergency appliances, and the implementation of satellite communications technology. The extensive level of support provided to the offshore drilling activity is unparalleled when compared with conventional marine activities such as shipping and fishing.

DESCRIPTION OF THE ENVIRONMENT

The physical environment offshore the East Coast of Canada is as varied and severe as any experienced in the offshore exploration and development areas of the world. The Labrador Sea and Davis Strait areas are confined to drilling operations during the open water season from July to November. Sea ice constrains these operations at the beginning of the season, and severe autumn storms end the season. The presence of iceberg activity requires constant surveillance and management if operations are to continue in a safe and efficient manner. Ice conditions, deep water, weather, and the relatively short operating season make dynamically positioned vessels the preferred drilling unit for this area as they are able to systematically move away from encroaching sea ice or icebergs and to quickly re-establish connection with the well once the hazard has passed.

On the Grand Banks, icebergs and sea ice are also significant factors, and the presence or absence of them varies from year to year. Extreme environment, heavy weather semi-submersibles have been utilized on the Grand Banks because of their better motion characteristics for year round operations. Even these semi-submersibles are not designed to work in sea ice and, as a result, temporary suspension of drilling activity is planned for and implemented when sea ice encroaches on a drilling location. This was evident in February and March of 1983 when sea ice covered portions of the exploration areas on the Grand Banks. Sea ice also limits the drilling season in the Gulf of St. Lawrence. Sea ice occurrence is rare on the Scotian Shelf but winter storms require the utilization of severe environment semi-submersibles in water depths greater than 60m and large, new generation, heavy weather jackups in shallower water depths.

Other environmental factors which are present and must be considered and addressed in the operations plans for safe operations include: cold air and sea temperatures which necessitate winterization and protection of machinery and work areas; covered lifeboats, fast rescue craft and availability of insulated survival suits for crews both in transit by helicopter and in the event of ship abandonment; fog which reduces visibility and challenges logistic management for the efficient movement of crews; and icing on supply vessel and drilling unit superstructures which necessitates reduction of available variable deck loads to compensate for the calculated ice buildup. Helicopters are not permitted to fly when there is a risk of icing. Ocean currents, although less significant, are important and must be considered in the mooring analysis for semi-submersibles and overturning moment analysis and foundation support or scouring effects for jackups. Tides to date have not posed a constraint on operations except at the mouth of the Hudson Strait where the tides and resulting water motions require that the operational procedures consider the currents associated with the tide.

RESPONSE PLANNING INITIATIVES

Since commencement of offshore operations in 1966, the operating companies, drilling contractors, and Government have continually strived to make the offshore a safer work place. Emergency response plans, and operational procedures and guidelines were developed and formalized so that an unplanned event could be dealt with in an expeditious manner. However, these plans, procedures, and guidelines are only as good as the equipment, experience, and training of personnel, the communications system, and the organization and command structure. The loss of the crew of the *Ocean Ranger* demonstrated some weaknesses existed in the system. Since the sinking of the *Ocean Ranger*, emergency response planning activity has been intensified and new initiatives have been undertaken, in consultation with Government, in order to enhance safety for offshore workers. Some of these improvements include:

1. Multi Operator Agreements. In the areas where more than one operator is active, agreements are entered into amongst the operators to improve safety offshore through co-ordinated communication and logistic support. For the Grand Banks operators these include:

- Flight/Marine Monitoring Service Plan
- Grand Banks Operators' Alert/Emergency Co-ordinated Response Agreement
- Grand Banks Operators' Emergency Resource Sharing Agreement
- Support Craft Services Sub-charter and Assignment Agreement
- Grand Banks Operators' Joint Ice Detection and Ice Reporting Plan
- East Coast Operators' Management Committee

2. Emergency Response Plan. Individuals who assume specific emergency response duties are usually selected based on their job function and experience. The Emergency Response Plan serves as a checklist for these individuals but primarily benefits other personnel who may have to assist or replace the designated individual in a given emergency response situation. The Emergency Response Plan provides direction for the mobilization of personnel and equipment for any serious emergency that may occur. Through the auspices of the Canadian East-coast Offshore Safety Committee (CEOSC), an industry common emergency response manual was prepared for use by operators as a format for company specific plans. The emergency situations addressed by the plan are:

- Code 1 – Personnel Injury or Death (only)
- Code 2 – Loss of Well Control
- Code 3 – Rig Damaged or Threat of Rig Damage
- Code 4 – Overdue or Lost Aircraft
- Code 5 – Lost or In Distress Vessel
- Code 6 – Divers
- Code 7 – Oil Spill

For rapid response, it is important that the essential details of an emergency be communicated immediately to the persons responsible for dealing with the emergency. Proper training, experience, and skill of on-site personnel is essential. Frequent communication exercises help to assess the readiness and ability of on-site and shore-based personnel to respond effectively to an emergency situation.

3. Alert Response Plans. Alert Response Plans were developed and implemented for responding to certain extraordinary situations which may not require immediate action but could lead to a serious incident. The Alert Response Plan is co-ordinated with the other offshore operators working in the immediate area to ensure that all available resources are used in the most efficient manner.

4. Alert/Emergency Response Manuals. The recent development of combined Alert/Emergency Response Manuals was a logical progression which recognized that one volume could cover both response aspects, some responses had no Alert phase and, in many cases, the Alert and Emergency Responses were identical, and the response organizations for Alert and Emergency situations were likely to be identical.

5. Ice and Iceberg Management Plan. Ice management plans have been developed and implemented for operations in ice fre-

quented waters. The plan provides guidelines for early detection and response to the threat of ice. If the ice threat cannot be managed then avoidance is recommended. The Grand Banks Operators' Joint Ice Detection and Ice Reporting System provides a co-ordinated information gathering system by which all ice observations are compiled and joint discussions reached on ice management matters.

6. Heavy Weather Policy. Heavy weather policies have been implemented to ensure that proper measures will be taken to suspend operations in an orderly and safe manner in the event of forecasted bad weather. In order to protect personnel and prevent damage to the equipment, a series of precautionary actions can be initiated depending on the severity of the environmental conditions. The precautionary decisions are categorized as follows:

- suspend rig operations and hang off the drill string
- disconnect from the well
- deballast to survival draft
- pull anchors and move off location
- evacuate the drilling vessel

7. Flight and Marine Monitoring. All flights dispatched from the shore base and drilling unit are monitored by the Central Flight Following Facility. The contractor provides monitoring of routine and emergency helicopter operations and also maintains and updates supply vessel status and location. The advantage of a central monitoring facility in an emergency is the ability to immediately determine which aircraft or vessel is in the best position to respond and render assistance.

ORGANIZATION AND MANAGEMENT

We believe that the present organizational structures for offshore operations are effective in ensuring safety of personnel and equipment for normal and emergency situations. The operators, contractors, and regulatory agencies on the East Coast have established safety as a priority and operational efficiency as a secondary consideration. It is the experience of industry that safe operations result in efficient operations. The operators working on Canada's East Coast vary in experience and operations knowledge. The drilling contractor who is new to the area and working for an inexperienced operator is at a disadvantage in his ability to relate to the local conditions and regulatory requirements. This operator/contractor combination relies heavily on other experienced operators and contractors to share their knowledge. It is through this co-operative sharing of knowledge and experience that potentially catastrophic situations are averted and the learning curve is accelerated.

NORMAL OPERATIONS ORGANIZATION

For normal drilling operations, the organization structure is made up of two distinct components: the operators' organization and the prime contractors' organization and onboard command structure. The oil company or operator generally acts as the focal point of the exploration program. The operator:

1. Defines the exploration program;
2. Contracts the drilling unit, helicopter, and marine and support services for a specific program;
3. Communicates directly with regulatory agencies on all matters relating to the program. The regulatory agencies deal directly with the operator in granting program approvals;
4. Sets up and maintains a shore support base facility for materials, supplies, administrative and technical support to operations;
5. Develops and implements emergency response plans and is responsible for ensuring compliance with all safety rules and regulations.

The operator's management structure for offshore operations includes:

1. Senior management at the operator's head office who interface with the client group and partners on timing, schedules, and budgets of ongoing and future exploration activities.
2. Operations management is normally located in the immediate vicinity of the drilling activity such as St. John's or Halifax. The operations office monitors day-to-day drilling activities, provides the logistic support and base personnel to ensure the equipment, services, and supplies necessary for executing the drilling program are available in a timely and cost effective manner. The operations office also consults on a daily basis with the operator's senior representative onboard the drilling unit to ensure his requirements are met and that the drilling operations are progressing as planned, informs the regulatory bodies of progress, current and planned activities, liaises with the drilling contractor and service support contractors on requirements and needs, ensures that the communication system is functional and operating at all times, consults with other operators on possible requirements and sharing of resources, and liaises with senior management as necessary.
3. Onboard supervision is performed by the operator's senior representative who is responsible for ensuring that the drilling program is followed and that the drilling objectives are met with due consideration for safety, efficiency, and protection of the environment. The operator's senior representative informs the drilling contractor's representative onboard of the operator's requirements.

The drilling contractor's organization consists of:

1. Senior management at the drilling contractor's head office who negotiate the drilling contract and establish policies and procedures for the conduct of operations;
2. Shore based management and support staff located near the operator's base onshore. The function of this staff is to monitor performance and progress of the drilling unit, purchase and expedite supplies and materials for the maintenance of contractors' equipment, ensure that adequately trained and experienced crews are available for crew rotation, consult with the operator on planned and current activities, and liaise with other contractors in the area. Shore based management is responsible to the operator and the drilling contractor's senior management for safe and efficient operations in accordance with applicable regulations and guidelines, and consistent with good oil field practice;
3. The marine crew and drilling crew. Internationally, the organizational structure defining the onboard command hierarchy varies with the type of drilling unit, its flag, the contractor and the operator. These organizations have developed over a number of years of experience and successful operation and are difficult and, in most cases, impractical to mix or alter. In Canadian waters, the preferred approach has been to a common command structure with one individual being identified as being responsible for the safety and security of the vessel and crew.

Information flow to the drilling unit for the benefit of the operator and contractor includes:

- Environmental, ice, and seastate
- Desired deviations from the approved well plan
- Aircraft, helicopter and marine vessel status
- Resupply schedule and status

Information flow from the drilling unit includes but is not restricted to:

- Weather and ice information for input into forecasts
- Daily drilling status report and progress
- Planned activities
- Equipment status
- Supply status

The communications system employs state-of-the-art technology with adequate redundant components to ensure totally reliable communication.

There are three basic types of drilling unit employed offshore the East Coast of Canada and, because of varying operational requirements, the onboard command structures of each are discussed separately. The role of the operator's representative onboard is the same for all situations discussed below and ensures that the regulatory obligations and operator policies are met and/or considered in the decision making process.

Jackups

The jackup rig is considered a marine vessel while under tow and is under the charge of a barge master or rig mover during such operations. Once the jackup is on location and stationary, there is a formal signover procedure which transfers responsibility from the rig mover to a senior drilling representative of the contractor. The senior drilling representative is then in charge and is responsible for the execution of drilling operations and safety of crew and equipment. Responsibility is again formally transferred to the rig mover when drilling operations are completed and the jackup is ready to be moved.

Drillships

A drillship is subject to the *Canada Shipping Act* and requires a master with Unlimited Foreign Going papers to be onboard. There are two types of drillship, the dynamically positioned drillship and the anchored drillship. The dynamically positioned drillship maintains position over the well by thrusters. This requires marine skills to be employed at all times and, as a result, the captain is in overall command. On an anchored drillship, however, the captain is normally in command when the ship is in motion. While anchored on location, the captain is responsible for the safety of ship and crew and stationkeeping, and the rig superintendent is responsible for the drilling operation and control of the well. In the event of an emergency, the captain takes full command.

Semi-submersibles

Self-propelled, semi-submersible drilling units are classified as marine vessels and, as such, are required to have a captain or master mariner onboard when the unit is functioning as a vessel. However, twin hulled, column-stabilized structures such as semi-submersibles do not behave like conventional ships and have complex ballasting systems to maintain stability. In our opinion, industry recognizes that both marine and drilling skills are required to effectively command a semi-submersible drilling unit.

There are two basic command structures for semi-submersible drilling units, the European model and the American model. The European model follows the conventional marine command structure with a captain in charge. Normally, the captain is required to hold Unlimited Foreign Going Masters' papers and will have served as a subordinate officer on a semi-submersible for two or more years prior to taking command. There are two variations to this model.

1. The captain is in complete command of drilling and marine activities.
2. The captain is in charge of the marine crew and the senior driller is responsible for rig operations under normal conditions. Total command reverts to the captain when there is a threat to vessel or crew.

The American model has the senior onboard contractor's representative in charge at all times. This person is fully knowledgeable on drilling operations, has been trained in marine operations, and is required to be in possession of a column-stabilized (MODU) masters' ticket. Although the senior onboard representative is in charge, the captain remains responsible for the safety training of crews and is delegated command of the unit when in transit.

From the operator's point of view, we endorse the philosophy that one person should be clearly in command at all times. The onboard person in command must have management and organizational experience, a sound understanding of drilling and well control procedures, knowledge of the working limitations of the drilling unit and complexity of support logistics, and be totally familiar with the marine environment. If a captain is in command, he must have a good perception of drilling operations and must have worked in a subordinate role on a MODU prior to taking command. If the contractor's senior onboard representative is in command, he must have full knowledge of semi-submersibles and must be in possession of a MODU masters' licence.

EMERGENCY RESPONSE ORGANIZATION

Safety in an emergency situation is of prime concern and a clear understanding of who is in command is essential if emergency situations are to be dealt with in an organized, efficient manner. In an emergency, the responsibilities and actions necessary are clearly defined in the alert and emergency response planning materials. The emergency response organization varies from operator to operator but is usually very similar to the normal response organization for that operator. The basic difference between normal and emergency responsibilities is that, in an emergency situation, shore based management performs a central co-ordinating role and the onboard personnel may have to make extraordinary decisions.

During emergency situations, it is essential that communications be as direct as possible. The drilling unit communicates with the operator and directly with dispatched support on operational issues. An Emergency Command Centre is established in the operator's office, and the contractor's shore based representative is requested to proceed to the emergency command centre. All communications (direct or monitored) are passed to the Emergency Command Centre. This permits timely and knowledgeable decision making and prevents unnecessary third party communications with the drilling unit. The Emergency Command Centre will co-ordinate all other elements in the response structure which can supply assistance. All operators recognize the importance of the communication process in ensuring an effective emergency response.

The basic elements of existing emergency response organizations are:

1. An organizational and command structure should identify lines of communication and actions to be taken by key emergency response personnel.
2. Emphasis should be on experience and training. In an emergency, the crew must believe in the competency of the person in command to avoid delays in response.
3. Emergency response exercises and drills under controlled conditions should assist in assessing the effectiveness of the plan, readiness of response organization, and maintenance of a high profile on safety and prevention programs. The exercises and drills must be co-ordinated to include the drilling unit, supply vessels, helicopters, shore base support staff, Coast Guard, Search and Rescue, and regulatory agencies, and designed to test the weaknesses and strengths of the communications system and logistic support network.
4. Operators' Liaison Committee (OLC) and related joint management and response assistance plans, such as those between the Grand Banks Operators, formalize a mechanism of extra operator assistance.
5. Effective lines of communication should be as short and direct as possible.
6. The individual responsible for directing onboard emergency response operations must be prepared to make extraordinary decisions in lieu of normal consultative processes.

CONCLUSIONS

From this paper, which addresses the organizational and management structures now in place for the conduct of safe and efficient operations offshore, the following conclusions are drawn.

1. The oil industry has operated offshore for approximately 80 years and has 18 years of experience offshore the East Coast of Canada. Technology has advanced at a rapid pace to meet the demands of drilling in remote locations and severe environments. This progress has taken place with due consideration for safety of personnel and equipment, efficiency of operations, and protection of the environment.
2. The sinking of the *Ocean Ranger* demonstrated to industry and Government that serious mishaps can occur in the Canadian offshore. Since this incident, Government and industry have instigated new initiatives relating to safety, training, and emergency reponse planning. The immediate and successful response to the Uniacke blowout may have been, in part, attributed to these recent initiatives.
3. It is recognized that there is a significant marine component to offshore drilling operations. However, the level of support provided to offshore drilling is now extensive and unparalleled in the marine industry.
4. Our industry and Government have established human safety as the priority, and operational efficiency as a secondary consideration. It is the experience of industry that safe operations result in efficient operations.
5. There are two distinct elements within the organizational structure for current drilling programs, the operator and the drilling contractor. While they have slightly different perspectives, each has to be cognizant of the other's concerns and needs, and they must work together towards a common objective.
6. The onboard organizational and command structure for normal operations is, for the most part, identical to that for an emergency situation.
7. The onboard person in command must have management and organizational experience, a sound understanding of drilling and well control procedures, knowledge of the working limitations of the drilling unit and complexity of support logistics, and be totally familiar with the marine environment.
8. Safe, efficient, and successful normal and emergency operations will be fostered by properly trained, experienced, and skilled personnel who have confidence in the person in command.
9. Continuous dialogue between the drilling unit and the shore base is essential. In order to accomplish this, state-of-the-art communications systems with necessary redundant components have been integrated into offshore drilling operations.
10. The establishment of an emergency communications centre at the operator's base minimizes the generation of misinformation in an emergency and ensures the availability of a complete record of all communications with the drilling unit.
11. There is a calculated risk to all ventures which must be understood and accepted. Government and industry are committed to continuing to investigate means of minimizing and, where possible and practical, reducing these risks.

ISSUES FOR DISCUSSION

This paper concludes that existing organization and management structures and communication methods are effective in dealing with both normal and emergency situations offshore the East Coast of Canada. The outstanding issues, in our opinion, are:

1. In Canada, there are no formalized qualification requirements for key positions onboard the drilling unit. Standards of required knowledge, experience, and competence levels for key positions have to be clearly defined and developed by both industry and Government, and a Canadian certification program which is compatible with other similar international certification programs must be implemented.
2. The ratio of trainees to experienced personnel onboard offshore drilling units must be reviewed by industry and Government, and an upper limit established in the interest of safety. The industry has expanded rapidly over the past twenty years and technology continues to evolve. In our opinion, industry faces a situation, particularly in Canada, where there is a shortage of adequately trained, experienced, and skilled individuals to effectively fill the key positions on drilling units. Contractors must recruit from the world market for qualified personnel to fill key positions while, at the same time, provide training opportunities for Canadians.
3. Canadianization of offshore crews must progress at a controlled pace and not accelerate to the point where safety will be compromised.
4. We believe that marine and drilling regulations, as they relate to offshore safety and drilling, are not industry specific. To ensure that these regulations become industry specific, joint involvement between industry and Government, with due consideration to the views and experience of operators, drilling contractors, and service organizations, is necessary.
5. The roles and responsibilities of industry and government agencies with respect to emergency situations need to be clearly defined.
6. The industry and Government need to come to an understanding regarding the level of search and rescue support required to support offshore exploration, development, and production activities.
7. There has to be a mutual understanding and acceptance by industry and Government as to the effectiveness of lifesaving appliances prior to their implementation.

References

(1) "An Evaluation of Industry Safety Management in Eastern Canada Offshore Drilling Operations." Submitted to the Royal Commission on the *Ocean Ranger* Marine Disaster. Manadrill Drilling Management Inc., March 1984.

(2) "Risk Assessment." Ian Burton. March 1984.
Part I – A Perspective on Risk with Special Reference to Eastern Canada Offshore Exploratory Drilling.
Part II – A Preliminary Risk Assessment of Human Safety in Exploratory Drilling Operations for Oil and Gas In the Eastern Canada Offshore Area.

(3) "Royal Commission on the *Ocean Ranger* Marine Disaster – Assessment of the Normal and Emergency Command Structures Relating to Drilling Systems for Eastern Canada Offshore Drilling Operations." Currie, Coopers & Lybrand. May 25, 1984.

COMMENTARY ON PAPER E

J. Hielm
Senior Contingency Planner
Elf Aquitaine Norge A/S

I was asked to comment or to amplify on Mr. McGrath's paper. Apart from complimenting Mr. McGrath on his presentation I must confess that I do not really feel in a position to make any comments. This is because his paper, as well as being general in content, is obviously adapted to the Canadian situation and I am not familiar with the operators' arrangements and agreements, and therefore any comment that I make could be way off target and consequently misleading and wasting your time. So, I have decided to amplify on certain things, and what I will do is go through some of the basic elements of contingency planning and crisis management.

I would like to make some general comments. I will show you how the Norwegian operators have developed a model contingency plan and then, time permitting, I will show you what we have done within my own company regarding the onshore emergency organization and the personnel qualifications and the training program that we have established. What I am going to say may, to a great number of you, seem both obvious and evident. Nevertheless I am often amazed to see how many times the obvious and evident are neglected in an emergency situation, simply because one has not carried out the thought processes or the evaluation relating to the incident. When developing a contingency plan for various situations, it is impossible to cover all the circumstances that can be involved. If you try and do that, you do not have a contingency plan, you have a filing cabinet. As a consequence, one cannot finalize in detail what should be done, who should do it, or how it should be done. The plan must therefore be limited to general operational guidelines to which elements may be important for the further development of the situation. The final plan of action can first be determined when the emergency has arisen and all the known elements can be included in the situation evaluation. One might say that the determination of the prime objective must include the possibility of alternate solutions and I will try and show you.

If we go into an actual situation, then we have one of two possibilities. The answer to the equation "50 + 50 = ?" is "100" or you are wrong. In other words, we have no possibity of variation to the problem. But if I do this the other way around and said, "My equation yields 100, I want to solve this problem. How can I do it?" Well, if somebody says, "Two times fifty," he is correct. In one situation you would choose a two times fifty solution, other times you would take four times twenty-five, another, ten times ten. You obtain your objective by using various methods. This once again will be dependent on the situation at hand.

Now, I would like to look at one of the tools we can use in the development of a contingency plan and I would like very briefly to try and adapt this to the *Ocean Ranger*. One of the key words is identification. In developing a contingency plan one has to identify:

1. Situations – What can happen? How can it happen?
2. Problem and Priority Areas – Where can it happen?
3. Individuals – Who is to take action?
4. Duties – What to do?
5. Systems and Equipment – What to use? When to use it?
6. Procedures – How to do it? How to use it?

This is a tool that can be used for the development of a contingency plan by the individuals concerned.

Earlier we were talking about the man/machine interface and this is one of the major drawbacks that we meet in all forms of contingency plans. It is this complex relationship between the probability of an incident occurring (which you might call risk analysis), the possible cause, the courses of action and the individual or individuals who decide on strategy and the persons who have to carry out the physical operation. Emergency procedures are designed to cover the most probable incident and the most probable course of action. The major weaknesses of such plans is that they have to assume that the emergency will develop along certain lines; that the platform organization is intact; and that individuals will react in a calm and rational manner. As I said previously, if we tried to cover all possible situations, our plan would be so voluminous that no one would ever read it. A friend of mine said, "Our contingency plan is the most dangerous thing in the world. It's so big that if you drop it on your foot, you end up in hospital."

No two situations are ever quite alike. We do agree on that and in order to cover this we have developed a tool for carrying out what we call a table-top exercise. A table-top exercise can be literally no cost whatsoever and can be used as a tool to check your contingency plan. We at Elf carry out what we call safety tactical training courses where we bring the platform personnel together with the onshore emergency organization, the masters of the standby vessels, and so on. Each person plays his own role and there is no time limit. We stop at each stage for discussion and we let people come out with their feelings. The first thing we do is determine the platform and we ask the people involved, "On your platform is there something that gives you the shivers, something that keeps you awake at night?" We use this approach to identify the type of incident.

Next we use a series of questions: Where on the platform would this take place? How would it take place? How many people would be involved in the accident? We discuss these items. We try to postulate the number of people who would be injured from the type of incident we could expect. We then ask the people to consider what they would do in such a circumstance. What about firefighting? Would you carry out a shut down? Would you carry out evacuation and how would your notification be carried out? We ask each individual, "Do you agree with what he says? Would you have done this in another manner?" And we check and go back and see what the contingency plan says. If people do not react according to the plan, it is either the plan or the people that are wrong. We have to correct this. If the people are correct, we modify the plan. If the plan is correct, we agree on that, then we have to retrain our personnel.

We then continue to the third stage where we add complications to the situation. The number of solutions identified to respond to these circumstances is really amazing. Man has the capacity to improvise in crisis situations. We did an exercise on one of our installations where we killed the platform manager, we killed his deputy, we killed the nurse, we killed the crane driver and we also put the sick bay out of operation due to fire, and they were left on their own. The way these people took over was really amazing. Although they did not have medical facilities and we gave them a great number of broken bones, they went into the galley and we had no broomsticks left, but we had an awful lot of splints. They improvised in a manner which was really amazing.

Even utilizing such a tool for training in crisis management, there are certain pitfalls. Consider the people who operate these systems, the people who are going to take over in the case of a system failure and the people who determine a plan of action. These are individuals who have all got their inherent weaknesses. I have seen different people react in different manners or the same man can react in a different manner on different occasions when faced with literally the same situation. Repeated training with no variation whatsoever will produce a sense of false confidence that everything will take place as it does during an exercise. An individual will develop a tendency, good or bad, to associate certain situations with certain results and if he gets into a situation he will try and adapt the situation to tie in with his solution and not his solution to tie in with the situation. If he cannot control this in the worst possible case, panic can be the result. This is what we refer to as a fixation. We look upon the members of a certain profession as having certain characteristics, qualifications, and abilities and we forget that these people are, in fact, human beings. They have their own reactions and they have their own feelings.

In his presentation Mr. McGrath made the following statement and I quote:

> The drilling contractor new to the area and working for an inexperienced operator is at a disadvantage in his ability to relate to the local conditions and regulatory requirements. The operator/contractor combination relies heavily on other experienced operators and contractors to share their knowledge. It is through this cooperative sharing of knowledge and experience that potentially catastrophic situations are averted and the learning courses are accelerated.

Well, in Norway we have tried to develop a standard contingency plan. We have tried to cover all forms of operations and a contingency plan relates really to four parts. First, the platform part which accompanies the platform regardless of the operator with whom it is working. The second part is designed by the authorities and other subcontractors. These parts dovetail together. In other words, I can have four rigs and my own fixed installations working but my procedures as operator are the same.

These dovetail with our own fixed installations and the platform clients. We have a common indexing system for each document. Then we define the emergency organization of each of these plans. The only external authority is the main Rescue Coordination Centre's organization and the government action control group that takes over. We have standardized situations so that chapter 41 in every contingency plan is a fire explosion, 42 a gas fire, 43 a helicopter on deck and so on. The reason we have done this is that in certain situations (diving and radiation accidents) it is the subcontractor who is best qualified to do the job and is responsible for that contingency.

I would not necessarily say this approach to contingency planning is the way you should do it here, but it is the way we seem to have solved some of the problems that you encounter here. It is a tool that one might utilize.

COMMENTARY ON PAPER E

F. Williford
Assistant Vice-President
SEDCO, Inc.

I am fortunate in that I know a number of people in the audience today. I have spent a number of years working in this part of the world and resided on the East Coast for a total of about five years. So, I ask that you listen to what I have to say today and remember I am bringing some experience but also a fairly narrow perspective to the problem we have at hand. The theme is safety; the specific topic is organization and management.

As a Drilling Contractor, I own the vessel, I operate it, and I employ the labour force. I am directly or indirectly responsible to four federal agencies, three provincial agencies, and five operating companies. I am being viewed with a critical eye from a number of directions and I can assure you I feel the pressure. At the end of the day, my only claim to fame, in fact, will be how much hole I managed to drill in the ground with, hopefully, no claim to any notoriety. I will not likely get much credit for the number of people hired or trained. I will only be told that I must do so in a credible manner. Fortunately, we have mutual requirements in this regard. I need a lot of good, well trained people and I am actively engaged in looking for them every day. There will only be a limited understanding of my needs and requirements for others, but I must understand the objectives, the needs, and the requirements of the host governments and the operating companies. Therefore, I appreciate with all due respect a good operational contingency plan. That is something I can understand and that is something I can respond to, because I do it everywhere I go. I must, however, have the flexibility and the freedom to run my own vessel and to train my people so that they suit the needs of my operation and perform in accordance with the characteristics of my vessel. Governments, rightfully so, advise, regulate, check, inspect and control a lot of the aspects of the workplace. I require that the operating company and the government entity provide me with an atmosphere and a scenario that allow me to respond to the job I am hired to do.

I support safety emphatically for good reason. I am really not misguided in this regard, because I spend far too much time out on the drilling vessels. If something goes wrong, I will surely be personally involved. I cannot escape this involvement. I can assure you that I have complete understanding and a desire to further the outline presented in Mr. McGrath's paper today, because the contractor knows the problems faced by the operator and he knows why the operator hired him. He knows that the job at hand is to work in the safest and most efficient manner if he is going to stay in business.

Summary of General Discussion Following Paper E

Mr. I. Manum (Norwegian Maritime Directorate) agreed with the importance of employing well trained and skilled personnel offshore, but he questioned whether the persons chosen for the most important positions actually possess the best and most appropriate personal qualities and capabilities. He cited the *Vinland* blowout incident, the investigation of which indicated that the person in charge had not used appropriate judgement in closing down the well. Mr. R. McGrath (Petro-Canada) disagreed with Mr. Manum's assessment of the *Vinland* incident, and added that an operator expects the drilling contractor to make available the most competent and capable people to fill the key positions on a rig. Mr. F. Williford (SEDCO, Inc.) said that this aspect is admittedly difficult; SEDCO goes to great lengths to avoid inflexible career paths for its employees and tries to identify capable personnel as early as possible so that proper training can assist them to rise to top, responsible positions.

Session Chairman Dr. G.M. MacNabb wondered about the relevance of physical and psychological competence of the people who are in key positions. Dr. H. Haakonson (Petro-Canada) responded that, in addition to identifying capable persons, companies should have some sort of mechanism in place which will allow personnel to identify their own capabilities (or lack of them) on a day-to-day basis.

Dr. B.P.M. Sharples (Noble, Denton) expressed concern over the practice of a drilling man being in charge of an offshore rig, only to have someone else take control in the event of an emergency. He wondered how this change of command is communicated to the crew and how emergency situations are identified. Mr. McGrath replied that, while the present situation is not completely desirable, industry is searching for a better solution. He described the following command structures: 1) on a dynamically-positioned drill ship the master is always and continuously in charge; 2) on an anchored drill ship the master is always in charge although he delegates this responsibility when the unit is in the drilling mode; 3) on a semisubmersible the master is always in charge for the safety and well-being of the unit, even though a drilling man may be the apparent man in charge when the unit is anchored and in a non-forward motion; 4) on a jack-up the drilling man is in charge when it is jacked-up into a stablized position. There is, however, a formal signover of command to the master when the jack-up is to be towed or re-located. Mr. Williford supported the explanations of Mr. McGrath and said that, although the drilling people are in charge of daily drilling operations, there is never a point in time when the master is not in charge of the vessel.

Dr. J.R. Hawkins (Esso Resources Canada) made reference to the keynote address of Mr. G.R. Harrison and questioned the advisability of charging the chief executive officer of an operating company with the ultimate responsibility for all aspects of engineering and safety operation in offshore drilling ventures. Mr. McGrath agreed with Mr. Harrison's idea of single-point responsibility, adding that a varying scope of single-point responsibility normally occurs at each of the management levels of an organization.

Vice-Admiral A.J. Fulton (CAF, retired) raised the question of the maintenance of an appropriate level of physical fitness of offshore workers as one aspect affecting their ability to perform routine and emergency duties. Dr. Haakonson indicated that, in his experience, most workers are very keen to learn and do whatever is required to maximize their ability to survive in the case of a disaster. Any program to increase the level of fitness of offshore workers would be limited to emphasizing the impact of fitness on the chances of survival. Mr. J. Hielm (Elf Aquitaine Norge) added that Norway requires all offshore workers to meet the terms and conditions of a health certificate, and that includes consideration of the physical weight of a worker. If the worker is judged by the examining physician to be too overweight, the worker is denied the right to work offshore. Dr. C. Brooks (DND Maritime Command Headquarters) indicated that the fitness of an individual to do a specific job may be a problem, and he suggested that varying physical fitness criteria will need to be identified for various types of positions to overcome this problem.

Mr. R.E. Johnson (NTSB) raised the subject of contingency plans and how the operators and contractors integrate their plans so that no confusion results during an emergency. Mr. McGrath responded that the regulations require the operator to submit a contingency plan for each drilling location. Upon approval by the regulatory authority, copies of the plan are placed in the operator's office on shore and on board the rig to be used to ensure that everyone who has a role in that contingency plan is aware of it. Mr. Williford pointed out that, as a drilling contractor, SEDCO establishes a vessel-specific contingency plan, adapts it to the particular environment and jurisdiction of the drilling program being undertaken, and then blends it with the needs of the operator. SEDCO also takes into consideration other equipment which may be available in the field, outside that provided by the operator. This integrated plan receives formal agreement by both the operator and the contractor.

Mr. J. Hornsby (CCG Ship Safety Branch) pointed out that the *Ocean Ranger* had contingency plans which were essentially ignored, and prior to its capsize, the *Ocean Ranger* was considered a successful vessel. Industry must assure the regulatory agencies, he said, that these plans are more than mere paper protection and that reporting procedures are being adhered to, thus enabling the regulatory agencies to monitor the rigs' actual safety performances and procedures.

Mr. McGrath again emphasized the importance to industry of the guidelines provided in a contingency plan. With regard to the reporting of incidents, he pointed out that the regulatory authorities have yet to define incidents which are "reportable" and not subject to interpretation. These differences need to be worked out to the satisfaction of both the industry and the regulatory authorities.

Mr. Johnson also raised the issue of the need for the establishment of qualification standards for rig workers, and asked what has been done by industry, particularly in the United States, in this area. Mr. McGrath said that, in Canada, the person in charge must be a master with more than four years experience on a vessel greater than 25 tons. Mr. Greif (SEDCO, Inc.) referred to a recent document in which the Canadian Association of Drilling Contractors agreed to job descriptions for various positions on a rig and applied minimum levels of training, education, certification and testing to each position. In the United States, a similar document, produced by the International Association of Drilling Contractors, will be presented to the U.S. Coast Guard in an attempt to have greater industry input into the licencing and certification of personnel. When asked by Dr. MacNabb whether these standards also address the degree of physical capability required in certain positions, Mr. Greif replied that they did not, because, as stated earlier, this has never been a problem. The IADC document emphasizes skills such as ballasting, weather forecasting, and dealing with emergencies.

In the United States the person in charge of a rig, in most cases, is a drilling man with experience and tested skills in marine matters and who holds a Column Stabilized Masters' Ticket. The industry has encouraged the Canadian Coast Guard to investigate and consider this approach and to work with the U.S. Coast Guard to develop a similar standard for Canada.

Mr. H.L. Zinkgraf (SEDCO, Inc.) interjected that approaches to Canadian Coast Guard to participate in the talks between industry and U.S. Coast Guard regarding qualification standards have had no response to date, as far as he was aware. He felt that this is unfortunate as it has hindered the possibility of developing a North American standard of qualifications for key offshore positions. Mr. Hielm alerted participants to the importance of differentiating between skills and certification, and referred to an incident in Norway when Red Adair was asked by authorities to kill a well at Ekofisk Bravo but was not certified to work on the Norwegian Continental Shelf.

Mr. R.A. Quail (Canadian Coast Guard) asked Mr. McGrath for clarification of what is meant by a "certification program", would it be part of a regulatory system, and if not, how would such a program be administered and enforced? Mr. McGrath felt that a program where individuals are "ticketed" as being qualified to command certain positions, would be workable through present regulatory agencies.

Mr. Johnson outlined the problem with highly technical data, particularly stability data, being made available to operators in a form which is too sophisticated and complex to be of real use. Mr. Zinkgraf explained that SEDCO requires its ballast control operators to have a fundamental understanding only of stability and hydrodynamic theory. SEDCO has various levels of sophistication in its training of ballast control operators, depending on the locale: in Aberdeen, an academic course, which ballast control operators from SEDCO's North Sea operations are required to pass, is offered through the Robert Gordon's Institute of Technology; in both Aberdeen and Dallas, SEDCO teaches a basic, in-house stability course to its permanent staff members (this has also been taught in St. John's); and, in Dallas, SEDCO has developed and will soon be using a ballast control simulator which has been designed to incorporate vessel-specific motion response characteristics.

Dr. G.P. Vance (Mobil Oil Canada) asked how a crew should respond to the multifaceted priorities of budget, training, safety and performance. Mr. Williford believed that perception of these priorities was different for the contractor, the operator, and the regulators. SEDCO, as a contractor, plans its programs in a manner which best conforms to the local situation, while keeping in mind that the safety of a whole rig is an all-encompassing factor.

As far as the safety of each individual is concerned, Dr. Foley said that individual perception of the priorities tends to be guided by cognitive locking, a process whereby the individual focusses on one aspect of a system to the exclusion of everything else. The cause of a particular item of focus, however, cannot always be easily explained; it could be the result of intensive training or propaganda, and occurs particularly during emergency conditions.

Dr. B.P.M. Sharples (Noble, Denton) asked about the role of rig day rates on total safety, and suggested that perhaps the establishment of a minimum rate would ensure a certain standard of overall safety. Mr. Hielm said that Norway approaches this problem by having a cost benefit analysis conducted for changes put forward by government. If the costs far outweigh the increase in safety, the change is not considered worthwhile and it is not required to be implemented.

4

EMERGENCIES


Safety Offshore Eastern Canada

EMERGENCIES

INTRODUCTION

The studies of emergencies examined the capabilities of existing evacuation systems for MODUs and the research and development which is underway into new and innovative methods of evacuation. As an adjunct to this, the systems for ensuring survival following evacuation were also examined, as were the response and rescue procedures and facilities that are provided by both industry and government.

This Technical Session was chaired by Dr. A.J. Mooradian, who has extensive experience in all aspects of the nuclear industry in Canada. He holds degrees in Chemical Engineering and Physical Chemistry, and joined the Chalk River Nuclear Laboratories in 1950 to work on plutonium separation with the Chemical Processing Group. Through the following years Dr. Mooradian held a number of senior positions with the Chalk River Nuclear Laboratories and the Whiteshell Nuclear Research Establishment, and in 1982 he was appointed to his present position of Senior Vice-President over both those organizations.

Mr. C. Shaar
President
SeaTek Corporation

Mr. Shaar holds an M.Sc. from Rensselaer Polytechnic Institute. From 1954 to 1961 he worked with Bendix Systems Division; from 1961 to 1976 he was Manager of Delco Electronics in Santa Barbara, and was responsible for the development of the Delco Dynamic Ship Positioning System. He also developed and built the lunar rover for NASA. Mr. Shaar is currently President of SeaTek, a company he founded in 1976.

PAPER F

Escape and Survival

INTRODUCTION

It is generally recognized that evacuation and escape from a mobile offshore drilling unit (MODU) in an emergency situation is an extremely dangerous process especially in very cold, stormy environments. It is also a matter of record that in the recent past several major MODU disasters have resulted in the loss of a large percentage of the personnel involved. The purpose of this paper is to discuss some of the important factors which affect the probability that personnel can escape and survive, and new equipment developments, which might improve survival probability. To accomplish this objective, a review has been made of the many excellent reports on recent marine disasters and discussions have been held with the U.S. Coast Guard, oil companies, drilling companies, and lifeboat and davit manufacturers. During this review process, it very quickly became apparent that there is general agreement as to the nature of the problem and the particular areas in which new engineering developments might improve the situation.

ESCAPE AND SURVIVAL

The Problem

In the case of a MODU, operating in Canadian or similar waters, escape and survival is made extremely difficult because of the environment. Even in the best of weather, high winds and rough seas are frequent and seas are cold. In addition, the practical stowage locations for survival craft and liferafts on MODUs are high above the water surface, 10m to 35m is typical. A further difficulty is that the MODU structure, between the main deck where the survival craft and liferafts are stowed, and the sea is quite open, and a lee from wind and sea cannot be provided.

Factors Affecting Survival

The primary factor affecting survival chances during an emergency evacuation from a MODU is the method of evacuation. A helicopter is preferred universally and is by far the safest means, if it can be used. If evacuation and escape by sea is the only choice, then the probability of survival is influenced by a number of factors which include, but are not limited to:

- The weather
- The nature of the emergency
- Training of the crew
- Placement, number and types of survival craft and means of deployment
- Protection from the cold by the use of exposure suits
- Communications
- Availability and capability of Sea Air Rescue

Most authorities, however, agree that there are four areas in which equipment design improvements would have the greatest impact on improving the survival of the personnel involved. These are:

- Lowering the survival craft
- Release of the survival craft from the davit falls for both on-load and off-load systems
- Moving away from the platform
- Recovery of personnel from the survival craft

Industry Reaction

Since all of these problem areas are widely-recognized, it is reasonable to ask what is being done about them. In Norway, the response has been a major government-funded research and development project which has resulted in what is now the Harding free-fall lifeboat. There are some critical comments which can be made regarding this new system. They include the fact that it is heavy, expensive, and possibly difficult to launch at moderate angles of heel or trim. Also, the idea of free-fall from great height presents a serious psychological problem for many potential users. Nevertheless, at this point in time, it is probably the best available solution to the escape and survival problem. Manufacturers of the conventional totally enclosed motor propelled survival craft (TEMPSC) have, on the other hand, tended to work on parts of the problem with the intention of improving existing systems. Some of this work, such as the Watercraft PROD, has been excellent. Nevertheless, no major new system development seems to have been initiated.

POTENTIAL SYSTEM IMPROVEMENTS

The conventional TEMPSC could become a much more effective means of escape and survival and a viable alternative to the Norwegian free-fall boat if a major system development is undertaken which addresses the four problem areas already identified as critical, namely, lowering the survival craft, release, moving away, and recovery. A review of these design problems will show that what is needed is a good deal of engineering work and little or no invention.

Lowering and Release of the TEMPSC

The greatest danger to the survival craft during lowering on the davit falls and release from the davit falls is collision with vessel structure which results in damage to the survival craft and injury to the passengers. Because of the davit height and wind and wave induced motions, the survival craft can be expected to be swinging on the davit falls through a wider and wider arc as it approaches the sea. Collisions with vessel structure are possible, and the system must be designed to avoid them, if possible, and to survive them, if they occur. The best means of avoiding collisions with vessel structure is to cantilever the survival craft as far away from the ship's structure as possible and pointed away from the vessel. This method has been adopted in many modern semisubmersible designs. An alternative is a gravity-powered, articulating davit which would accomplish the same purpose. The best such device, which we have seen, is a new development by Kosafe A/S of Halden, Norway. The action of the davit is shown in Figure 1. An important feature of the davit is that it automatically senses the horizontal and lowers to that position. The development of this type of davit should be pursued unless a better equivalent solution can be found.

In high winds and seas, even if the maximum clearance has been achieved by davit or cantilever, swaying of the survival craft in the davit falls can result in collision with MODU structure and this problem becomes more likely as the survival craft descends and the length of the davit falls increases. It is, therefore, important to minimize the time required for this process with davit winches which will lower the lifeboat toward the sea at a reasonably rapid rate. In addition, in our opinion, release of the survival craft should be accomplished 10 to 30 ft. above the water surface, using releases which operate under load. The use of on-load release is not inconsistent with either current I.M.O. recommendations (5) or U.S. Coast Guard findings (4). A program of rapid lowering on winches, followed by a short free-fall, would require several major design changes in the survival craft. These must include strengthening the basic structure, proper restraint of passengers to protect them from accelerations which would cause injury and a means of controlling the impact deceleration at the time of water entry.

The structure of many of the survival craft in use today needs to be strengthened. There are ample reports of damaged survival craft structure to justify this conclusion, including the *Ocean Ranger* case (6). The specifications to which the fiberglass reinforced plastic hulls are built in the U.S. are given in the *U.S. Code of Federal Regulations* (7) and in Military Specification P-17549D (SH) (8). A Grade 3 laminate is specified (7) and is defined as (8):

> Grade 3 is a medium strength, bidirectional or isotropic laminate reinforced with style 7544 woven glass cloth or equivalent or random glass mat.

The structural strength of this laminate is specified as 31,000 lbs/in^2, whereas, better grades are of the order of 50,000 lbs/in^2. Many of the survival craft in use today use the "random glass mat" which consists of randomly-oriented short pieces (one or two inches) of fiberglass. Multiple layers of woven glass cloth are a superior structure. Not only should this type of structure be used, but there should be a specification on the number of layers and type of lay-up, as well. This construction is used in many U.S. Navy small boats, including U.S. Navy whaleboats and should be used on MODU survival craft.

The accelerations to which survival craft passengers may be subjected during lowering and release are a serious problem, and they are not properly provided for by the seats and seat belts in current survival craft. The accelerations which must be guarded against during impacts with ship's structure are not specified by I.M.O., although a 3.5m/s impact velocity is given (5). However, accelerometer instrumented tests of current lifeboat designs were conducted by SeaTek. Tests at a drop height of 10 ft. (the U.S. Coast Guard test required of all survival craft) showed that peak accelerations could easily reach 20 g's. A typical test record is shown in Figure 2. Figure 3 shows the acceleration range which is acceptable for a human passenger, seated in a conforming cushioned seat and restrained, with both lap and shoulder harness (9). Without these restraints, serious injury is likely at much lower accelerations than experienced in a 10 ft. drop.

If the survival craft and its passengers are to survive the accelerations they will likely experience, at least two changes should be considered. First of all, the interior seating and passenger restraints of the survival craft must be redesigned to provide conforming seats and proper passenger restraints. This will result in a decrease in passenger capacity of any given survival craft of about 15%. Secondly, a means should be provided to reduce accelerations at the time of water impact after an on-load release from a height of as much as 30 ft. Devices which will do this and which are attached to the keel of the survival craft and can be dropped after water entry have been successfully tested by SeaTek Corporation and others. The SeaTek device, when subjected to a 30 ft. drop on a 28 ft. Watercraft survival craft, resulted in very low accelerations, as shown in Figure 4.

In Figure 5, a water entry system (W.E.S.), designed for a 90 ft. drop height and successfully tested in full scale at 60 ft. can be seen. A W.E.S., designed for a 30 ft. drop, would be significantly smaller. If an on-load release from known, but small, height above the sea is to be routinely used, then a reliable height measurement is needed. There are several approaches which can be used. Von Tell/GVA have used a thermistor extending below their "Lifescape" to perform this task. A bubbler type of pressure measurement would also be possible. It is probably desirable to investigate both types of device.

Moving Away from the MODU

Once in the sea, the problem is then to escape from the vicinity of the MODU without being pushed back against the vessel structure by wind or wave action. Survival craft, especially when loaded with passengers, are heavy; 14,000 lbs. is not unusual. The engines in current models are not high powered: 40 to 80 H.P. is typical and starting may not be reliable. In storm seas, water particle velocities in waves can be 20 ft/sec or more, and the threat of collision with the vessel structure could be great. The PROD system now being developed by Watercraft is the best potential solution to this problem that we have seen. It can probably be used with any form of survival craft stowage. If used with a davit, such as the Kosafe design, the PROD boom could be attached to the end of the davit as shown in Figure 6.

Recovery of Personnel from the Survival Craft

The survival craft should be designed and equipped so that once it is safely away from the MODU the occupants can survive until seas abate, however uncomfortable this may be. Recovery in storm seas is such a hazardous operation that it should be attempted only if waiting is not possible.

FULL SCALE TESTS AT SEA

Naval architects normally use a wave basin as a guide in developing their designs. The wave basin has also been a useful tool in studying survival craft problems, such as the Watercraft PROD and the SeaTek W.E.S. However, a very strong case can be made for a series of instrumented, unmanned, full scale tests of any new TEMPSC, including

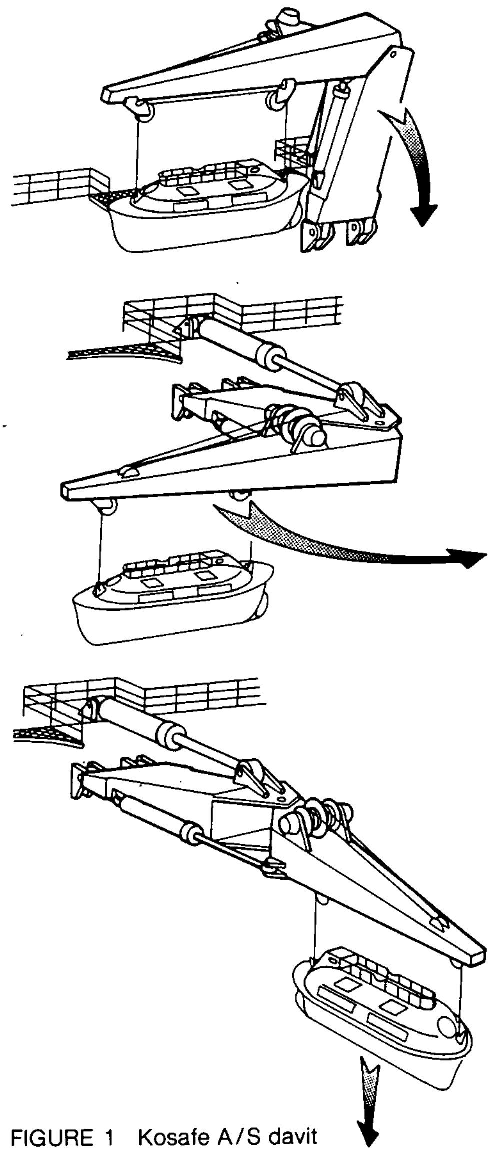

FIGURE 1 Kosafe A/S davit

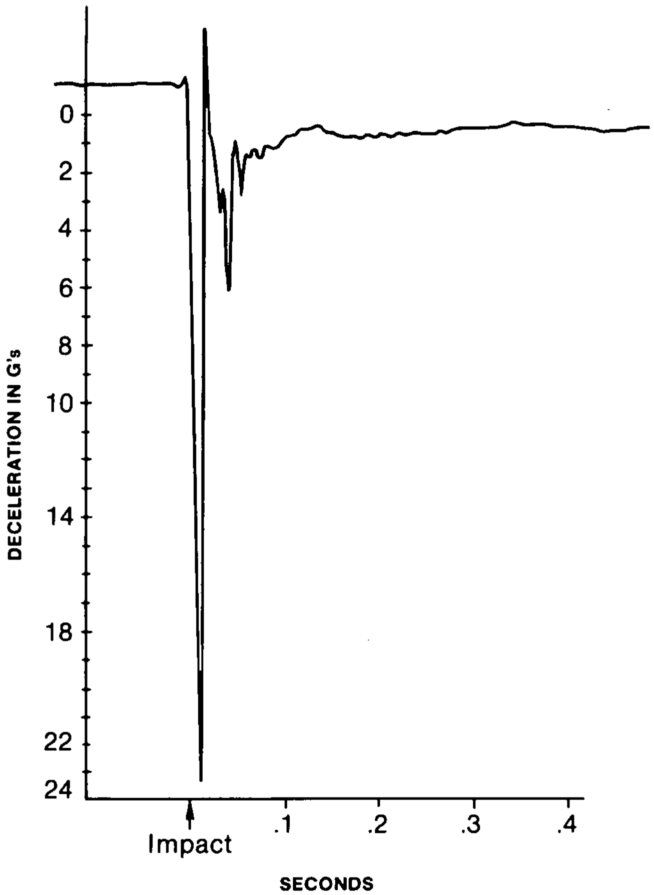

FIGURE 2 Deceleration of survival craft during 10 ft. drop to water surface

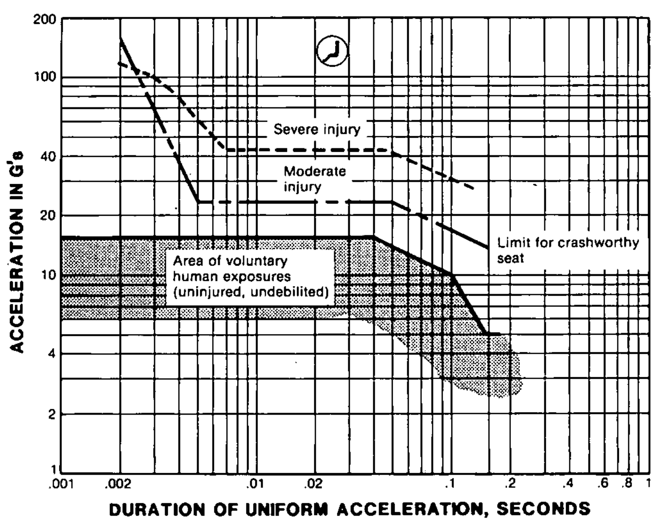

FIGURE 3 Duration and magnitude of headward acceleration

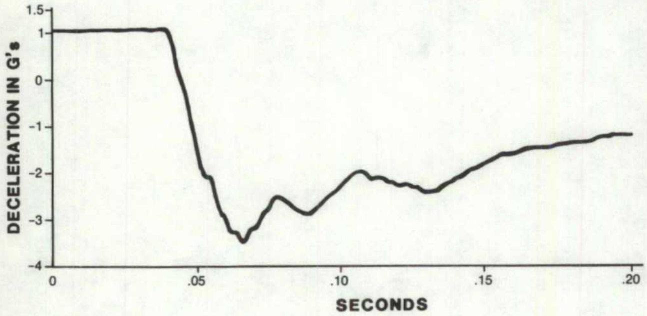

FIGURE 4 Deceleration of survival craft during 30 ft. drop to water surface with water entry system

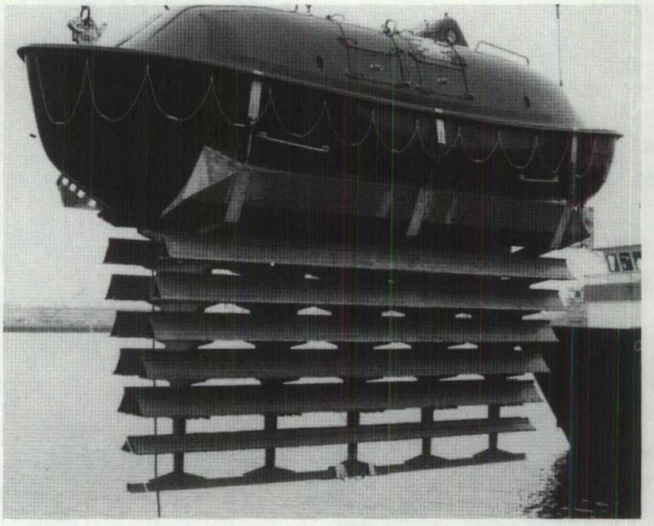

FIGURE 5 SeaTek water entry system designed for 90 ft. drop height on Watercraft TEMPSC

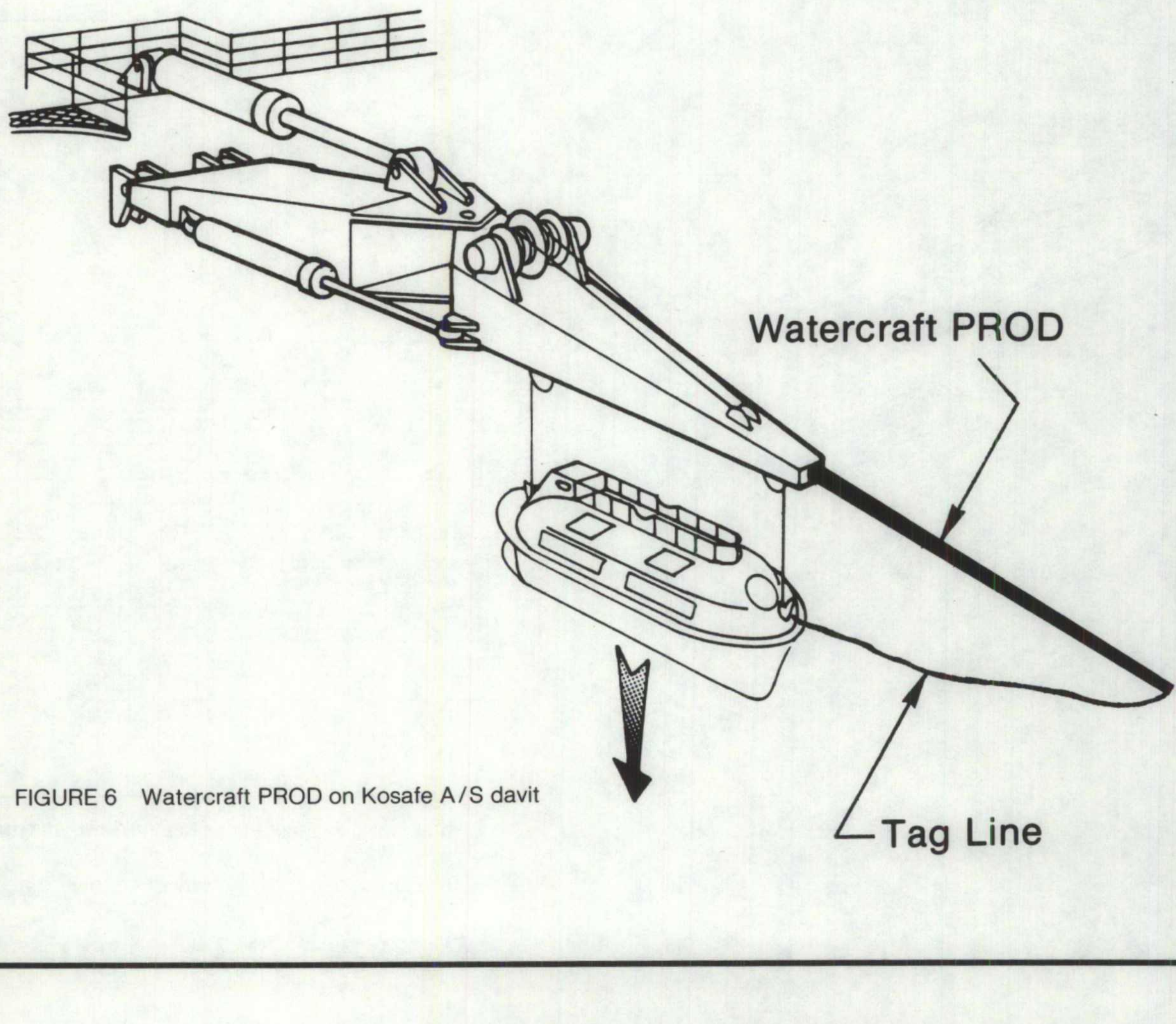

FIGURE 6 Watercraft PROD on Kosafe A/S davit

the Harding free-fall system, by deployment from a MODU into storm seas. The TEMPSC is, after all, a complex system for saving life in emergencies at sea. A series of instrumented full scale deployments of TEMPSC, which are tracked and recovered, would not only show up equipment problems, if any, but would yield information difficult to obtain in a wave basin. Water particle velocities in storm seas can be 20 ft/sec or more, and this combined with high winds and breaking waves could cause problems at water entry, during escape from the rig and for survival in the open sea. These tests can easily be instrumented so that the survival craft steering and engines are controlled by the recovery vessel, and there are several ways of maintaining a continuous track on the TEMPSC until it is recovered.

SYSTEM DEVELOPMENT

It is our conviction that no major new TEMPSC system development will take place in industry unless something deliberate is done to bring it about. In the case of Norway, the impetus was a government-funded research and development program which resulted in the free-fall Harding system. The U.S. Coast Guard seems to have recognized this mechanism as possibly required by stating (4):

> The problem of lowering lifeboats and life rafts from MODUs, due to the heights involved and due to the lack of a lee because of the open construction of the rig, has not been satisfactorily solved. A joint government-industry effort on an international scale, through the International Maritime Organization (IMO), should be initiated to address this problem.

We feel that joint international programs are cumbersome, and at least in the U.S. would like to see a government development administered by the U.S. Coast Guard.

Advocacy of a government-sponsored development project should not be interpreted as a criticism of industry. It is, perhaps, a criticism of the entire system within which we all work in the offshore industry. The drilling contractors and oil companies both resist the application of new government regulations, and this is understandable. Yet while the offshore industry has exhibited great talent in solving drilling and production problems, improvements in the quality of TEMPSC installations have not kept pace. The TEMPSC and davit manufacturers have no ready means for introducing radical change. When they bid on TEMPSC, it is usually a competitive bid to the existing specifications and the low cost bidder gets the job. This is one reason for the rather widespread use of "random glass mat" in survival craft structure and the use of the simplest possible personnel restraints. A major factor which would seem to argue for a government-sponsored development is the cost. The system required involves new survival craft hulls and structure, man rating of new personnel restraints, probably new davits, and expensive full scale tests. In addition, new government regulations must be put in place to require use of the new system once it has been developed.

CONCLUSIONS

A review of the available literature has made it clear that there is general agreement on the problems which must be solved to improve the probability of survival if an emergency requires escape by sea from a MODU in Canadian waters. Some engineering solutions have been suggested, and there are, undoubtedly, other alternatives. In fact, it seems clear that considerable progress can be made with a well-directed engineering effort. Invention is not required. The major obstacle seems to be the creation of a mechanism within our offshore industry and our respective governments to make it all happen.

References

(1) Technica. "Risk Assessment of Emergency Evacuation From Offshore Installations" a study carried out for the UK Department of Energy. London, September 1983.

(2) Joughin, R. W. "Ship Operators View of Failings in Design of Survival Craft" a paper delivered at the RINA Conference on Marine Survival Craft. London, November 14-16, 1983.

(3) Hollobone Hibbert and Associates. "Assessment of the Means for Escape and Survival in Offshore Exploration Drilling Operations" a report prepared for the Royal Commission on the *Ocean Ranger* Marine Disaster. January 1984.

(4) U.S. Coast Guard. Report No. USCG 16732/0001 HQS 82, "Marine Casualty Report Mobile Offshore Drilling Unit (MODU) *Ocean Ranger*." May 20, 1983.

(5) I.M.O. Revision of Chapter III of 1974 SOLAS Convention.

(6) Government of Newfoundland and Labrador. "Technical Investigation of *Ocean Ranger* Accident." April 1983.

(7) U.S. Code of Federal Regulations, Vol. 46, Subpart 160.035 pages 120 to 142. October 1, 1981.

(8) U.S. MIL-P-1754D (SH). "Military Specification: Plastic Laminates, Fibrous Glass Reinforced, Marine Structural." August 31, 1981.

(9) U.S. Air Force MIL-S-04793

COMMENTARY ON PAPER F

Dr. C. Brooks
Command Surgeon
Maritime Command Headquarters

About February of this year, Dr. Solandt came in my office and said to me, "I know you are interested in escape and survival. Would you please come along and be a discussant at our *Ocean Ranger* meeting? We would like you to give us some provocative comments." So, I will do just that for you, Dr. Solandt.

Mr. Shaar, I was delighted with your paper, and what I am going to say is actually going to compliment you on your paper.

Your SeaTek system has really taken a technology which is Second World War and improved it somewhat, and really if we are truthful about it, it maybe is not going to work as well as it should do. I think that the time has come when we have to take the leaf out of the book of our aviation life-support group of companies, and let me give you an example of this.

An RAF Lightning on the approach to Farnborough just before the practice for the International Air Show was at about 350 to 400 feet when it ingested a large bird and the pilot had to get out. To activate his ejection, his seat was broken away, his parachute deployed, and in about three seconds, he landed on the ground safely. That is 1950s technology. Since then it has been quite normal for high speed, low level flight aircrew flying at 450 to 550 knots, at 100 feet above the deck, to eject. They get out and we save the majority of them. Admittedly, a few of them have a compression fracture of the spine, a few have dislocated elbows, but the point is this that they are all very alive and well now. The initial injuries they had were very survivable and we have got them back.

With our new CF-18 aircraft we are in the lucky situation where if the airman is on the runway, maybe travelling along at 70 knots just before take-off, and he has a fire on board, instead of having to put the aircraft to a full stop, take down the quick release box, remove his communications, his oxygen, climb over the canopy, having jettisoned the canopy, jump 8 feet 6 inches to the ground from the leading extension to the wing, he just pulls the ejection seat handle and within three seconds, not only is he up 250 feet in the air, he is in a full deployed canopy and back down on the deck again. That is the sort of technology that we have.

Really what I am saying to you is, that I think that we should be looking at that as an option for launching people from a 100 foot MODU in a storm. It is only one logical step further to get the technique to do this. It has great advantage: we get well away from the rig, we do not have to start engines up, we do not have the problems of icing with it, and last but not least, once it is in the water, it acts as its own protective shell where the people can survive until a helicopter can get there when the storm abates. The immediate disadvantage to this, and I can hear the oil companies squealing like crazy now, is that it is going to cost a bundle to do that. But I am not sure that it is. We went around the beautiful facility of the wave making tank and I am sure that with less money than that, we could have a superb situation where we could have such a system. This would do for all sorts of other marine craft, particularly well for people in the Arctic Sea, where they will have to land on ice most likely.

I maintain, because of maritime disasters that have always been with us, and that it has always been taken as an act of God, fate, and part of the job that we lose people, that both government and industry have never really put as much money into looking at proper equipment for these people and I think that it is about time they did so.

My second question concerns training. We have talked a lot about training this morning. An escape system is only as good as the training system you have on board your vessel. If I owned the rig, I would not have anyone on board unless he had been through flooded compartments, unless he had shown me and the regulators that he could behave in a correct manner in being able to escape from it.

I also question the problem of whether we should allow on rigs people who cannot swim. Let me just talk a little about drowning. You are probably aware that the heart has a thing called the vagus nerve; it is the main electrical piece of string between the brain and the heart. This nerve has one strange condition when you stimulate it, instead of speeding up like every other nerve in the body does, it slows down. So, you have a condition where people, when they are immersed in cold water, the cold water driving up into the nose and into the throat stimulates these segments of the vagus nerve, and slows the heart, and even stops it. We have another condition where, in stages of extreme fright and terror, there is a considerable amount of adrenalin running around the system and that predisposes the heart to an irregular beat or even predisposes it to stopping. What I am really saying to you is, when we have a tremendous catastrophe occur to someone, these guys who have never been in water before, who are frightened of water, when we plunge them into cold water, even with the best life preserver around, even with the best immersion suit around, they are basically going to be dead when they arrive in the water.

I think it is also time we looked at training our senior operators in when to abandon rigs. I think that some people amongst us would believe that there is a great amount of just simple seamanship here and if someone had made the right decision to stop drilling and get the hell out of it, we would not be here today discussing it all.

I would like to make an observation on our helicopters. We spend an awful lot of money with Dilbert dunkers and HUET dunkers, getting people to escape from them. We all know perfectly well that when you dunk a helicopter into the water it immediately rotates and we have to get people out from an inverted helicopter. I wonder why the oil industry who must have a huge lobby, do not go to the big helicopter manufacturers, and ask them to design us a helicopter right from scratch which will float if it goes into the water, or if it will not float, why on earth can we not blow off the top of the helicopter? We have miniature detonating cord around now and that takes care of pieces of canopy so we can eject through them; it is only a little bit of further technology to do this sort of thing.

I am going to get on a little pet subject of mine now, and that is immersion suits and dingies. I am going to tell you a few truths about them. First of all, we do not have any new technology in materials at all. In fact, the old 28 Frankenstein material that was invented in 1940, the breathable fabric, is still the best that we can provide. I am afraid that Goretex and all of these things really have shown us no advantages over old 28. We have a problem obviously, with the only way you can make a neck seal is to have a complete rubber ring around the neck. People have tried, and they keep bringing to me, different immersion suits with split neck seals. Well, we have a problem of human engineering here. We have an Adam's Apple which completely wrecks any fit if we try to split it. It is just a physical impossibility to get a neck seal. The only way we can make a neck seal is to put on a complete hood and bring out a zip which comes out about the side of your ear. Now we all know what happens when we give equipment to operators that they do not like wearing; they do not wear it. So we are wasting everyone's time. We have to look technically at new sorts of immersion suits.

Further with immersion suits, when you take a look at some of the ship abandonment suits, they have something in the order of 30 pounds of inherent buoyancy in them and they have no selfrighting characteristics whatsoever. You have got to put on something like a Beaufort Mark 29 life preserver with a 45 gram charge of CO_2 on board to get a self-righting moment. Now you take that and I just wonder if any of you guys here have tried to scramble into a dingy with something like that on, in the pool, not in a force six or a force seven gale. It is physically impossible, you have to take your life preserver off. It is absolutely exhausting doing it. So we have to spend a lot more money on looking at new materials and new methods of survival suits.

I said I was going to be deliberately provocative, and I am going to fire my last "salvo" now. As a Navy man, I have to confess it is another leaf out of the Air Force's book. The Air Force has two positions within their squadron operation which have a tremendous impact on their equipment. One is what we call the Base Flight Officer and the other is called the Life Support Equipment Officer. These two people, it is their secondary task, and a very definite secondary task, in other words, it is not the last of about 15 tasks to do, and so it gets that amount of priority, these two people have immediate connection with both their Squadron Commanding Officer and their Base Commander. If they feel strongly enough that the operation should stop because it is in some danger, then they will approach the Squadron CO and he will stop things until they get things going and they get new equipment or a change. I would say that is one of the reasons why the aviation industry generally has far better equipment than the maritime environment. I would recommend these people to offshore oil business.

COMMENTARY ON PAPER F

D.J. Riffe
Senior Project Engineer
Gulf Oil Corporation

The disaster last week off the coast of Brazil clearly indicates that the development and implementation of emergency egress equipment has yet to be perfected. The loss of 40 lives, at last count, was not due to the blowout which occurred on the *Petro Bras* platform, but due to personnel attempting to escape from the platform in an open lifeboat. All men aboard the boat apparently drowned as a result of the lifeboat capsizing in the rough seas.

The escape from a platform is very demanding, physically and mentally, because of the circumstances required for escaping from the facility. The escape from the platform must be simple, fast, and above all it must be safe. The use of the free fall or drop systems requires that all the crew members be seated and strapped in prior to descent of the craft. The fact that personnel inside the craft are human presents a situation where some of the crew members may not be strapped in, if a panic-stricken crew member prematurely releases the craft. The impact of the boat, be it 3 G's or 12 G's, will most likely result in injury to those crewmen who have not been strapped in. A horrifying example of this was the incident which occurred on the *Ekofisk Alpha* platform in the North Sea where three men were killed because they were not strapped into their seats when a panic-stricken crew member released the hook mechanism and the capsule fell approximately 20 meters into the water. To illustrate the horrifying tragedy of this incident, two of the three men who were killed were found with their heads in their chests because of the tremendous impact.

For restraining its passengers safely, the free fall lifeboat is equipped with a harness which is placed over the chest, waist, and shoulders, with perhaps the most alarming restraint being the band which pins the head to the seat to avoid neck injury. This restraint gives the rightful impression that one is embarking on something which could be potentially very dangerous, if everything does not go in the logical order. Having ridden a free fall craft a few years ago, I can assure you that the falling and impact rival any amusement park ride, with the exception that the amusement park ride has the capability of controlled descent and it is possible to get off the amusement park ride after a short period of time, which is not necessarily the case when you are in a free fall lifeboat. It is interesting to note that psychological research has shown that it is not the impact but the free fall that is the most concern to the crew members.

The Harding craft will completely immerse under water following impact. The fact that the boat is underwater for a short period of time has presented the question of control during this period, particularly in rough sea conditions. To my knowledge, testing in rough sea conditions, similar to those which occur in the North Atlantic and the North Sea, has not been conducted. Questions regarding the performance of this craft in harsh sea and wind conditions still remain unanswered.

Admittedly, there is a lot of research underway which takes a close look at this particular problem area, but as yet there are no ideal escape craft available. Several new techniques presented not only fail to improve egress capability but worsen it. These concepts must be tested under the extreme conditions before approvals should be given. In the case of the free fall craft, no one really knows if it will perform the required task in an emergency. We may find that the free fall craft would not have been the answer to the problems encountered by the *Alexander Kielland* and the *Ocean Ranger* and might, in fact, have been detrimental. The keys to any safe launch are the disengaging apparatus, the assurance of good maintenance, the proper care of the apparatus, and the training of personnel to understand the operation of the covered lifeboat.

There are problems with emergency egress other than the lifeboats which dominated discussion in Mr. Shaar's report. I wish to touch briefly on a few of these problem areas.

1. Survival suits on the market today have the following deficiencies:

- Self-righting of the survival suits has not been incorporated into the design of most suits available on the market today.
- Better corrosion resistant and maintenance-free zippers for the suits must be developed.
- Better material and seam strength should be considered and used in the future, as these suits tend to develop defects in distress conditions.
- Universal sized suits are often too large for small persons who may disappear in the suit when jumping in the water. Face seals on the suits are not yet satisfactory.
- All regulatory bodies governing offshore areas should have their own means of production control, despite what is being used by other agencies.

2. The life rafts available on the market have the following deficiencies:

- Water and food rations on the rafts are inadequate, and are only provided for very short term survival.
- Life rafts are not equipped with homing or communications devices which would assist would-be rescuers in locating the raft during adverse conditions.
- The traditional means of egressing to the life rafts, knotted ropes and rope ladders, are very unstable and will likely result in the premature falling of crew members into the water with resultant injury.
- Sea anchors provided on the rafts, which are used for drift and positive stability, are inadequate in many sea states.

3. Finally, training of personnel in the use of emergency equipment in various emergency situations is presently inadequate. This lack of knowledge has been at least partially attributable in personnel losses in several offshore accidents.

Training, as well as improved equipment, may lessen the personnel losses in emergency egress situations. However, it is very important to note that time to escape may be the most important factor of all.

Summary of General Discussion Following Paper F

Mr. Per Klem (Ship Research Institute of Norway) clarified his Institute's role in the development of lifeboat design by saying that the Institute is independent of the lifeboat industry, and first developed a free fall lifeboat in 1973 in cooperation with Harding. He said that the free fall concept was first conceived in 1897 and the system which is now installed on the *Dyvi Delta* is based on that initial design with only engineering changes added. The Institute is currently seeking funding to conduct further research into the free fall principle in order to reduce cost, weight, and mechanical complexity in the application of the system to MODUs.

Mr. Klem agreed with Mr. Shaar's approach of retrofitting existing davit-launched systems to make them more successful, but he doubted that the davit system has any advantages over the free fall system and said that its inherent dependence on complicated mechanical devices leads to numerous disadvantages. Mr. Klem, however, agreed that self-bailing and self-righting are important aspects in the problem of the recovery of personnel. He also agreed that full scale testing in stormy seas is desirable, but cited several difficulties: of having all instruments and equipment ready when a storm is forecast; of accommodating the extra personnel during the test; of compensating for the dispensed lifeboat until it is recovered and re-installed. Another difficulty is the fact that free fall boats can only be tested a few times at full scale without incurring damage. He emphasized that the free fall tests to date have not resulted in any major injuries, whereas conventional lifeboats have been shown to cause injuries even during training sessions. Mr. Klem regretted that no mechanism seems to exist to encourage cooperation between industry and government in carrying out the research necessary to develop improved systems.

Mr. Klem commented that while survival suits as they exist today have many unresolved problems, they have saved many lives and should therefore not be discouraged. Mr. R.L. Markle (U.S. Coast Guard) also commented that the self-righting feature of survival suits is over-rated and that it is better for the survivor to practise breath control. Mr. R. Fodchuk (Shell Canada) agreed that self-righting in immersion suits is over-rated and that not all suits professing to have that feature actually do self-right although it is easy to do so with some practice. He said that industry has initiated a cooperative effort with the Canadian Standards Association to develop better suits as part of the total escape system.

Mr. E. Dudgeon (NRC) said that the approach of the Commission in its Part One Report, that not all of the crew of a MODU can or should be equally trained in the use of evacuation systems, is reasonable. Therefore, he advocated increased dependence on support vessels with properly trained crews. This view is supported by a system under development in the U.K. which evacuates a MODU crew by transferring its members, by means of a cable-car-type system, to a support vessel with the aid of a highly trained rescue crew on that vessel.

Dr. C. Brooks (DND Maritime Command Headquarters) felt it is not unreasonable to provide everyone who intends to go offshore with a basic briefing on survival, a tour of the rig, and also some experience in water immersion. Vice-Admiral A.J. Fulton (CAF, retired) agreed that good training in all aspects is highly essential. He doubted the feasibility of transferring personnel from MODUs to support vessels via the cable system and cited the Navy's experience with it as demonstrating that relatively sophisticated equipment with a large number of highly trained people is required to operate it successfully. Mr. Markle agreed that this transfer sytem does not have much potential for the offshore and that it is better for a rig to be self-sufficient.

Mr. J. Gow (Mobil Oil Canada) informed participants that all workers going offshore in Eastern Canada are given a one-week minimum survival training course sponsored by both industry and government. Mr. J. Turton (Survival Sytems Ltd.) briefly described the role of the Basic Offshore Training program and said that, in Nova Scotia, over 1300 have already been trained. In Newfoundland, workers are being trained under a similar program called Basic Offshore Survival Training. He said that industry has taken this initiative and is constantly re-developing and re-assessing the course contents. Mr. R. Fodchuck reiterated the industry's interest in training, and said that the courses include water immersion, both in pools, and in the open sea, with the use of survival suits.

Mr. Gow questioned the installation of survival craft on the upper decks of MODUs, since he viewed access to escape systems as part of the problem. He also pointed out that more responsibility for improved survival craft should be placed on the marine industry rather than the oil industry.

Mr. C. Shaar (SeaTek Corp.) pointed out that the regulatory system and the competitive market in which the lifeboat manufacturers deal do not encourage them to devote a great deal of research time and effort into developing a product which exceeds minimum regulatory requirements. Mr. Fodchuk said that their lack of entrepreneurship and initiative has frustrated the oil industry which looks to them for a solution to the escape problem. Mr. Shaar advocated the setting up of a mechanism which would encourage research and development, even if aimed at improving the free fall system which is the only major development currently being investigated. Full scale tests of the free fall lifeboat should be undertaken, but not to the exclusion of improvements to conventional lifeboat systems that are also practical from an engineering viewpoint.

Mr. Turton asserted that maintainability of lifeboats is an important aspect which is too often overlooked. He pointed to the problem of quality control during the manufacturing process and suggested that the regulatory bodies are not adequately ensuring that lifeboats are either properly produced or consistently maintained. He cited examples of inadequate seat belt attachments, difficult start-up of engines, inadequate sea anchors, and faulty non-skid materials on floors and decks. Mr. D.J. Riffe (Gulf Oil Corp.) admitted that they have experienced deficiencies, many of them due to improper maintainence, in areas of the world where they operate. Mr. Turton also thought that regulators had the responsibility to ensure that escape equipment purchased in one area of the world is suitable for the area where the drilling is to take place. Mr. J.J.S. Daniel (Hollobone, Hibbert) thought it reasonable to set operating criteria for lifeboats in relation to the conditions found in the various parts of the world where drilling takes place and then to design an escape system most suited to those conditions.

Mr. Shaar felt that too much responsibility for the regulatory agencies was being suggested, as they are not sufficiently staffed to exercise such rigid control over the manufacture, sale, installation, and maintenance of lifeboat systems. Mr. Markle said that U.S. Coast Guard regulations do require quality control during the manufacture of lifeboats, but that such control is difficult to enforce without destroying completed equipment. Nevertheless, Mr. Turton stressed that current manufacturing inspection procedures leave a lot to be desired and result in too much faulty equipment finding its way to the field.

Mr. I. Manum (Norwegian Maritime Directorate) pointed out that, while further development is indeed necessary and should be encouraged, accident statistics do show that the present design of covered lifeboats has proven effective in saving many lives. He referred to the *Alexander Kielland* and *Vinland* incidents, and said that on the *Vinland* particularly, the lifeboats are installed so that during launching they move away from the rig very early. Mr. Markle reemphasized the need for launching systems which allow lifeboats to be deployed so that they remain intact, since it is only in the intact condition that they can be effective. He preferred the development of an operationally and mechanically simple system which would lower the operation performance demand and thus decrease training requirements.

Mr. Markle commented that while life rafts are not a primary source of abandonment, new stability systems are being developed to increase their effectiveness in heavy weather and they should therefore not be ignored.

Session Chairman Dr. A.J. Mooradian wrapped up the discussion by referring to the need for performance criteria as a focal point in the development of adequate escape systems. He thought that, in view of the cooperative atmosphere evident among the participants, it could be achieved.

Dr. E. Klippenberg
Director
Norwegian Defence Research Institute

Dr. Klippenberg has been with the Norwegian Defence Research Establishment for the last 30 years, working in his specialty of operations research. This period has included a four year term as Chief, Operational Research Division, SHAPE Air Defence Technical Centre, The Hague. Dr. Klippenberg is current Director of the Norwegian Defence Research Establishment.

PAPER G

An Operations Research View of a Rescue System for Effective Response to Emergencies in a Cold Ocean Environment

INTRODUCTION

The purpose of this paper is to examine the rescue system as one main part of the overall program affecting safety offshore eastern Canada. For the purpose of this paper the rescue system is defined to include those elements concerned with the rescue process from tasking of available search and rescue resources to mission completion.

The characteristics of an effective rescue system are, however, very much a function of the nature of the other main parts of the overall program to prevent loss of life and injuries in offshore activities. For the purpose of the discussion in this paper, those other main parts are emergency prevention, the alerting process including decisions and tasking orders to the rescue system, and measures to insure the safe escape and survival of the victims of the emergency up to the time when the rescue units are on the scene. As the total resources available for safety measures will not be unlimited, an optimum overall system will require careful trade offs between its main parts. An examination of the rescue system will therefore have to take place in relation to the other main parts of the total system.

It is not the purpose of this paper to discuss and promote a specific rescue system for emergencies in the cold ocean environment offshore eastern Canada. Neither the necessary information nor the efforts required to do a proper analysis have been available, and Canadian resources would of course be much better qualified and placed to do that. Rather the aim is to examine the main considerations which should be taken into account in the analysis of the present rescue system and its possible enhancements to provide an acceptable system. In so doing I will not bring forward anything really new or startling. A sound and appropriate approach to the analysis and design of a search and rescue system is discussed in the Canadian Report on *Evaluation of Search and Rescue* published under the authority of the Cabinet Committee on Foreign and Defence Policy in 1982, the "Cross Report". Several of the reports prepared for the Royal Commission appear to discuss other important aspects of the system. It is my hope, however, that I have been able to put the main considerations into the proper overall context and demonstrate how they interact and influence the overall performance of the system. To stay within the allotted time and at the risk of appearing superficial, I have had to leave out of the discussion several factors and issues which have to be taken into account in the planning of the future rescue system.

The logical point of departure for examination of systems as complex as the search and rescue system is to attempt to establish the objectives of the system and the criteria against which the effectiveness of the system in meeting its objectives can be measured or at least assessed. Secondly, the paper briefly reviews the types of scenarios in which the system may be called upon to perform its functions, and the chain of events which may characterize such emergency scenarios. Following a brief recollection of the main characteristics of the on-site escape and survival system and of the alerting and decision making process up to tasking of the rescue elements, the paper then examines the various elements of the rescue system, their characteristics and their integration into an effective rescue system.

OBJECTIVES AND CRITERIA

The objective of the Canadian national SAR programme as recommended by the "Cross Report" could apply to any soundly based safety programme for offshore activities. The recommendation reads:

> To prevent loss of life and injury through search and rescue alerting, responding and aiding activities which use public and private resources; and by ensuring priority to aviation and marine safety measures focused on owners and operators most commonly involved in SAR incidents.

Taken literally, however, this objective is obviously not achievable. No practical safety programme will be able to prevent loss of life and injury with 100% assurance. As for most other complex man/machine systems the relationship between the degree to which the system meets its broadly formulated design objective and the total system cost (investments plus recurring costs) is of the well known S-type illustrated in Figure 1. For other systems not concerned with issues as sensitive as the rescue or loss of human lives it is usually not too difficult for responsible authorities to decide on an acceptable compromise between system performance and total system cost. Often the knee of the S-curve is taken as a good compromise. Above this point the marginal return in terms of increased system performance per additional dollar system cost, is diminishing. For a safety programme the decision on how much is enough is a much more contentious issue, and will, probably in most cases, be a result of considerations of acceptable total programme costs rather than an explicit decision on programme performance resulting in a certain programme cost.

In the preceding section the rescue system was defined to include those elements which respond to a tasking order and carry out search and rescue. Its performance as a function of total resources allocated to this subsystem describes an S-curve similar to that of the overall programme. However, its shape and location along the cost axis depend very much on the characteristics of each of the other major subprogrammes, namely:

- Emergency prevention
- Alerting, decision making and tasking of rescue resources
- Escape and survival in local area

Emergency prevention measures such as improved design of MODUs and vessels and better trained crews will of course reduce the chance of emergencies occurring. Perhaps of more importance from a rescue system point of view, is the extent to which such measures would make early detection of a developing emergency more likely and slow down the rate at which a beginning emergency develops into a crisis, immediately threatening lives or forcing abandonment of the MODU or vessel, Figure 2. That would provide more time for rescue operations and reduce the cost-driving time pressure on the rescue system.

Similarly, measures to ensure the safe and orderly escape of personnel from the MODU or vessel when forced to abandon, and measures to extend the critical survival time after abandonment would further increase the time available for rescue operations and reduce the pressure on this system, Figure 3.

From a rescue subsystem point of view, some of the total time (B-D in Figure 3) available for rescue is, however, eaten up by the command and control process which includes alerting the rescue control system, decision making in this system, and tasking of rescue vessels and aircraft. Reduction of this time through appropriate delegation of responsibility and dependable communications further increases the time available to the rescue system to complete its mission, Figure 4.

Strictly from a rescue system point of view all efforts to improve the other subsystems in the safety programme are highly desirable because this would reduce the strains on the rescue system. From an overall cost/effectiveness point of view efforts in the four subprogramme areas should of course be balanced in the sense that each additional dollar allocated to any one of the subprogrammes should produce the same improvement in overall system performance.

Because of the criticalness of the time factor and the fact that time available for rescue is determined by the other subprogrammes a useful way of expressing the performance of the rescue system would be the rescued fraction of persons involved in the emergency, as a function of time. The shape of the curve describing the fraction rescued as a function of time will of course vary from one type of scenario to another. In serious emergencies and difficult rescue conditions the shape of the curve in the first and very rough approximation will also be S-shaped, Figure 5. A closer examination will undoubtedly reveal that its shape is more complicated and influenced by the rescue characteristics of the subelements making up the rescue system. But the fact remains that some time is required before the rescue platforms arrive in the area and the rescue process can begin. As the rescue process proceeds, the curve raises with a certain slope; the rescue process will, however, take time, and as time passes the victims may be spread over an increasing area. Additional search to locate the victims may therefore slow down the rescue process and the slope of the curve decreases.

As stated above, the relationship between time and fraction rescued will of course also depend on the type of emergency and its location. A given rescue system will perform differently in an emergency involving a MODU with a large number of persons and an emergency involving a supply vessel. For an assessment of a rescue system it will therefore be necessary to construct the time versus fraction rescued relationship for a not too large number of different emergency scenarios. To this end computer simulation of the rescue system and its operation will be a useful tool. If the system does not meet required performance levels in one or more of scenarios, modifications to the rescue system may be tried out through simulation until an acceptable system is found.

EMERGENCY SCENARIOS

The report on Search and Rescue, contracted by the Royal Commission, suggests five types of incidents or emergencies for consideration in an assessment of the rescue system, Table 1. This set of incidents is probably a good and useful representation of the spectrum of emergency types under which the rescue system may be called upon to perform its mission. Considering future oil production it is, however, possible that stationary production platforms may be used in some of the areas offshore eastern Canada. For reasons of economy they could be quite large and the number of people aboard, particularly during the installation and development phase, could be a few hundred rather than the 50 to 100 on a MODU. By adjusting the number of people involved the MODU cases in Table 1 could also represent stationary production platform emergencies.

The planned evacuation of a MODU could occur as a result of the forecast of severe storm conditions, encroachment of ice or other factors. The evacuation with limited warning could occur if planned evacuation is not successful, or due to undetected encroachment of ice, loss of stability or other factors. A major structural failure, a blow-out with fire or some other catastrophic effect could require immediate evacuation.

The supply vessel faces the same hazards at sea as other ships. But because of its function there are additional problems such as transfer of heavy cargo at sea, operation very close to the MODU, and in the shifting of deck cargo and ballasting while at sea.

The hazards associated with helicopters mainly revolve around a helicopter crash while landing on a MODU or vessel and crash or ditching of a helicopter while in transit. A crash or ditching enroute will probably result in the helicopter overturning before the survivors can be evacuated.

The incidents may occur under any weather situation, day or night. The meager statistics available on the other side of the Atlantic Ocean, about the weather offshore eastern Canada, indicates that limited visibility and ceiling could prevent helicopter operations from about 10 to perhaps 100 hours of every month, depending on location and month of the year. Icing conditions will also prevent helicopter operations and may last for a number of hours when it occurs. Weather necessitates helicopter IFR operations for about 70% of the year. This considerably reduces the effective range of helicopters.

Sea ice and icebergs are also part of the scenario, and the low temperature of the sea water makes rescue of persons in water and in liferafts highly time critical. The "Cross Report" states survival times for unprotected persons in the water from 15 minutes to one hour during nine months of the year. Injuries can reduce this time while good abandonment suits can perhaps multiply these times by a factor of ten, while for current helicopter survival suits the multiplication factor is about two. Finally, the emergencies may occur anywhere in the vast areas offshore eastern Canada where the offshore industry is active, Figure 6.

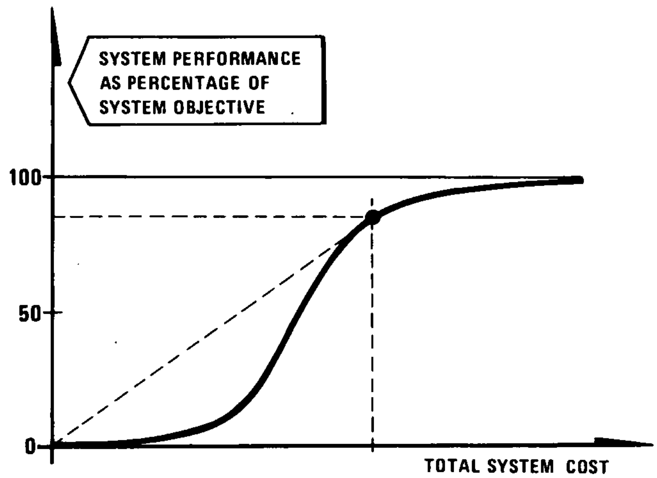

FIGURE 1 Relationship between system performance and total system cost

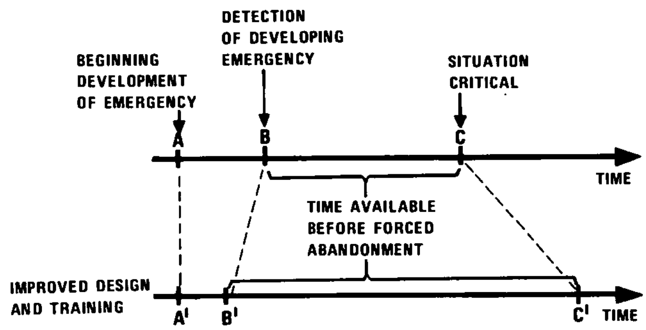

FIGURE 2 Effect of improved design and training on rescue system

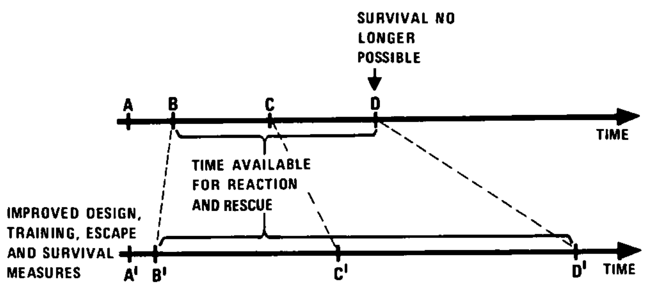

FIGURE 3 Effect of improved design, training, escape and survival measures on rescue system

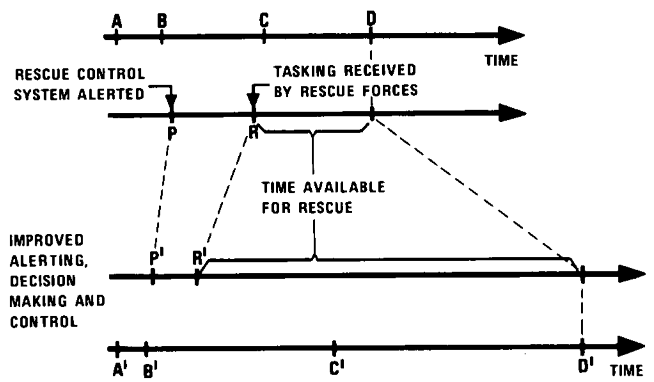

FIGURE 4 Effect of improved alerting, control and tasking on rescue system

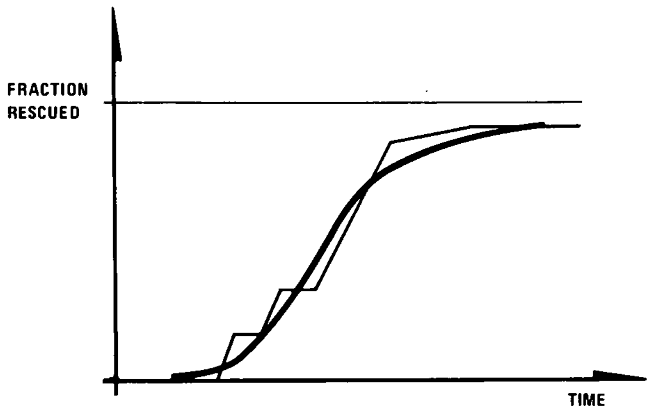

FIGURE 5 Criterion of effectiveness for rescue system

	PERSONS INVOLVED	TIME FOR EVACUATION	REMARKS
MODU – PLANNED EVACUATION	50–100	12–18 hrs	DRY TRANSFER TO OTHER VESSEL OR LIFEBOAT
MODU – EVACUATION WITH LIMITED WARNING	50–100	1–2 hrs	AS ABOVE, POS SOME IN LIFERAFTS ON WATER, WEARING SURVIVAL SUITS
MODU – IMMEDIATE EVACUATION	50–100	Few mins	POS LARGE NO OF PEOPLE IN WATER W AND W/O SURVIVAL SUITS
SUPPLY VESSEL	12–16	Few mins – 1 hr	MOST IN LIFEBOATS AND LIFERAFTS, POS SOME IN WATER PROB ALL IN SURVIVAL SUITS
HELICOPTER	UP TO 20	–	MAJORITY IN WATER W/IMMERSION SUITS

TABLE 1 Types of incidents

THE RESCUE SYSTEM

Description of system elements

For rescue operations of the sort which may be required in connection with industrial activity offshore eastern Canada, two types of rescue platforms seem to be of primary importance, vessels, and helicopters. The primary role of fixed wing aircraft in such hostile environments would seem to be limited to searching, in those cases where the location of the emergency or its victims is uncertain or unknown.

From a rescue point of view helicopters and vessels have quite different characteristics. A brief examination of the time line for helicopter and vessel rescue operations may therefore be in place, Figure 7. In this discussion it is not the intention to examine the difference between national SAR resources and industrial or commercial resources which could be used for search and rescue, but rather to emphasize the generic characteristics of the two primary types of rescue platforms.

Helicopters

The reaction time for a helicopter on the ground or on an offshore helicopter deck is the time from receipt of tasking order (R and R' as shown in Figure 4) to take-off. This covers the time required to assemble and brief the crew about the emergency, develop a flight plan, and refuel the helicopter. For national Canadian SAR helicopters the maximum reaction time is one-half hour during working hours and two hours at other times. The effective reaction time for an airborne helicopter would depend upon fuel status and the number of passengers or load carried. Industrial helicopters would normally carry a fairly full load which would have to be disembarked on shore, on a MODU or a ship with a helicopter deck before diversion to a rescue mission.

Refueling might also be required. The same considerations would probably apply to national SAR helicopters except perhaps when on a training mission. A helicopter located on a MODU would probably have the shortest reaction time, perhaps 10 to 15 minutes. In summary, the reaction time could vary from 10 minutes to 2 to 4 hours, depending on the circumstances.

Normally the transit speed of helicopters is in the range of 115 to 135 knots or nautical miles per hour. The distance from Sydney to the Sable Island area and from St John's to Hibernia is about 160 nmi and would take about one and one-half hours, Figures 8 and 9 (from the Rescue Report). To reach the more remote areas under IFR conditions would take two and one-half to three hours because refueling, for example at Hibernia, would be required. With head-winds the transit times could be considerably longer. In the areas further north the distance from the offshore activity to the nearest shore base could be greater and the time correspondingly longer.

Assuming that transport helicopters enroute report their position every 30 nmi, that supply ships and other industrial vessels report their positions every four hours or at least their time and point of departure as well as destination, and that the rescue control system maintains reasonably up-to-date records, the position of an emergency should be known with sufficient accuracy for a helicopter to locate the emergency site without much loss of time. This assumes radio transmission from the ship or MODU in distress or from free-floating emergency radio transmitters permitting the helicopter to use its direction-finding equipment to home in on the site.

If, however, the ship or MODU had to be abandoned before the arrival of the helicopter, the personnel would under fortunate circumstances be in covered life-boats and, under less fortunate circumstances, in liferafts or in the water.

Following a helicopter crash or ditching the survivors would also be in the water, possibly in liferafts. Depending on the time since abandonment, wind and sea currents, life-boats and survivors in the water could have drifted off a considerable distance. A two or three nautical mile drift in one hour is not unlikely. Even so the location of covered life-boats with emergency radio beacons should represent no great problem. Persons in the water could be spread over a fairly big area and, except under favourable conditions with good light and visibility, the search could take considerable time. Already at 15 knot winds and three to four foot swell heights the effective detection range for persons in water under daylight conditions may be as little as a few hundred feet. Survival suits should therefore be made of a strongly fluorescent material giving good contrast to water and be equipped with lights. U.S. Coast Guard trials seem to indicate that strobe survival suit lights could increase the effective detection range to several nmi and dramatically increase the chance of locating persons in the water under conditions of reasonable visibility. For conditions with less visibility the development of some sort of survival suit radio transponder seems highly desirable.

Having located the object of the search, helicopters would require only a few minutes to land on a helicopter deck or get into the correct hover position and deploy rescue gear. A helicopter able to land on a helicopter deck would only need minutes to embark personnel, but loading of persons on stretchers would take more time.

The most reliable way of rescuing persons in the water and on liferafts under most conditions seems to be for a rescue man to be winched down from the helicopter to assist the survivors into a horse-collar for hoisting up, one by one. With a good hydraulic winch capable of continuous operation and no significant spread of the persons in the water, rescuing of 15 persons could take 30 to 40 minutes. If, however, the persons in water are dispersed and search is necessary to find single survivors, considerably more time would be required. The evacuation transit time would of course depend on the distance to the nearest MODU, ship or shore base for disembarkation.

The characteristics of a well equipped helicopter in rescue operations may for the purpose of this discussion be summed up with Figures 8, 9 and 10. Figures 8 and 9 show the maximum coverage of two typical offshore helicopters under IFR conditions which in this area prevail about 70% of the time. The coverage assumes only 30 minutes search and assistance time in the emergency area. Helicopter operations will not be possible, mainly due to low ceiling and visibility, from 10 to 100 hours per month, depending on location and time of the year. Depending on the location of the emergency relative to the helicopter base and assuming a nearly perfect alerting, decision making and tasking system, it could take up to three to five hours for a land-based helicopter to reach the site of the emergency, Figure 10. A helicopter on a helicopter deck or in transit in the area of offshore activity could in many cases reach the emergency site much sooner. Under favourable conditions it could quickly pick up its full, but relatively small load of survivors. Under less favourable conditions the search and pick-up process could be much slower and fuel limitations might not give room for picking up a full load. The time required before the helicopter could return to continue the rescue operation would depend very much on the presence of ships and MODUs with helicopter decks where the survivors could disembark and the helicopter be refueled. The capacity of the helicopter, from 12 to about 20 depending on type, matches well the needs in supply vessel incidents. In a helicopter incident the capacity of a single rescue helicopter could be on the low side. In a MODU emergency, the capacity of a single helicopter is likely to be inadequate except for planned evacuation with many hours available to complete the operation and with another MODU or ship with helicopter deck in the vicinity to receive the personnel.

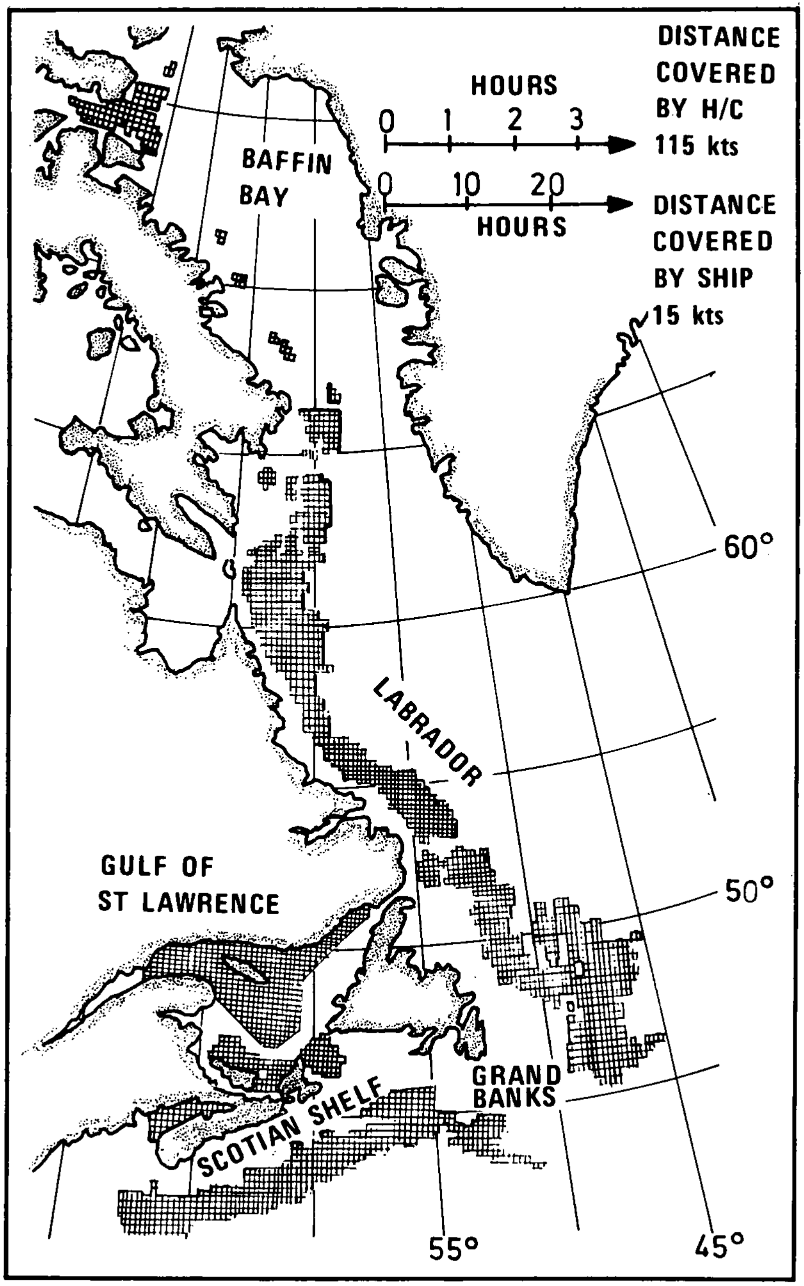

FIGURE 6 Oil and gas exploration lease areas

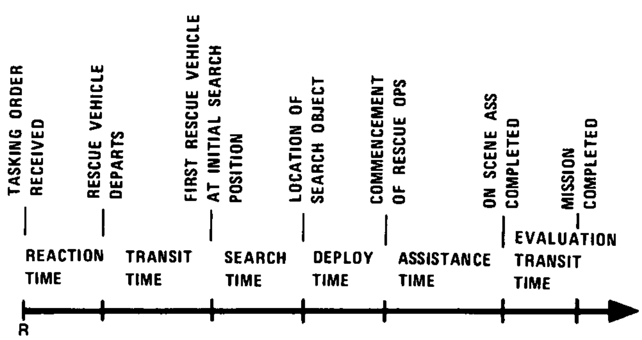

FIGURE 7 Time-line for rescue operation

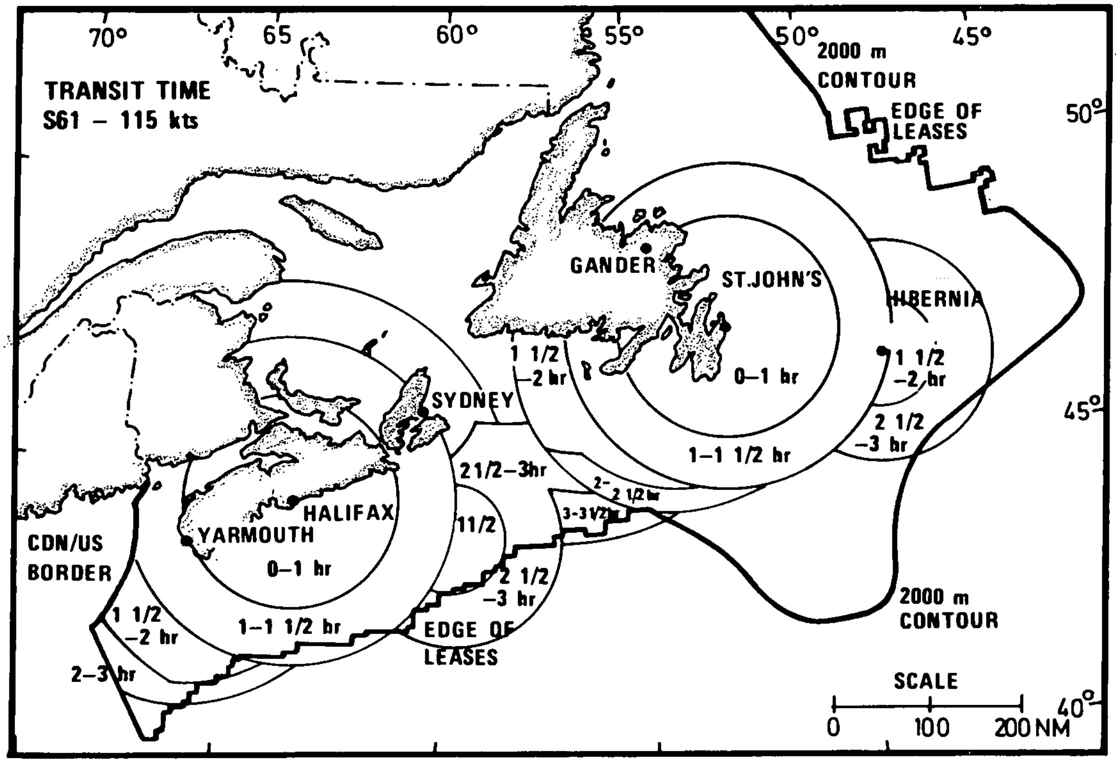

FIGURE 8 Transit time: S61 – 115 kts

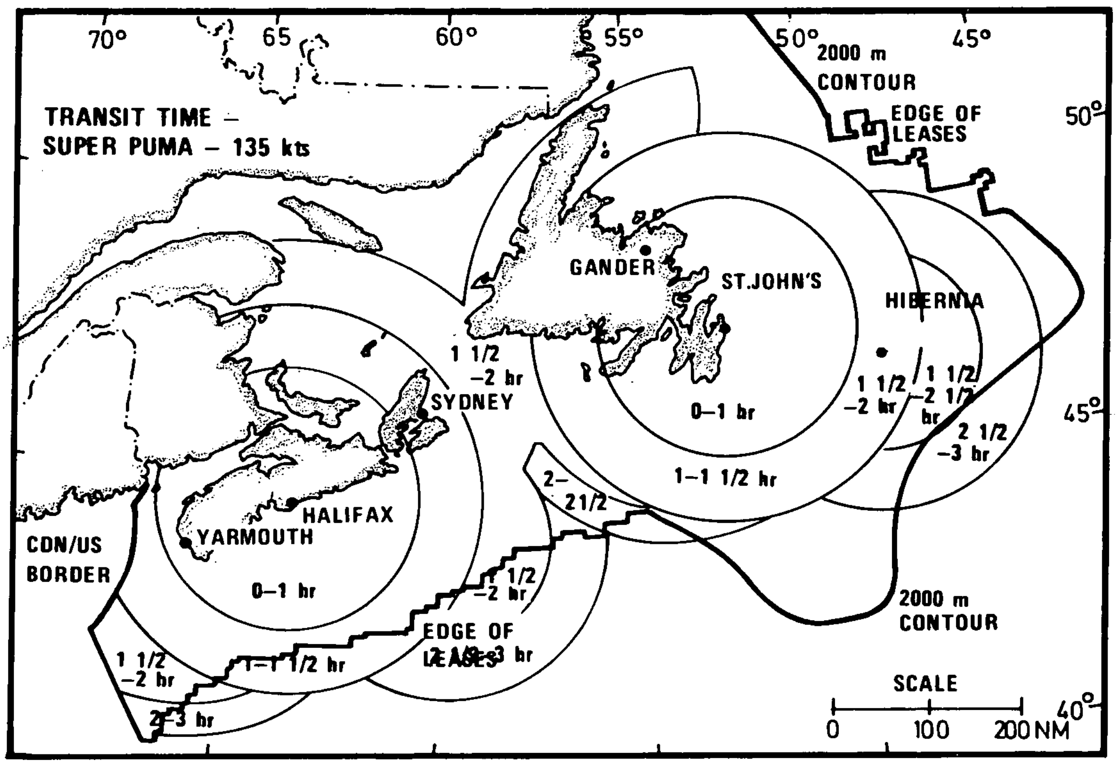

FIGURE 9 Transit time: Super Puma – 135 kts

Vessels

Vessels as rescue platforms are primarily characterized by their low transit speeds and their capacity to accommodate a large number of survivors once in the emergency area. The effective speed of the majority of vessels operating in the area is between 10 and 15 knots. In reasonable weather the transit from St. John's to Hibernia could take from 11 to 16 hours. The additional reaction time could vary between 30 minutes and a few hours. Ships in port would therefore not be very useful for rescue operations unless the emergency site was not too far from the port or the emergency was developing slowly.

A ship under way, on the other hand, would have a very short reaction time and the transit time for ships in the area of the offshore activity would also be short. In the case of a MODU emergency a suitable stand-by vessel located within the required one nautical mile could within minutes manoeuvre into a favourable position for assisting people abandoning the MODU. Under favourable conditions this could take the form of dry transfer with one of the cranes on the MODU. Under less favourable conditions the stand-by vessel would assist lifeboats and rescue people on liferafts and in the water. The stand-by vessel would launch one or two fast rescue craft to increase the rate at which people in liferafts and in water could be recovered and brought aboard the stand-by vessel. Such fast rescue boats can operate under most conditions and are very fast (25 knots). Normally they can be launched within minutes and very quickly reach located liferafts and persons in the water. With many persons in the water, the rescue operation will nevertheless take time and persons and liferafts would drift off and become spread over an increasing area. Except with a moderate sea and with good light and visibility conditions, this could increase significantly the time required to locate survivors and slow down the rescue process. Survival suits of fluorescent material with reflectors, flash or strobe survival suit lights, and preferably some sort of radio transponder could greatly accelerate the process. Regrettably, it has not been possible to locate any data which could help quantify the rescue process with vessels and FRC. Under moderate sea conditions and with the survivors not too widely spread, a FRC and a vessel could probably get people out of the water and liferafts at a rate not much slower than a helicopter. In a heavy sea, however, both vessel and FRC would probably find it more difficult to locate survivors because their means of search have less height above the sea.

In the case of a supply vessel or helicopter emergency not too far from a supply or stand-by vessel, such a vessel could be under way a few minutes after receipt of a tasking order. In one and one-half hours the vessel could transit about 20 nmi and its fast rescue craft about 35 nmi. Within such distances vessels could reach the emergency site about as fast as helicopters available on a MODU in the area. Assuming moderate delays in the alerting and tasking system and activated free-floating emergency radio beacons, the search for the emergency site should not take much time. But the search for liferafts and persons in the water could pose problems as discussed above.

The rescue characteristics of a well equipped stand-by or supply vessel may be summed up with Figures 11 and 12. Figure 12 shows the area within which a stand-by vessel at Hibernia and its FRC can reach an emergency in less than one and one-half hours. The Figure also shows the corresponding coverage of a supply ship under way between St John's and Hibernia. In a MODU emergency the stand-by vessel and its FRC could quickly initiate assistance and rescue, and under reasonably good conditions take people aboard at rates possibly not too different from the rate at which a hovering helicopter could hoist people aboard. Under more difficult conditions with survivors spread over an increasing area the search would, as for helicopters, slow down the rescue process significantly.

The vessel has, however, a much higher capacity than a helicopter and should be able to take aboard the whole crew from a MODU. Contrary to the helicopter, restricted visibility and ceiling represent no absolute limitation on its operation. Very limited visibility and very heavy weather would of course slow down rescue operations.

Rescue system consideration

Having briefly examined the major elements of the rescue system and their characteristics, some of the main considerations pertaining to the rescue system will be discussed.

No emergency prevention, safety precautions or escape measures will ever provide full assurance against a number of people ending up in a liferaft or in the water following an emergency. In the hostile environment offshore eastern Canada the survival time without additional protection would be so short that no rescue system could be expected to have more than a very modest chance of success. Although there seems still to be room for desirable improvements in survival suits, the issuing of such suits to everyone involved in offshore activity would dramatically change the situation and bring a reasonably effective rescue system within reach. At a cost of about $450 (Canadian) per suit, the cost for the full complement of a MODU would be less than $50,000, which is less than half the daily rate for a second generation MODU.

Considering the distances from shore bases to the areas of offshore drilling and the criticalness of time in many of the conceivable emergency situations, a credible rescue system seems to have to be based to a large extent on rescue platforms available in the local area.

In light of the number of people involved in a MODU or a production platform emergency and the fact that weather prevents helicopter operations some 10 to 100 hours each month, a properly equipped and trained stand-by vessel at each MODU or platform would seem to be an essential first element in a rescue system. The effectiveness of the stand-by vessel would depend very much upon its manoeuvrability and stability, good communications and navigation aids, means for locating liferafts and persons in water, proper free-board and a well designed and equipped rescue area midships, at least one FRC and the best means for launch and recovery of the FRC, and a sufficiently large open area for landing people from a helicopter or a MODU crane. The daily rate for such a vessel in the Norwegian Sea runs about $20,000, while the corresponding daily rate for a second generation MODU is about $100,000.

Another element of primary importance would seem to be the equipping and training of supply ships and their crews to deal primarily with emergencies involving another vessel or a helicopter. If helicopters and supply ships where following roughly the same transit lanes, such equipped and trained supply ships would represent a significant rescue capability in areas which other rescue vehicles may require more time to reach. Ideally the supply vessel should have the same rescue fit including at least one FRC as the stand-by vessels, but of course not the same accommodation capacity. The additional cost of operating a so equipped and trained supply vessel would not be much higher than the normal rates for a well equipped supply vessel ($25,000 to $35,000 per day.)

The rescue characteristics for helicopters are in many ways complementary to those of vessels. They are well suited to lift people off MODUs and ships even under very difficult conditions; with a rescue man and hoist they are able to hoist people from liferafts and out of water under very severe conditions; within unrefueled range they transit faster, and they are also more effective in search for liferafts and persons in water. But the number of people they can carry is somewhat limited. Although to some

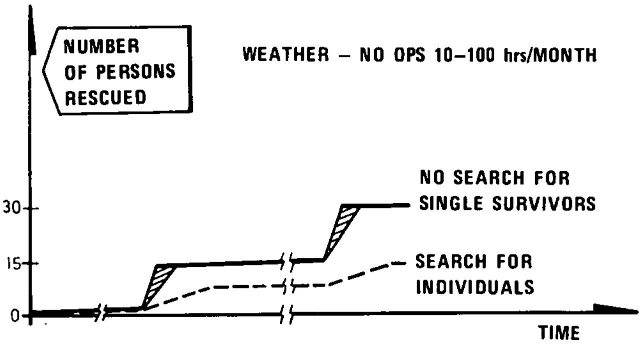

FIGURE 10 Helicopter rescue characteristic

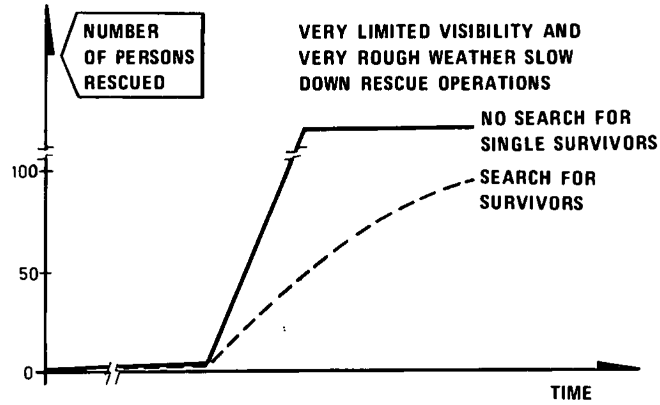

FIGURE 11 Vessel rescue characteristic

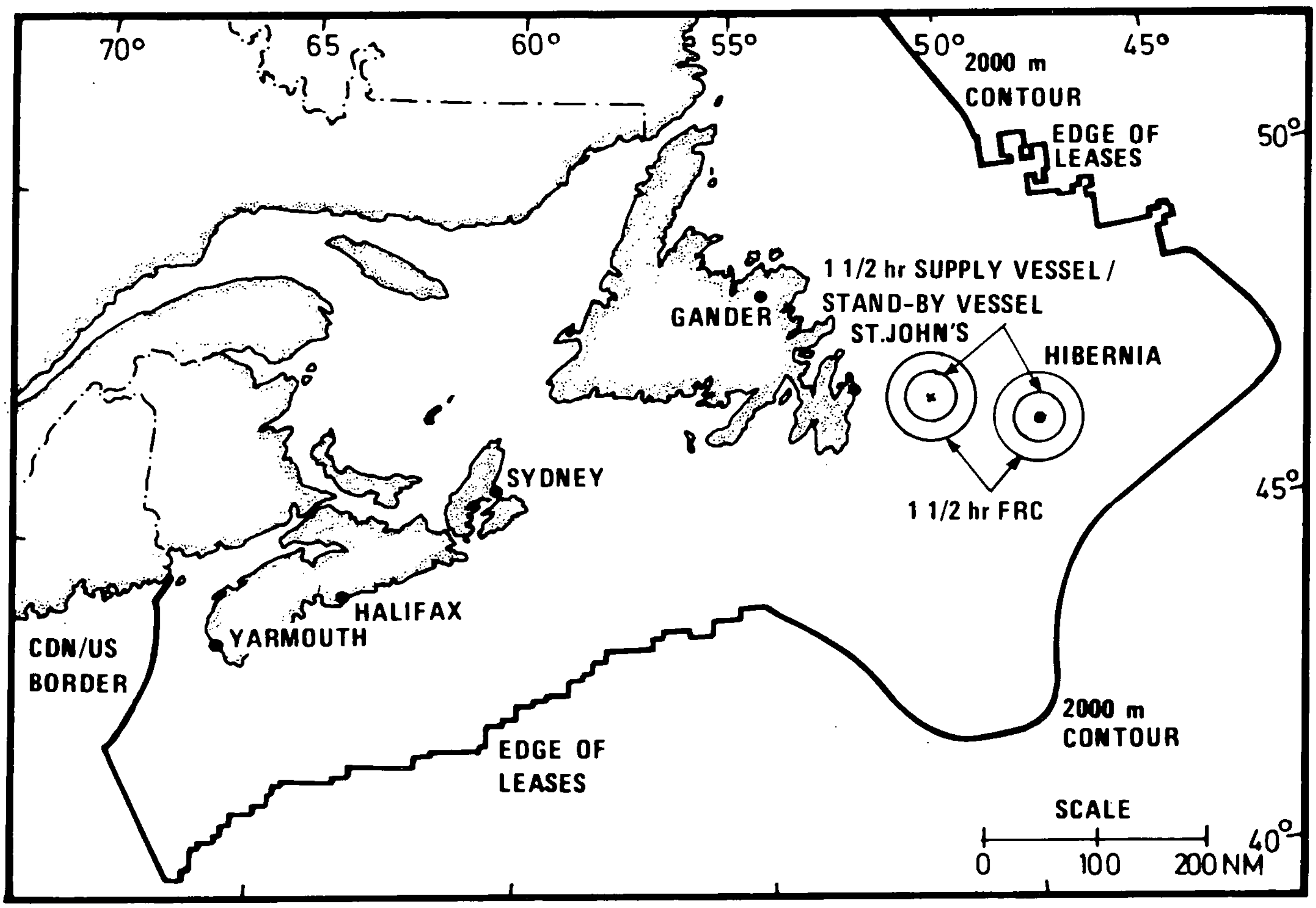

FIGURE 12 Transit time for stand-by vessel/supply vessel and fast rescue craft

extent weather limited, they appear to be essential elements in a balanced rescue system.

It seems, however, highly desirable to have helicopters in the rescue role with less response time than shore based rescue helicopters. With the increasing activity offshore eastern Canada this could probably to an increasing extent be achieved by adopting the current Norwegian Sea practice of diverting transport helicopters to rescue missions when the need arises. The hoists for the transport helicopters are stored on the shore base and aboard the MODUs and at least one member of each MODU crew is trained as a rescue man and ready to join the helicopter crew. In this way industry helicopters may quickly and at a modest cost be converted to rescue helicopters. Agreements between the operators in the area about standardization of rescue equipment and training and about coordination and mutual support in emergencies would appear to offer the potential for a cost effective and reasonably responsive helicopter element in the rescue system.

While impressive and capable, the current national Canadian SAR organization appears not to have adequate capacity to deal with many of the conceivable offshore emergencies. The number of rescue vehicles is limited, and they are based to be able to respond also to the many non-offshore incidents. From an overall national economy point of view more rescue capacity at less cost can probably be secured by maximum use of helicopters, vessels, and communications and supporting systems already available in the offshore industry. Whether the additional costs for such exploitation of offshore resources are to be carried by the operators or the state is of course a matter of policy and a difficult negotiation.

Although the command and control system has been covered by others, a comment on control principles may be in place. Since time is likely to become such a critical factor in many emergency contingencies, delegation of authority to initiate and execute rescue operations to a MODU or vessel close to the scene of the emergency would seem highly desirable. This would avoid communication, interpretation, and decision making delays at higher and more remote levels. Of course, higher levels should be kept as well informed as possible in order to be prepared to take over control if the need arises. As an example, Norway has delegated the primary responsibility for rescue operations to the offshore operator companies. Their rescue operations are at least initially controlled from a MODU or stand-by vessel. If extent or development of the emergency so requires, control is taken over by the onshore company rescue control center. The national SAR organization would normally take over control only if their resources or other non-company resources were required.

It is of course realized that creation of an effective rescue system is more than a question of rational reasoning about the characteristics of the various elements and their most cost effective integration into a system. The objectives and interests of the various governmental departments concerned with offshore activity, of the national SAR organization, and of the offshore operators and their contractors are not necessarily coinciding, and difficult legal, economic, and standardization issues are involved. Nevertheless, an analytical and largely quantitative assessment of the desirable configuration of an effective rescue system would probably be a good point of departure for the planning and negotiations which will eventually lead to the real rescue system.

CONCLUDING REMARKS

In conclusion, the intention has been to discuss the main factors influencing the design of an effective offshore rescue system, and their interrelationships.

While the formulation of acceptable and achievable objectives is a contentious issue, unrealistic goal statements are likely to frustrate efforts to achieve the best rescue system with available resources. The rescue system is only one of several subprogrammes in the overall offshore safety programme. Its performance and the success of the whole safety programme critically depends on the proper matching and balancing of the subprogrammes.

Time is a critical factor in rescue operations and particularly so in the hostile environment offshore Eastern Canada. Good and accessible survival suits for everyone active in the offshore areas appear to be a precondition for an effective rescue system.

Vessels and helicopters have complementary rescue characteristics and both have an important role to play in a balanced rescue system. Because of the geographic distance in the eastern Canadian offshore activity, any but slowly developing emergencies require locally deployed rescue resources. From an overall economy point of view exploitation of industrial vessels and helicopters seems very attractive. Industrial involvement and responsibility for at least the initial phases of rescue operations would facilitate local control and reduce time delays in the control system.

Simulation and quantitative analysis could provide a good basis for the development of a cost effective rescue system for offshore activities. With the reputation of Canadian analysts there can be no doubt that Canada has the skills and resources to undertake such analysis if it so wishes.

[Editor's Note: Much of the material used in Dr. Klippenberg's paper was based on a draft report prepared for the Royal Commission by Vice-Admiral Fulton et al, the final version of that report contains some minor revisions.]

COMMENTARY ON PAPER G

I. Denness
Frontier Drilling
Gulf Canada Resources

Owing to the short time that was available for responding to Mr. Klippenberg's paper, let me say that I am presenting my own views based on my own experience which may not coincide with the views of the East Coast offshore operators.

Because prevention is better than cure, there are probably two main options in preventing the need for a rescue operation: firstly, in order to achieve as near perfect safety as is humanly possible, we would probably have to spend millions of dollars, as is done in the space programs or nuclear industry. Alternatively, we could dispense with the human element on the vessels altogether, as the trend has been in the diving industry where remotely operated vehicles (ROVs) are playing an increasingly major role.

Neither of these two options I suggest are really feasible or even necessary as an immediate or short term remedy. We must step back from the ideal world and revert to the real world where the name of the game is, after all, cost effectiveness, in terms of drilling and finding oil in offshore Canada. We must turn our attention to the practicalities and what can reasonably be done to incorporate an effective rescue system into our offshore operations.

I agree with Mr. Klippenberg that there are three elements to the rescue system:

- Emergency prevention
- Alerting, decision making, and tasking of rescue resources
- Escape and survival in the immediate vicinity

With regard to emergency prevention, I think everyone appreciates the validity of the statement that better trained crews will reduce the chance of emergencies occurring.

With regard to alerting, decision making and tasking of rescue resources, the mechanism now exists for the offshore industry, regulatory agencies, and SAR authorities to communicate both formally and informally at both the senior management level and the technical operator level, and this has led to a far better working relationship and many improvements and advancements have been made. For example:

1. A traffic management system called FLIGHT FOLLOWING which monitors and plots the location of all ships and aircraft associated with offshore operations is in use.
2. Joint exercises in communications and simulated emergencies have been held.
3. Dedicated SAR radio frequencies are in use so that in the event of an emergency both aircraft and vessels are able to communicate effectively.
4. Co-ordinated alert and evacuation procedures have been written by individual operators to cover their specific operation, and when an emergency necessitating an abandonment occurs, there should have already been a planned staged evacuation.

Perhaps it is worth mentioning at this point that having alerted the rescue resources, where are they? And where do they come from? Mr. Klippenberg quotes the 1982 "Cross Report" objectives and terms of reference for the SAR programme: "To prevent loss of life and injury through SAR alerting, responding, and aiding activities which use public and private resources; and by ensuring priority to aviation and marine safety measures focussed on owners and operators most commonly involved in SAR incidents." He then states that there appears to be an inadequate SAR capacity to deal with offshore emergencies and I would agree with this, even taking into consideration the existing arrangements which utilize private assistance. The Canadian offshore industry still turns to DND for maintaining the SAR responsibility even though there is increasing pressure on the operators to do more. The offshore operators do accept their own responsibility in terms of emergencies, such as medical evacuations and search and rescue capability. It is industry which is promoting the use of the EMPRA basket as a simple and effective means of plucking people out of the water. It is the industry's view that the EMPRA basket does have distinct advantages over the horse collar in that it does not put the SAR technician at risk and also it can lift more than one person at a time with the large size basket. Furthermore, industry does not have time or facilities to train SAR technicians. It does, however, have the disadvantage that a back-up rescue facility, such as another MODU or standby vessel, should be close at hand so that survivors can be treated.

In the way of short term improvements to the SAR capability, I agree with the Rescue Study carried out for the Commission which recommends that contracted SAR helicopters should service the oil industry. On the question of financing, I see the upgrading of the helicopters and crew training as being a Government responsibility, with industry paying a user fee, when and as required.

In the way of long term improvements, I would like to see much more emphasis given to the type of aircraft used for SAR work; not only must it have all the latest electronic gadgetry for navigation and detection plus increased range and speed, but as Chris Brooks stated, it should be designed so that it is truly amphibious and will not turn over when forced to ditch. Another feature worth considering is the capability of a helicopter to recover either a lifeboat or life raft directly from the sea.

Mr. Klippenberg mentions that Norway has delegated the primary responsibility for rescue operations to the offshore operator. This is a concept I find very interesting, and I wonder if Mr.Klippenberg would explain the rationale for relegating the SAR organization to a secondary role.

With regard to Mr. Klippenberg's third point, escape and survival, it is generally accepted that helicopters are the prime means of evacuation; however, several limitations are imposed which reduce their effectiveness. Therefore, we must turn our attention to an alternate method, the standby vessel. Its great advantage is that it is on location and able to accommodate a large number of survivors. Mr. Klippenberg supports the use of a dedicated standby vessel, and here I would also agree. Purpose built and dedicated standby vessels have numerous advantages over utilizing supply boats or converted trawlers. Their design may then be able to incorporate other safety and operational functions such as:

- Fire fighting
- Anti-pollution measures
- Iceberg towing
- Anchor handling

By having a dedicated standby vessel, I believe the crews would be better trained and equipped, not only to use the existing rescue equipment, but to provide feedback for improvements and new designs in rescue equipment.

The idea of helicopters and supply boats following approximately the same traffic routes is a simple idea, yet as Mr. Klippenberg points out, can provide yet another rescue capability. Mr.Klippenberg has not mentioned evacuation by lifeboats but they too must also be considered a vital part of any rescue system. Several studies have been carried out on the ability to launch an enclosed lifeboat during rough sea conditions. The conclusions reached in these reports would indicate that improvements in launching systems are required. Indeed, the whole aspect of lifeboats, from launching to recovery systems, and also what has up until now been a disregarded subject, survivor comfort, should be the object of R & D programmes and funding. I would like to see not only lifeboat manufacturers and regulatory bodies discussing design features, but also end users and SAR groups. The latter two, I am sure, have ideas which they would like to see incorporated in any totally enclosed lifeboat. For instance:

- Where do stretchers go?
- A top access hatch to allow for SAR winching operations might also be a good idea.
- An adequate supply of sea sickness bags should be included.

Mr. Klippenberg stated that some improvements in immersion suits are required. I agree and am glad to say that at the moment a technical committee under the Canadian Government Standards Board and comprising members from Government (and Dr. Brooks), manufacturers, and end users are currently working on a new standard for helicopter passenger suits and also towards improving the existing standard for abandonment suits.

COMMENTARY ON PAPER G

Dr. G.R. Lindsey
Chief, National Defence Headquarters Operational Research & Analysis Establishment

Rather than discussing the details of Dr. Klippenberg's very useful and interesting paper, which was directed primarily towards the subject of rescue from drilling platforms and their supporting services in cold water, I would like to analyze beyond the subject that he covered, but still stay within the Conference theme of Safety Offshore Eastern Canada. An analysis of search and rescue offshore Canada could take, as its objective, the optimization of the safety of:

1. Drilling platforms on the Atlantic coast;
2. The services supporting the drilling like the supply ships and helicopters which are probably more susceptible to accidents than the big platforms;
3. All commercial maritime activities on the Atlantic coast;
4. All maritime activities including pleasure as well as commerce;
5. All activities in eastern Canada on land as well as the sea which produce a need for search and rescue.

Now the target for this Conference is Safety Offshore Eastern Canada and it may not go as far as my objective number 5. I suggest that it certainly should extend beyond number 1, that is drilling platforms only, and even if we decide to go no further than number 2, that is drilling plus its supporting activities, we will still want to draw on the resources already provided in numbers 3, 4 and 5 by the existing Government Search and Rescue services. We should recognize that the Government SAR system has been built up with its primary concern being number 5, that is, whatever it can do for people who need search and rescue, whether on land or near the coast or far away. Numbers 1 and 2 are rather relatively recent arrivals on the scene.

Now the tragedy of the *Ocean Ranger* was of such a magnitude that we focus our attention on number 1. There is a tendency in all society to concentrate attention on major disasters, even if the total loss of life may be less than that from a number of smaller, lesser newsworthy events. We get great excitement on the rare occasions when a large passenger aircraft is lost and we pay very little attention to the much larger death toll from the thousands of automobile accidents that are now a fact of life.

However, if we look at present trends, it does seem that search and rescue requirements for downed transatlantic airliners is, thankfully, very low. At the beginning of transatlantic air travel, it was expected that such incidents would occur quite often; fortunately they have not. We also do not seem to have much of a concern these days over the rescue of transatlantic passenger liners. That is probably due more to their shrinking numbers than their expert navigation or their fire-proof policies. However, the number of offshore drilling units in the eastern Canada offshore is large and increasing. The number of ships and helicopters needed to support them is also increasing and we hope it will go on increasing for production as well as exploration.

I doubt that the sequence of events which caused the loss of the *Ocean Ranger* will ever be repeated, but other major accidents undoubtedly have to be a cause of concern. The next one may be caused by a blowout, a fire, or on a MODU that is under tow rather than drilling. These could occur during production as well as during exploration. It is far more probable that what we will face in the next two years are minor accidents, perhaps associated with the supporting ships and helicopters, as well as with the large platforms. These probably deserve at least as much attention although they are not as spectacular.

It was illustrated very well in Mr. Klippenberg's paper and by some of the other studies produced during the *Ocean Ranger* investigation that a characteristic of the requirements for search and rescue, in connection with drilling on the East Coast, is the need for coverage far from shore because of the location of the exploration leases, and for rapid rescue, because of the short time that people can survive immersion in cold water. But nearly all of the search and rescue incidents, other than for oil drilling activities are close to shore or on land and many of these have a more serious problem with search than they do with rescue. Many of them have less urgency regarding the speed of rescue. Fixed wing aircraft fly faster than helicopters and produce a much greater search rate, though they are not so good for rescue. The bases are now located to give the best service to the large number of clients and most of those areas are on land or close to the shore. The drilling activity requires search and rescue resources that are markedly different from those that are needed for all of the other beneficiaries. Also the drilling industry posesses the resources in the right place to conduct the search and rescue that they need. One would ask, "Should the existing system be distorted in favour of the drilling clients or should a separate system be created just for the drilling activities?" The Government land-based SAR resources that have been put in place are in the best place for the other users, but they are not in the best place for the drilling clients.

Some conclusions could be offered as a result of the analysis that we have heard today. Much can be done by measures such as preventive actions including safety training, provision of immersion gear, strobe lights, and other technologies that will certainly make rescue more likely to be successful. We obviously will have to include things like position reporting and the exchange of information as a routine activity so that when trouble arises everybody knows precisely what the situation is. There is a strong case for tasking and equipping by industry of their standby ships and helicopters, ones that are regularly in or near the right place for rescue duties. This may, of course, require the provision of helicopters with necessary apparatus that they may not have to carry for their normal duties, and standby ships may have to be provided with additional apparatus, perhaps for rapid rig-to-ship transfer of personnel. Certainly, rescue training will need to be pressed for at least an adequate number of specified individuals, although perhaps not necessarily for everybody.

We must take full advantage of certain features of the drilling and support activities that do not apply to the other recipients of search and rescue services. For instance, helicopter support activity is concentrated into daylight hours and the approach of ice or storms is probably something that will come with a fair amount of warning. We should reserve the land-based Government SAR assets for those functions which they can perform for the drilling community without detracting from their many responsibilities, such as a large helicopter lift when there is sufficient warning and the use of fixed-wing aircraft for search when there is reason to believe that survivors may be able to live for more than a short time.

We must clearly encourage and support the oil industry in every way so they should improve their knowledge and equipment to prevent major accidents and to make provision for rapid rescue using only the vehicles that are already in the right place.

Summary of General Discussion Following Paper G

Vice-Admiral A.J. Fulton (CAF, retired) spoke about DND's search and rescue system and pointed to the duplication of effort in the development of a contingency plan by both Maritime Command and industry, without any consultation between the two. He criticized this lack of communication and said it is detrimental to the success of safety offshore. He also criticized the marine community's lack of knowledge regarding how to access properly the SAR system. He said that the SAR resources are often called on when it is too late to effect a successful rescue. Vice-Admiral Fulton stated also that SAR resources are there to serve not only the offshore oil industry, but many others, and that, in fact, the oil industry has not really been a big user. While he encouraged the idea that the industry should be required to mount its own system to serve its own needs, he felt that it is up to government to specify what standards are to be expected and how they might best be implemented.

Mr. Per Klem (Ship Research Institute of Norway) asked whether the idea of a standby helicopter had ever been considered. Dr. E. Klippenberg (Norwegian Defence Research Institute) doubted that standby helicopters would ever replace standby vessels, although the relative merits of each have not been examined closely. He felt that weather limitations, particularly in Canada's East Coast offshore, would severely limit their effectiveness. Mr. J.J.S. Daniel (Hollobone, Hibbert) expressed surprise that the Chinook helicopter, with its superior range and carrying capacity, has not been seriously considered as an abandonment and/or rescue vehicle, but Dr. G.R. Lindsey (DND Operational Research & Analysis Establishment) pointed out that it is oversized for most of the incidents which call on the deployment of SAR resources.

Mr. W. Parsons (Newfoundland and Labrador Federation of Labour) asked whether the industry's Safety Committee included any worker representation, and Mr. Ian Denness (Gulf Canada Resources) explained that the Safety Committee is comprised of individuals who each have a certain degree of expertise in safety. He felt that each company represented on the Committee had its own method of ensuring that the views of workers are brought forward to the safety representatives on the Committee.

Mr. Parsons also asked about the degree of worker representation through unionization currently in place in the North Sea. Mr. J. Hielm (Elf Aquitaine Norge) replied that, in Norway, workers' representatives participate in all aspects related to safety, including the research and development aspect.

Mr. Daniel supported the concept of dedicated standby vessels manned with crews with specialized rescue training. Mr. D. Pease (Husky/Bow Valley) commented that the standby/supply vessels currently in use in offshore eastern Canada are the state-of-the-art in such vessels, having high manoeuverability and horse power, and numerous items of rescue equipment. He asserted that, with their specially trained crews, they are superior to the specially built, dedicated purpose, rescue vessels which are available today. Mr. R. Fodchuk (Shell Canada) supported this and re-affirmed that crew training is ongoing and that this includes rescue exercises alongside a rig.