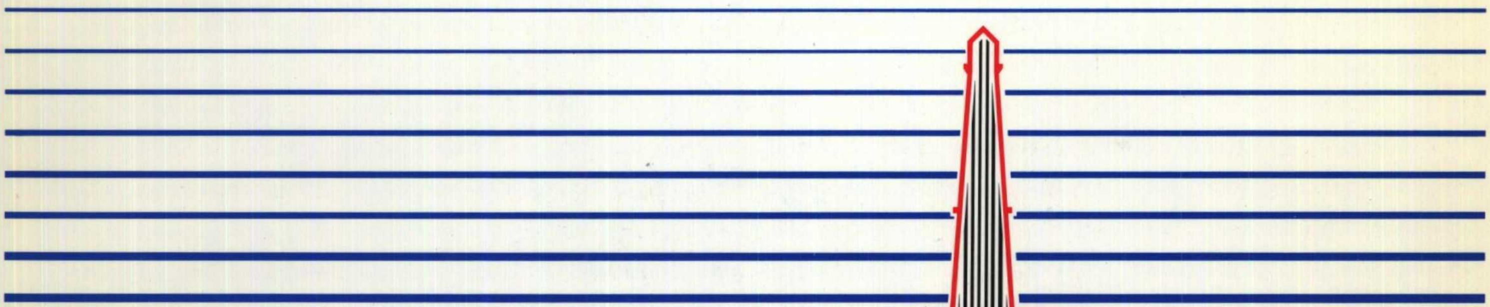
Royal Commission on the *Ocean Ranger* Marine Disaster

Canada

Commission Royale sur le Désastre Marin de l'*Ocean Ranger*

Newfoundland & Labrador



Report Two: Safety Offshore Eastern Canada

The Royal Commission on the *Ocean Ranger* Marine Disaster was jointly established and funded by the Governments of Canada and Newfoundland

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Commission Royale sur le Désastre Marin de l'*Ocean Ranger*
Newfoundland/Terre-Neuve

To Her Excellency
The Governor General

May It Please Your Excellency

We, the Commissioners appointed to inquire into and report upon the reasons and causes for the loss of all members of the crew of the semisubmersible self-propelled drill rig Ocean Ranger and of the Ocean Ranger on the 15th day of February, 1982 on the Continental Shelf off Newfoundland and Labrador and to inquire into, report upon and make recommendations with respect to safety offshore Eastern Canada, beg to submit to Your Excellency the following second report, which is our final report.

Chief Justice
The Honourable T. Alex Hickman
Chairman

The Honourable Gordon A. Winter, O.C.
Vice-Chairman

Fintan J. Aylward, Q.C.

Jan Furst, P. Eng.

M. O. Morgan, C. C.

N. Bruce Pardy, P. Eng.

June, 1985
St. John's, Newfoundland

Commissioners/Commissaires

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The Honourable Gordon A. Winter, O.C., Vice Chairman/Vice-Président
Fintan J. Aylward, Q.C.
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The Lieutenant Governor

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The two reports of the Royal Commission on the *Ocean Ranger* Marine Disaster consist of the following four volumes:

Volume 1 **Report One: The Loss of the Semisubmersible Drill Rig *Ocean Ranger* and its Crew**

Volume 2 **Report Two: Safety Offshore Eastern Canada**

Volume 3 **Report Two: Safety Offshore Eastern Canada**
Summary of Studies & Seminars

Volume 4 **Report Two: Safety Offshore Eastern Canada**
Conference Proceedings, 1984

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ACKNOWLEDGEMENTS

Distilling the results of three years' work into this final report has been a formidable task. The staff of the Royal Commission has worked ably and imaginatively to reach its goal. Throughout the inquiry, the pressure of successive deadlines has called for long hours and a high degree of dedication. That we have completed our work within the forecast schedule is the result of their efforts and we thank them as individuals and as a group for what they have done. Their names appear in Appendix A, Item 1.

The Royal Commission has been fortunate in its external advisors who have made valuable contributions, some by preparing draft material to be used as a basis for sections of the report, others by providing advice and commentary at various stages of this inquiry. Their names are listed in Appendix A, Item 2. We are particularly indebted to our senior advisor, Dr. O.M. Solandt, C.C. and to the chairmen of the advisory committees on environment, design and construction, safety and training, and regulation, respectively: Dr. W.L. Ford, Dr. A.A. Bruneau, O.C., P.Eng., Dr. J.M. Ham, O.C., P.Eng., and Dr. A.E. Pallister. They helped us to mobilize and use productively the talents of a distinguished and knowledgeable group of people drawn from governments, industry and universities in Canada and abroad.

Throughout its work, the Royal Commission called on the governments of Canada and of Newfoundland and on the petroleum industry for a great deal of information relating to current offshore operations and to evolving policy and procedures. Dr. A.E. Collin and Mr. J. Fitzgerald for the two governments and Mr. K. Oakley for industry ensured that we received co-operation and they gave their personal support and encouragement throughout the process. The effective co-ordination provided by Mr. F. Brodie and Ms. S. Vorner-Kirby was in great measure responsible for the informed and prompt responses received from relevant federal government agencies and departments.

In addressing the second part of its mandate, the Royal Commission consulted widely and listened to the views of the many and diverse interests that are involved in this international industry. In completing its work, we acknowledge with gratitude the help and support we have received from innumerable people, some of them in government and in industry, others from among offshore workers and members of the general public. Their concern and the co-operation which have been manifested during the course of the inquiry need to be harnessed on a continuing basis in the interests of offshore safety.

The Honourable T. Alexander Hickman, Chief Justice

Commission Chairman

PREFACE

The capsize and sinking of the semisubmersible drilling unit *Ocean Ranger* on the Grand Banks of Newfoundland with the loss of its entire crew sent shock waves throughout Canada and beyond. The seriousness of the tragedy and its implications for future offshore drilling operations led to the establishment of Royal Commissions of Inquiry by both the Government of Canada and the Government of Newfoundland. In response to public concern that two official investigations would duplicate effort and create problems, the two levels of government moved quickly to combine the inquiries and adopt identical terms of reference. One Royal Commission was appointed jointly under the chairmanship of Chief Justice the Honourable T. Alexander Hickman, and the Chairman of the Provincial Royal Commission, the Honourable Gordon A. Winter, O.C., was appointed Vice-Chairman.

This unusual joint Royal Commission was given a unique mandate in two parts: the first and most immediate was to launch a formal inquiry into the loss of the *Ocean Ranger* and its crew; the second involved a process of study and consultation through which ways and means might be identified of improving the safety of eastern Canada offshore drilling operations.

In response to the first part of its mandate, intensive technical investigations were carried out and public hearings were held. These hearings began on October 25, 1982 and finished on March 22, 1984. On August 8, 1984 the Royal Commission submitted to the two governments *Report One: The Loss of the Semisubmersible Drill Rig* Ocean Ranger *and its Crew*. That report examined the reasons and causes for the loss and established the contributing factors. It analysed those areas of vulnerability within which lay the potential not only for the capsize of the *Ocean Ranger* but for other future disasters. This aspect is the basis for the transition from the specific concerns of the Part One investigation to the much broader approach that was adopted in the Part Two inquiry.

The Terms of Reference given to the Royal Commission for the second part of the inquiry (Appendix A, Item 3) called for it to:

> Inquire into, report upon and make recommendations with respect to both the marine and drilling aspects of practices and procedures in respect of offshore drilling operations on the Continental Shelf off Newfoundland and Labrador and . . . to the extent necessary and relevant, such practices and procedures in other eastern Canada offshore drilling operations.

It was recognized that these Terms of Reference would have to be brought into much sharper focus. It was decided to exclude the development and production aspects of offshore operations and to limit the subject of investigation to offshore exploration and delineation. The enhancement of human safety was seen to be the main issue; property safety was considered only to the extent that it affected human safety. Environmental safety was not regarded as a central issue for the inquiry although, because of the expressed concern of fishermen and environmentalists, attention was given to the impact of exploratory drilling operations on fish, on sea birds and on marine mammals.

A plan was developed for a study program which would provide the Royal Commission with a concise but comprehensive review of current information and knowledge in the main areas of concern: environmental factors, design, human safety, and regulatory control. An informed group drawn from industry, government and universities critically reviewed the study plan and a number of recommendations were made with respect to the proposed content of the plan and the process to be followed during the Part Two inquiry.

As a result of these recommendations, advisory committees composed of knowledgeable people were set up in each of the four principal study areas to assist in defining the nature and scope of the studies to be undertaken. These studies were carried out under contract by experts in the various fields and have been regarded as input to the Royal Commission, but the views expressed and conclusions reached are those of the authors. These reports have all been subjected to a process of peer review. They are listed in Appendix A, Item 13 and summaries of some appear in Volume 3.

A problem faced by all inquiries is that the world does not stand still to be studied. The moment a study is complete, the conclusions and information in it begin to be dated and it becomes clear that there are areas that have not been covered adequately. As the Part Two study program progressed, it was recognized that the Royal Commission required additional information and informed views in a number of areas. This need was met by appointing advisors and by bringing together groups of experts, drawn from industry, the consulting community, government and universities, for a number of one-day seminars to make presentations and to debate the issues.

Another problem was the validation of the data collected and of the conclusions suggested in the course of the studies and the seminars. It was decided to bring together knowledgeable people in a forum that would be conducive to the frank exchange of ideas on the basic issues with which the Royal Commission would have to deal in its final report. The medium chosen was an international consultative conference, Safety Offshore Eastern Canada, organized in association with Memorial University of Newfoundland, to which were invited experts from a variety of backgrounds. The formal presentations were designed to stimulate fresh thinking and constructive debate on the basic issues. Summaries of most of the draft study reports were sent to all participants in advance of the conference in the form of briefing papers. Shortly before the conference, Report One was released to the public and those who took part in the conference had access to the results of all the work that the Royal Commission had completed up to that time.

A notice calling for written submissions was issued in September, 1983 and was followed up by letters to associations, companies and other organizations directly or indirectly involved in worldwide offshore drilling operations. A number of submissions were received (Appendix A, Item 7) which have provided useful input to the Part Two inquiry. A notice was also issued inviting the views of the public on matters relevant to the Part Two mandate of the Royal Commission to be presented at public hearings in Halifax, Nova Scotia and in St. John's, Newfoundland. In the event, the response did not warrant proceeding with a formal hearing in Halifax. The final public hearing was held in St. John's on November 5, 1984. The Royal Commission met informally in St. John's and in Halifax with a number of individuals and public interest groups. A Commissioner, accompanied by Commission staff, visited rigs operating off Newfoundland and Nova Scotia, participated in safety meetings and interviewed rig workers (Appendix A, Item 12). Shortly thereafter, a worker representative chosen by fellow workers from each of six rigs attended a meeting of the Royal Commission to discuss current practices affecting the safety of offshore drilling operations.

Throughout the course of the past three years, there have been innumerable meetings between Commissioners or Commission staff and industry representatives, government officials, members of the academic and consulting communities, and members of the work force in the offshore drilling and related service industries. These have taken place in Canada, the United States and Europe. They include discussions with a wide variety of people in the course of visits to mobile offshore drilling units, training institutions and emergency facilities serving offshore marine and drilling operations off Newfoundland and Nova Scotia and in the North Sea (Appendix A, Item 11).

The process of an inquiry is in itself productive of change regardless of the results. While a Royal Commission is in existence, its presence induces self-examination and improvement. It is this awareness that is required on a continuing basis to maintain the offshore safety regime. Much still remains to be done.

No commitment has yet been made to proceed with development and production of eastern Canadian offshore oil and gas resources. The mounting pace of activity, however, foreshadows the transition from exploration to production. Canadians from all parts of the country are now employed in all aspects of this industry and their numbers will increase. Canadian regulatory authorities and the industry itself bear the responsibility for their safety.

INTRODUCTION

The inquiry by the Royal Commission has addressed three basic questions:

Why did the *Ocean Ranger* capsize and sink?

Why was none of the crew saved?

How can other similar disasters be avoided?

Answers to the first two questions and an initial answer to the third were provided in Report One. This final report presents the results of the investigation into the third area, the goal of which was to identify ways and means of improving human safety during exploratory and delineation drilling operations off eastern Canada.

The offshore petroleum exploration industry embodies in its many components the rapid evolution of many industrial and engineering traditions. Structural engineering, naval architecture, materials fabrication, protection and control systems, instrumentation and testing, aviation and marine engineering are only some of the obvious areas in which this industry has challenged these traditions and continues to challenge current ideas and practices. The industry deploys and operates physical systems in locations, particularly off the East Coast of Canada, where the complexity and intensity of the environmental phenomena in which they must function safely are severe by any standard, not yet fully known and uncertain in their effects.

The general regulatory environment in which the industry functions offshore throughout the world is an intricate one. It includes elements of voluntary self-regulation that have evolved in the marine shipping industry over two hundred years and in the petroleum industry during this century. Other elements are embodied in international rules and agreements on marine safety, and in regulations imposed by the Flag and the Coastal States that draw on safety legislation founded on shore-based industrial traditions. This highly mobile international industry is increasingly subject to the requirements of many Coastal States and of international bodies committed to the formulation of codes and regulations that can be applied wherever the industry may operate.

In seeking to enhance the safety of offshore drilling operations in a practical way, it is recognized that human safety is a state of freedom from actual harm but not from risk, a state of being secure even when threatened. The more involved the activity, the more attention and the greater priority must be given to analysis, review and surveillance if human safety is to be maintained, let alone enhanced. The weakest links in any system, which are seldom the most obvious, must be identified and either protected or strengthened. The pace of change demands that standards be constantly reviewed and revised and that effective mechanisms exist to implement the process speedily. The hazards to be encountered in offshore drilling need to be seen in the perspective of the risk that surrounds all human endeavours.

The loss of the *Ocean Ranger* and its crew was examined in Report One against the industrial-marine background, the emerging regulatory system and the evolving technology that are still characteristic of offshore drilling operations. In addition to inquiring into and reporting upon the reasons and causes for the loss of the rig and its crew, the Royal Commission was also required to report on a number of specific matters that were relevant to the accident. These included: some aspects of the design of the *Ocean Ranger* and of its critical systems; the command structure; the composition of the crew and how the rig was manned; operations on the Grand Banks leading up to the disaster; all aspects of safety of life at sea, including the sufficiency of available lifesaving equipment; and the regulatory system and how it functioned. Although none of these factors was found to have contributed directly to the disaster, all were deemed to have been instrumental in contributing, although often indirectly, to the loss of the rig and its crew.

This report now critically examines the same key aspects of offshore drilling operations and analyses those areas of continuing vulnerability in which may lie the seeds of future disasters. The introductory section includes a brief historical review of the international industry with an account of its activities and record off eastern Canada. This is followed by a chapter that provides a perspective on safety, considering its relationship with risk, costs, human nature and the compromises made in these relationships. The introductory section concludes with a chapter which assesses our knowledge of the physical environment in which eastern Canada offshore drilling operations are conducted. This environment – the waves and currents, the weather and the ice – affects the design of the structures and systems that are built to function there and also the day-to-day management decisions which determine the ongoing safety of the operation and of the people employed in it.

There follows a chapter on design, in which the roles of rig designers, builders, and owners of mobile offshore drilling units (MODUs) are analysed, as well as the roles of classification societies and regulators. The chapter also examines critically the process that is followed to design a MODU and to maintain the integrity and safety of its structure and of its key systems throughout the life of a rig. It also examines the mode of determining the suitability of MODUs for operations off eastern Canada.

The safety and seaworthiness of a MODU depend on its being properly designed, built and maintained to operate in the environment for which it was intended but they also depend upon its being properly managed and manned. The next chapter of the report provides a critical examination of management responsibility at the levels of the operator (the oil company holding the permit to drill), the owner of the MODU (the drilling contractor retained by the operator) and on board the MODU itself. Command structure, the process for reaching operating decisions affecting the safety of the rig, the management of safety in the workplace and the participation by workers in the process are all examined in this chapter.

A chapter follows on training, which analyses the level and quality of training for safety required of the crew of the drilling unit. It examines critically the requirement for orientation, specialist, team, and emergency training. The discussion of operations concludes with a chapter on occupational health and safety which analyses the basic issues affecting health care on offshore drilling units.

The section on emergencies opens with a chapter on escape from the MODU and on survival in the event of an unplanned evacuation. It contains an examination of existing means of evacuating a rig and of surviving in a harsh environment, while awaiting rescue. The chapter concludes with an analysis of possible improvements to lifesaving equipment and of how innovation in this field might be encouraged and supported.

A chapter on rescue provides an analysis of the capability of industry and of government to rescue workers engaged in eastern Canada offshore drilling operations in the event of an emergency and considers measures required to improve their capability and organization and to provide an acceptable level of rescue services.

The chapter on regulatory control considers the modes of control adopted by both government and industry for offshore drilling operations, and analyses the Canadian regulatory framework and practices in comparison with those of Norway, the United Kingdom and the United States.

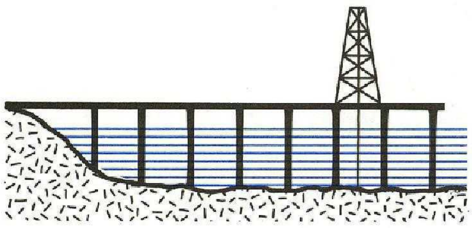
The final section contains the conclusions and recommendations which are, as in Report One, presented in relation to the Terms of Reference of the Royal Commission. A brief epilogue chapter deals with the impact of offshore drilling operations on marine life. Appendices contained in this volume and the material in the accompanying volumes will be of assistance to readers who require supplementary information. They provide a synopsis of the data base, which supports the analyses and conclusions in Report Two. Summaries of the study reports, together with summaries of the organized seminars are included in Volume Three. Volume Four contains the proceedings of the international consultative conference on Safety Offshore Eastern Canada.

CHAPTER ONE HISTORICAL REVIEW

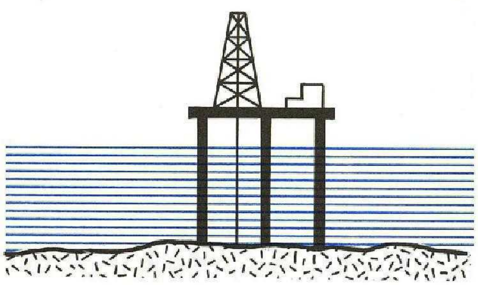
The petroleum industry as we know it today is often depicted as a monolithic, multinational giant affecting every aspect of the global economic system. Its operating base includes both industrial and consumer product manufacturing and distribution, but its raw materials come from the exploration and production of oil and gas reserves, both on land and over water. The industry began in the nineteenth century with the discovery of substantial hydrocarbon deposits, primarily in North America. The increased economic need for petroleum, coupled with easily accessible reserves, provided the industry's pioneers with the stimuli they required to locate and exploit petroleum resources and to develop increasingly efficient drilling technology. Around 1900, these same motives induced expansion into exploratory drilling over water, and by the early 1950s, offshore exploration and production had become an industry in its own right with its own experts, service companies, and equipment to cope with the unique problems of drilling at increasing water depths into the seabed.

The complex technology that is currently in use by the petroleum industry to find and develop offshore hydrocarbon resources has evolved over the past one hundred years. The first recorded offshore drilling venture took place in the late nineteenth century near Santa Barbara, California, where the presence of oil had long been recognized. In the 1860s, natural asphalt seepages were extracted from the beaches and prospectors eventually discovered that oil-bearing formations extended underneath the ocean. In 1897 the first "over-water" exploration wells were drilled from wooden stages which extended from the shoreline, and by 1900 beaches in the Summerland, California area displayed clusters of wharves, up to 1,200 feet in length, from which exploration wells were successfully drilled.

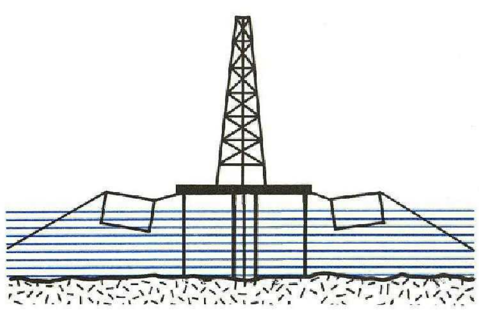
Oil and gas seepages, similar to those found on the California coastline, were prevalent in the Caddo Lake area of northeastern Texas and northwestern Louisiana, where in 1870 a well intended to locate water encountered natural gas. This accidental discovery caused numerous technical problems associated with well control. Blowouts were frequent in early gas wells and, in some instances, uncontrolled wells burned for years. As a result of the Caddo Lake experience, the United States government enacted well control regulations, and, through lease sales, limited the development of land surrounding and beneath the lake. To conduct drilling operations over water, equipment was transported by barge to the drill site where a drilling platform and pipe rack, like those used on land sites, were constructed. Wooden pilings were driven to provide a fixed base for the drilling equipment. In 1911, Gulf Oil Limited, using this type of drilling system, produced the first oil from underneath an inland lake. Platform design and production techniques pioneered by Gulf in Caddo Lake became an accepted standard in the industry and were used to produce oil in Lake Maracaibo, Venezuela, in the early 1920s. Derrick foundations progressed



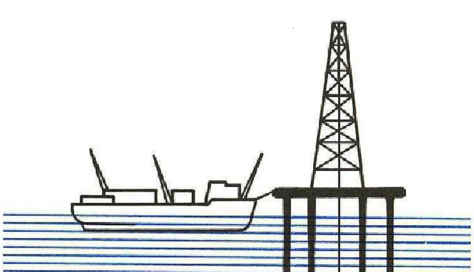
1.1 Offshore drilling rig evolution.
Wooden stages, 1897-1918
Water depths to 30 feet.



Pile-supported platforms, 1910-1940
Water depths to 60 feet.



Submersible barges, 1933-1960
Water depths to 20 feet.



Fixed platforms and tenders, 1934-1960
Water depths to 75 feet.

from wood to concrete, and by the 1930s, steel derricks became the standard.

Geophysical and seismic exploration along the coastlines of Texas and Louisiana produced numerous prospects, but the open bays, bayous, lakes and swamps of the area presented unique problems and required a totally different approach to platform design. Because of the silty subsoil of the Gulf Coast, Texaco Inc. commissioned the construction of a submersible barge equipped with a derrick and drilling equipment for exploration on inland waterways and lakes. The barge could be floated to a drilling site, flooded and submerged to rest on the bottom which provided a solid support for drilling. This innovative concept eliminated the costs of constructing fixed platforms because the barge could be refloated and moved to another site when drilling was completed. The first submersible rig, consisting of two barge hulls each with several watertight compartments, was designed to operate in ten feet of water. A distribution manifold with seacocks adjusted the flow of water during submerging. A steel superstructure supported the derrick, drilling machinery, pipe racks, and ancillary equipment such as mud tanks and pumps. Submersible barges provided an efficient and economical method for exploration of inland waterways.

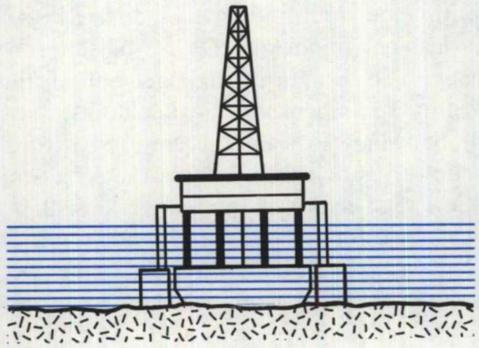
As exploration in the Gulf of Mexico expanded in the 1930s, it was still restricted to drilling from fixed platforms. In 1947, Kerr McGee Oil Industries pioneered an innovative platform design which was considerably smaller than those previously used in the Gulf of Mexico. The derrick and basic drilling machinery were located on a small fixed platform, with ancillary equipment, consumables and crew's quarters located on a floating tender. Since the platform and tender were stationed farther offshore, they had to be capable of withstanding increased wind and wave forces. This design proved quite effective but the mooring system was not always capable of keeping the tender on location during severe weather.

The oil industry responded favourably to Kerr McGee's innovative concept which subsequently inspired the design of floating structures for the entire drilling operation. In 1948, John Hayward designed a drilling platform combining the submersible barge and pile-support concepts. Hayward's design incorporated two pontoons which could be ballasted or deballasted independently. The barge hull could be floated to a drilling location, then submerged to rest on the bottom, providing the platform with the necessary support, freeboard and stability. By 1949, the industry's first mobile drilling platform was launched and operated on several locations in water depths of up to 18 feet. In 1954, the Ocean Drilling and Exploration Company (ODECO) built a submersible barge based on Hayward's concept to operate in water depths of up to 40 feet. Operators began to commission similar designs for deeper water, adding buoyant vertical columns at each corner of the platform.

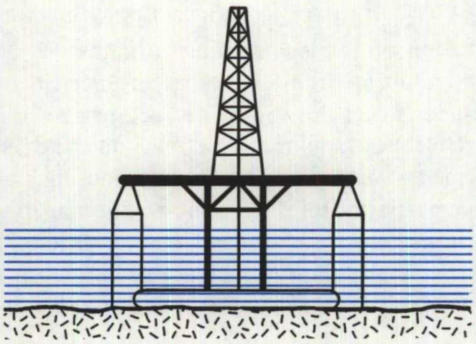
As activity in the Gulf of Mexico increased, other areas of the United States, principally the California Coast, became interested in exploratory drilling. Public pressures discouraged the use of fixed platforms there and the industry was forced to examine alternate designs. The result was an experimental program in 1953, which converted a navy vessel to a ship-based floating drilling system by installing a cantilevered drilling platform amidship. This experiment resulted in the development of equipment and systems which compensated for the vertical motion of the ship (heave) and its effect on the drilling operation.

In 1956, the first purpose-built drill ship was completed. The drilling platform and derrick were located amidship over a hole through the hull called the "moonpool". The vertical motion characteristics of the drill ship were substantially compensated for and, as more drill ships were designed, improvements to the industrial and marine systems evolved rapidly. A slipjoint to compensate for vessel motion was developed, improved mooring systems were designed, and a subsea system was devised to position the wellhead on the ocean floor. The design of the slipjoint and heave compensation systems permitted drilling to continue in moderate seas and enabled the operator to suspend operations during storms.

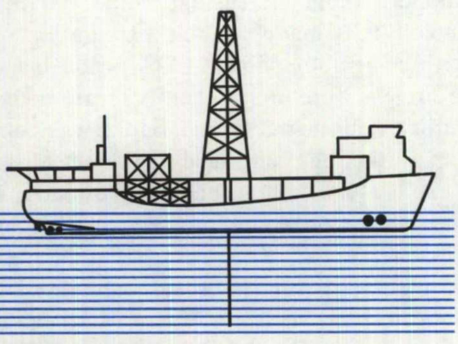
1.2 The *Mr. Charlie*, a submersible barge with hinged pontoons, built for the Ocean Drilling and Exploration Co. (ODECO) in 1954. Completely rebuilt in 1982, the rig is still in service in the Gulf of Mexico and is capable of drilling a 25,000-foot well in 40 feet of water.



Submersible barges, 1949-
Water depths to 45 feet.



Submersible barges with buoyant columns, 1956-
Water depths to 175 feet.



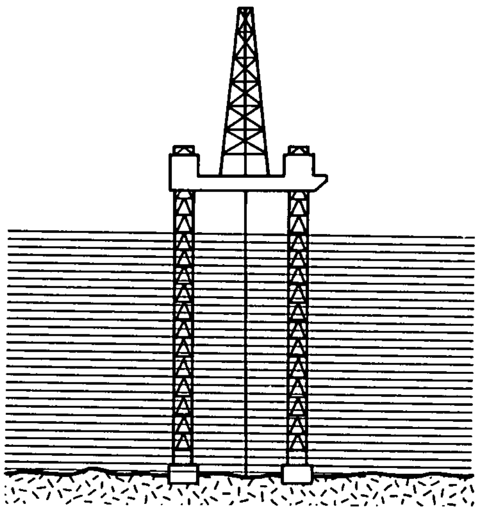
Drill ships, 1953-
Water depths to 6,000 feet.

The industry continued to design and improve drilling units that were stable, mobile and cost effective. Their research led to the evolution of truly mobile (self-propelled) floating drilling units and through the 1960s the drilling fleet expanded in size and type. Four generic forms of mobile drilling units evolved from the design innovations tested in the 1940s and 1950s. The submersibles and jack-ups were bottom supported and the drill ships and semisubmersibles were free-floating.

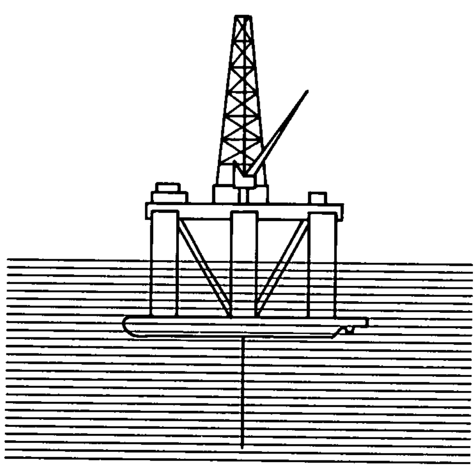
Submersibles generally have an upper hull for drilling equipment and crew's quarters, and a lower hull for flotation while in transit and for bottom support while in the drilling mode. The rig is usually towed to the drill site where its lower hulls are flooded until they rest on the sea floor. In this position, the submersible is a relatively stable drilling platform. Once the drilling is completed, ballast water is pumped out of the lower hulls and the submersible is refloated. Because the submersible is designed as a bottom-supported drilling unit, its operation is limited to water depths of up to 175 feet. With the increasing requirement for exploration in deeper waters, the submersible fleet has seen limited growth since the 1960s.

The "self-elevating" or jack-up rig is the most widely used platform in today's offshore drilling industry. The basic design first appeared in the 1950s. The jack-up has a large buoyant hull fitted with a number of retractable legs. The platform can be towed, transported on barge or self-propelled to a drill site with its legs drawn up above the deck. Once on location, the legs are lowered until they make contact with the seabed. The deck, supported by the legs resting on the sea floor, is then jacked up above the water until a sufficient air gap is created to permit drilling operations unhindered by wave action. While jack-ups provide a stable drilling platform on location, they are extremely unstable during towing and jacking operations and can be used only where the seabed provides a solid foundation for the legs. As with the submersible, the jack-up rig is restricted by water depth. Current designs can accommodate depths in the order of 400 feet. In Canada they are used at present only in relatively ice-free areas such as the Scotian Shelf.

The drill ship received more recognition after successful experimental programs in California in the late 1950s. The ship-shaped design permits a large cargo capacity requiring less frequent resupply. The benefits of self-propulsion allow drill ships to operate in deep water, with the assistance of either conventional mooring or



Jack-ups, 1953-
Water depths to 400 feet.



Semisubmersibles, 1962-
Water depths to 6,000 feet.

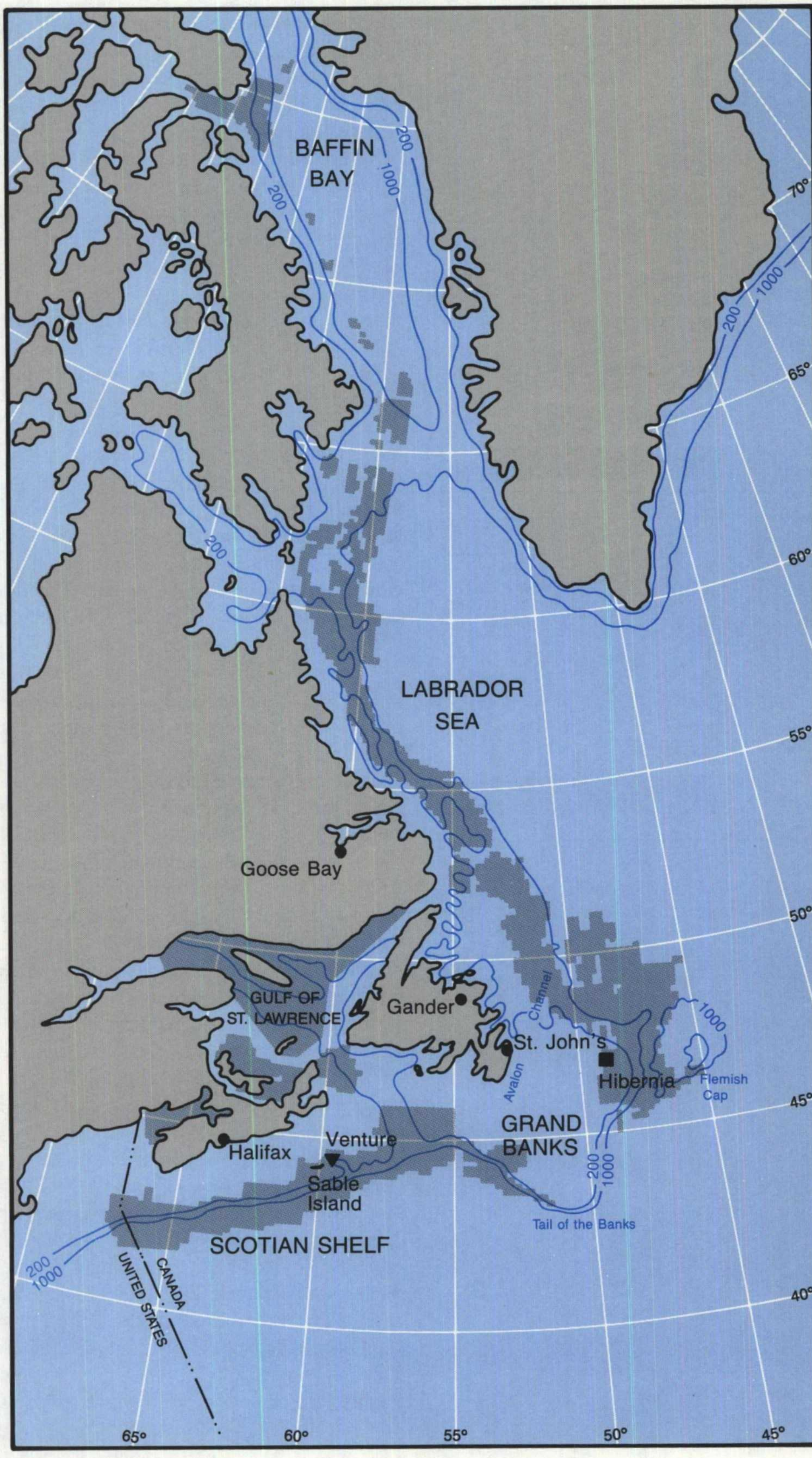
dynamic-positioning systems. Because of the hull shape, however, drill ships tend to have poor motion response, particularly in respect of heave. Since the efficiency of an offshore drilling program is affected by the motion of the drilling platform, drill ships tend to be restricted to regions having small wave heights and low wind velocities. In Canadian waters drill ships are used on a seasonal basis primarily in the Beaufort and Labrador Seas.

The semisubmersible evolved from the submersible drilling unit and was introduced in the early 1960s. It had been found that the submersible exhibited satisfactory stability characteristics during all stages of ballasting operations and, with certain structural changes, a submersible drilling unit could be designed to be partially submerged, providing a floating platform with good stability. As the industry began to explore deeper waters and harsher physical environments, the use of semisubmersibles became increasingly advantageous. The structural arrangement of the semisubmersible consists of a deck supported by a number of vertical columns, cross braces and pontoons which have sufficient buoyancy to float the entire structure. This arrangement makes the semisubmersible very stable and reduces the effects of wave action, since much of the vessel is below the surface of the sea while drilling. The pontoons of the semisubmersible are designed for storing bulk liquids, such as fuel oil and drill water, and salt water for ballast. When the semisubmersible moves from the transit mode into the drilling mode, it is ballasted down by taking sea water into its ballast tanks. During drilling the deckload changes continually as supplies are consumed and the rig takes on or pumps out ballast water to maintain its draft, trim and stability.

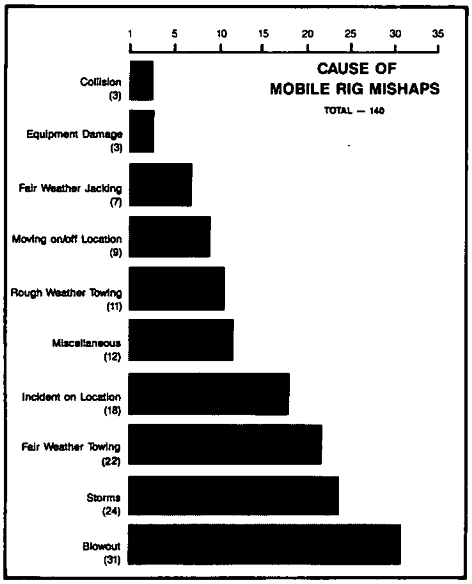
Since the introduction of the semisubmersible, a wide variety of designs has evolved. Many of the early units were designed to operate in both the free-floating and the bottom-supported condition and the drill floor and derrick were located at either the edge of, or overhanging, the deck structure. The *SEDCO 135* or "arrowhead" design is typical of the first generation of semisubmersibles. In the 1970s, designs began incorporating improvements resulting from earlier experience in the Gulf of Mexico and the North Sea. The deck structure was made rectangular and the drill floor was placed close to the centre of buoyancy; motion effects on the drilling operations were thus reduced. Improvements were also made in the mooring systems and several rigs were fitted with either partial or total dynamic-positioning systems. The semisubmersibles of the 1980s have more standardized structural designs which reduce construction costs. The basic principles, however, of stability, mobility and reduced motion characteristics, upon which the first generation of semisubmersibles was designed, still apply.

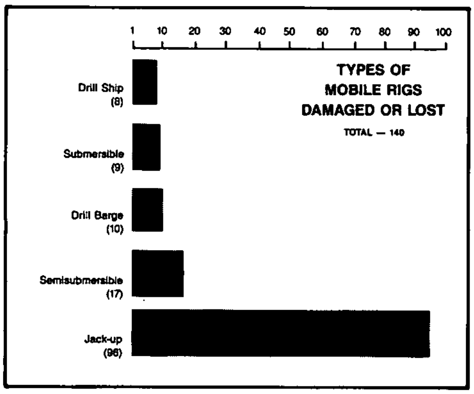
During the past two decades there has been a rapid acceleration in the evolution of offshore technology. The growth in demand for petroleum, the drive to achieve national self-sufficiency in energy, the apparent depletion of known land-based reserves, and the vagaries of OPEC policies have led to a surge of exploration on a worldwide scale into deeper waters offshore under increasingly harsh environmental conditions. The evolving new technology has made possible exploration off the East Coast of Canada, particularly with semisubmersibles. Exploration began there in 1960 when geophysical and seismic surveys were undertaken to locate potential hydrocarbon reserves. The first exploratory well on the Grand Banks was completed in 1966 and since then the pace of exploration has continued unabated. Major oil companies have conducted year-round exploratory drilling on the Grand Banks and on the Scotian Shelf as well as seasonal drilling programs in the Labrador Sea and the Gulf of St. Lawrence.

Discovery of oil on the Grand Banks in the Hibernia field was announced in 1979 and later oil was also found in the Hebron, Ben Nevis and Terra Nova fields. To date, all four discoveries indicate the potential of sufficient oil to support production. On the Scotian Shelf, gas in quantities estimated to be potentially sufficient to



1.3 The continental shelf off eastern Canada covers a vast area. Since the first well was spudded there in 1966, exploratory drilling activity has gradually increased; in May, 1985, a total of twelve MODUs were operating off Newfoundland and Nova Scotia.





1.4 Types of MODUs damaged or lost, and the cause of the incident, 1955 to 1981. A number of other rigs, including the semi-submersible *Ocean Ranger* and the drill ship *Glomar Java Sea*, have been lost since that time.

support production has been discovered in the Venture and Glenelg fields. Gas in significant quantities has also been discovered in the Labrador Sea but the possibility of production there is at present slight because of impediments to operating in this ice-frequented area. In the Gulf of St. Lawrence there has as yet been no significant discovery of either oil or gas.

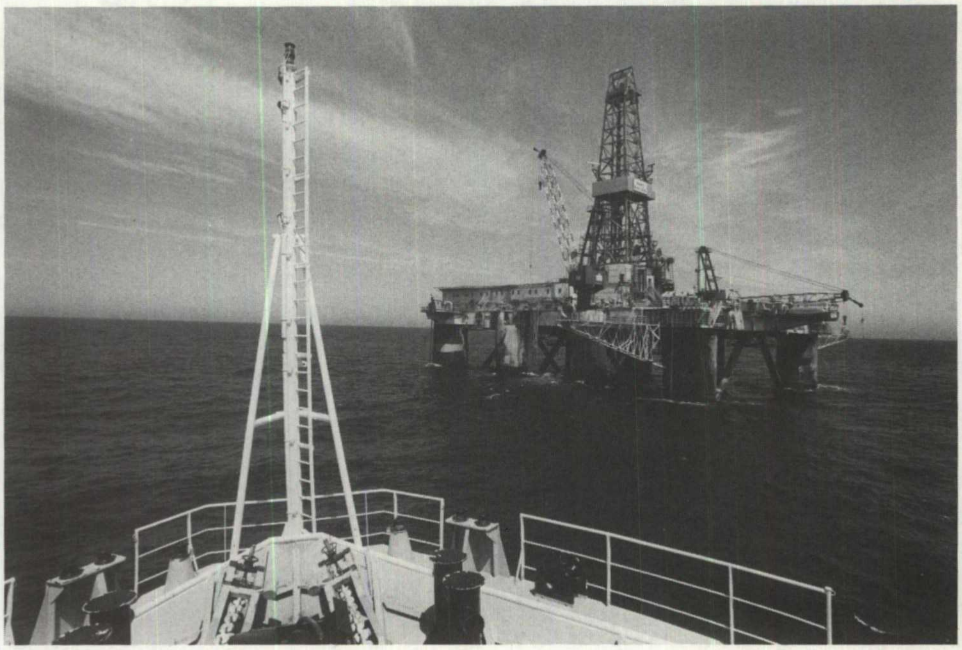
Offshore production on the eastern continental shelf is contingent upon sets of complex variables. The number of persons employed offshore will therefore be contingent upon the mode and pace of production and the extent of new discoveries. Several employment estimates for persons working on exploration rigs, production platforms and service vessels have been prepared but at present they are largely conjectural.[1] More precise estimates must await the preparation of offshore development plans. What is clear, however, is that when production begins there will be a significant increase in the number of persons who will be at risk working offshore, and safety will become an even more complicated problem because of the greater risks inherent in the production process.

In the search for and production of oil and gas in deeper water and harsher climates, the industry has had to face many risks and problems that constantly test the bounds of known technology. But the oil industry has a strong tradition of tackling difficult engineering problems and solving them successfully. It has accordingly brought this approach and the practical experience on which it was based to the evolution of offshore drilling techniques. The objective has remained unchanged: to provide a stable platform from which to drill. It is not surprising, therefore, that the pursuit of this central purpose has been by the extrapolation of existing land-based oilfield technology and the extension of tested methods.

Despite this predominantly industrial focus the activity takes place at sea. The unique nature of this industrial-marine endeavour, together with the constant evolution of new technology, has presented a challenge to agencies established to set standards and to govern the design and activities of more traditional craft. These agencies have tended to evolve their standards and their role, as did the rig designers, on the basis of experience. It was not until 1968 that a classification society developed rudimentary rules to govern the design and construction of MODUs and only in the 1970s did governments begin the process of developing regulations to control the activities which were occurring off their coastlines. Consequently, as the industrial technology evolved and accidents occurred, so did the regulatory system develop. The Caddo Lake blowout of the 1930s provided the stimulus for improved well control regulation. The loss of the *Sea Gem* in the 1960s focused concern on the structural integrity of MODUs and led to the development of classification rules which addressed the specific requirements of this type of floating structure. Latterly, the loss of the *Alexander L. Kielland*, the *Ocean Ranger*, and the *Glomar Java Sea* centred concern, on the part of both industry and government, on the adequacy of existing design and construction methods, training requirements, evacuation systems and rescue capabilities.

Past experience clearly indicates that the causes of accidents which result in either the partial or total loss of MODUs, and endanger the lives of the personnel who work on them, include environmental factors such as wind and waves, the design, construction and operation of the MODU itself, and the capability of those on board to deal with emergencies. There is generally no single cause of these accidents, as experience, particularly in the case of the *Ocean Ranger*, has shown. Blowouts have led to over 22 percent of all mishaps on MODUs and represent the largest single contributing factor to major offshore incidents. Structural fatigue, towing incidents, collisions, stability losses, drilling equipment malfunctions, fires, and explosion are also major factors which have led to partial or total MODU losses.

[1]These estimates fall in a range between 4,000 and 7,000 people. There are currently around 3,000 people working within the eastern Canada offshore.



1.5 A semisubmersible drilling on the Grand Banks of Newfoundland. Although drill ships were used there in the earlier years of exploration activity, the semisubmersible is now widely employed because it provides a more stable platform; jack-ups have not yet been used on the Grand Banks, primarily because of the presence of pack ice and icebergs.

The safety record shows that some types of MODUs are more prone to mishaps than others. The self-elevating or jack-up type has been the most vulnerable to damage or total loss; almost 70 percent of all mishaps since 1955 have occurred with jack-ups. There are unique characteristics of the jack-up which account for the higher incidence of mishaps: when its legs are jacked up for transit, its centre of gravity is high and consequently so, too, is the risk of capsize; during the jacking process there is the risk of punching through the seabed and losing stability. Drill ships and semisubmersibles have also had their share of mishaps since blowouts and structural failures are as applicable to these MODU types as they are to jack-ups. Most of the accidents to floating MODUs, however, have resulted from loss of stability because of mechanical failures, collisions, structural failures or human error.

Analysis of the risks in exploratory drilling off Canada's East Coast is limited by lack of experience. Although exploration began there in 1960, the total experience in terms of rig-years has been approximately 50 compared with 5,000 worldwide. No significant statistical conclusions about safety performance of drilling operations offshore eastern Canada can consequently be drawn. It has however been demonstrated that blowouts can occur as in the case of the semisubmersible *Vinland* and the jack-up *Zapata Scotian.* In both cases moderate wind and sea-state conditions made evacuation of the crew possible without loss of life. In the case of the *Ocean Ranger*, a chain of events including faulty design, a winter storm and lack of knowledgeable intervention led to the loss of the rig and of all on board. There have also been less serious accidents resulting from collisions with supply vessels and near-accidents from passing ships and icebergs.

Accidents may occur to support vessels, to helicopters, and to divers as well as to rigs. The seismic vessel, the *Arctic Explorer* sank in July 1981, with the loss of 13 crew members and the supply vessel, the *Seaforth Jarl* sank in 1984 when its cargo shifted during a winter storm because it was improperly secured. Accidents to helicopters used to transport crew and supplies have occurred in the North Sea. There have been recent helicopter accidents off eastern Canada and experience elsewhere indicates that this risk will increase and that more precautions will be required as exploration and production activities expand. Although diving activities off eastern Canada have not been accident-free, the safety record is appreciably better than in the North Sea or the Gulf of Mexico.

With the advent of the modern offshore drilling industry, the increasing complexity of the industry's organizational arrangements has fostered a dilution and diffusion of responsibility and of accountability of all the participants – designers, builders, owners, operators, contractors, and regulators. The *Ocean Ranger* disaster highlighted many of the deficiencies in the total management process which underlies and controls an offshore exploration operation. These deficiences have raised concerns in the minds of the public at large about the industry's ability to conquer the Northwest Atlantic and government's ability to assure acceptable standards of safety for persons working offshore and for those who will work there during the development and production phase. It is to these concerns that this Report is addressed.

2

PERSPECTIVE ON SAFETY

CHAPTER TWO PERSPECTIVE ON SAFETY

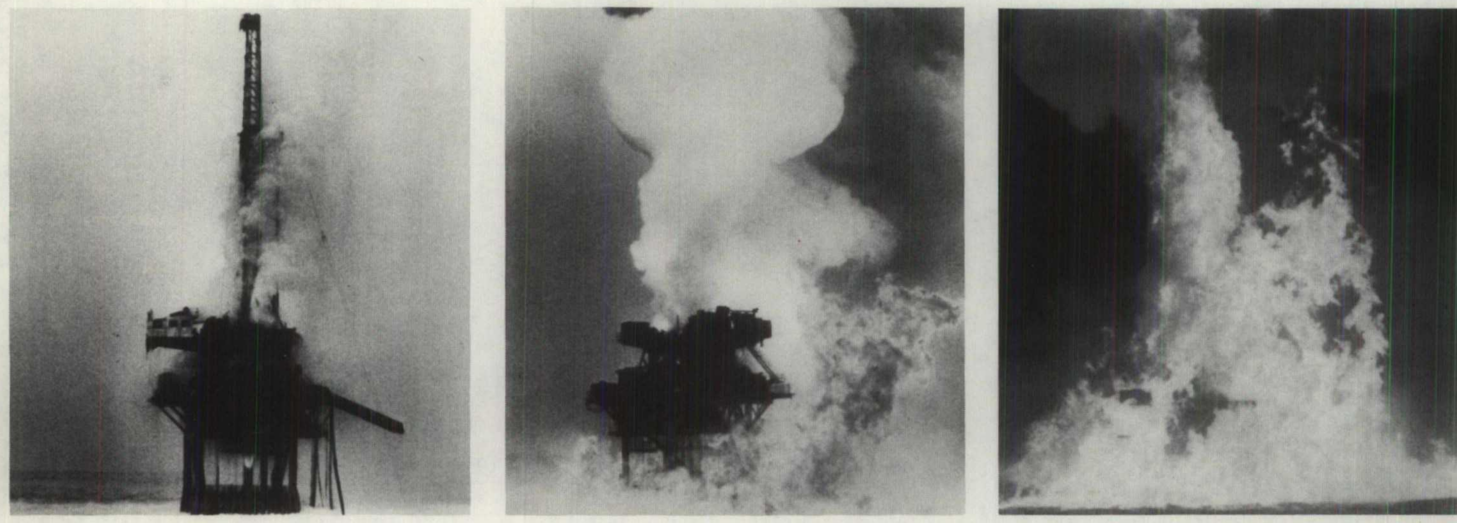
The *Ocean Ranger* marine disaster was not an isolated event. Its loss, following so closely upon the capsize of the *Alexander L. Kielland* for a combined loss of 207 lives, has raised serious questions regarding the reliability of the technology involved in drilling operations under winter conditions in the Northwest Atlantic and regarding the adequacy of the measures being taken to ensure the safety of those engaged in these operations. It has also raised questions regarding the nature of the risks that should be undertaken in the pursuit of oil and gas offshore.

Offshore drilling is predominantly an industrial activity taking place in a marine environment rather than a marine activity undertaken for industrial purposes. It is an extension to the oceans of a land-based industry where injuries to personnel at work are not uncommon and where catastrophic events such as blowouts and fires have punctuated the history of operations.

Those who live by the sea and earn their living from it have learned through experience how dangerous the sea at times can be and how cautious one must constantly be in facing the perils of the deep. The risks inherent to drilling into the earth's crust, when combined with these perils, make offshore exploration and drilling an unusually hazardous activity in which the achievement of acceptable levels of safety demands reliable technology, capable management, competent workers, and unrelenting vigilance.

The offshore oil industry is, of necessity, on the cutting edge of technological innovation. Until recent years, technology has been almost entirely the result of an evolutionary process extending back over several centuries. In this process, the traditional approach to safety has been: first, to identify and examine carefully all potential hazards; second, to do everything possible to eliminate the hazards or to mitigate their consequences; and finally, to proceed cautiously according to established principles. Whenever this evolutionary process has been ignored and a quantum leap forward taken, tragedy tends to result, as in the case of the collapse of the Tacoma suspension bridge when an innovative design, exceeding proven proportions, failed to take into account vitally important aerodynamic considerations. Man has learned from experience to do more of the right things and fewer of the wrong and to know that sound engineering principles, proven over time, are ignored at his peril.

Man's use of technology to extract mineral resources from the earth, to generate and distribute energy, to harvest timber and crops, to manufacture goods, to erect buildings, to transport and distribute people, messages and goods, has generated wealth but also created risks to life and limb. In spite of the contribution of technology to human welfare, people today are questioning, on a scale never before witnessed, the direction and values of western society and are expressing concern regarding the resulting threats to human safety from acid rain, toxic contaminants in



2.1 The devastating results of a blowout on a fixed production platform. Although well control technology continues to advance, the potential for the violent release of hydrocarbons from subsea wells is always present.

food and water, nuclear power, and a seemingly endless list of other putative hazards. Yet it is out of technology-based activities that the wealth is created to sustain health care and other social services that improve our collective welfare. There are those who would demand an assurance of complete safety before new ideas or new technology could be applied. If that had been the guiding rule in the evolution of the human race, man today would be a simple competitor with other predators in a hunting society. The great majority, on the contrary, have, often tacitly and without facing the underlying issues, opted for a cautious advance into the unknown. An underlying dilemma, however, is that those who reap the benefits may not be the same persons whose safety is endangered.

But, what is safety? The term in its human context has no meaning except in relation to potential risk of harm. It is essentially a relative term, the complement of risk. Risk is not new to our times and place. It has been a pervasive and persistent factor of man's condition since the beginning of life. It remains a constant companion, since man is daily at risk whether at home, at work, or on the highway. It is a feature of everyday life nor can it be avoided. There is no such thing as absolute safety; all that is achievable is a state or condition that can be deemed to be "safe enough" – acceptable to society and capable of being tolerated by those directly involved.

Human perception of risk varies whether the perception is individual or public, whether the risk is voluntary or imposed. The perception also varies with time, with place, and with the context of the activity. Man individually takes risks voluntarily and routinely that would cause a collective uproar, if imposed to the same degree by a corporate or public body. We are loath to have others do unto us what we consciously do unto ourselves. Perception of risk is highly coloured by the culture of a society and the context within that culture in which the activity takes place. Risks accepted as normal in some cultures would not be tolerated in others. The risks faced by a roustabout on an oil rig or a sailor on a ship are peculiarly different from those of an office worker on land. The risks encountered by those who earn their living on the sea or by steelriggers on high-rise structures may appear highly dangerous and recklessly undertaken to a prairie farmer. Perceptions change over time, and risks of years ago would not be acceptable to society today.

Many factors influence our perception of risk. One of the most potent of them is fear of the unknown – of the future side effects of current scientific enterprises and of new technologies; of radiation, for example, undetected by any of the senses, the effects of which may be long delayed even to the next generation. Another factor is the size of the disaster, real or apprehended. The crash of a large aircraft, the loss of a semisubmersible, the collision of a school bus at a railroad crossing cause shock and an outcry for improved safety measures. And yet, hundreds more people are killed in automobile accidents and die unnoticed except for those close to them. It is also a curious feature of human nature that a society which balks at heavy expenditures to prevent possible accidents and which permits, for example, a lack of protective covering over a well will spend unlimited sums to rescue a child who has fallen into one.

The incidents that nowadays attract public attention arise in complex systems of men and machines. A classic example of a complex system is an offshore drilling operation. It has a unique feature, adding to the normal risks to be faced, in that it combines marine and industrial cultures in a hazardous marine environment, thus creating demanding challenges both for the designers of rigs and for their operators. In the operation of offshore drilling rigs, as of all complicated structures, the essential element in safety, however good the technology involved, is the human element. The maintenance of the quality of the drilling rig as a safe haven and as a productive platform depends critically upon sound practices in operating those systems, such as ballast control and well control, through which human intervention to avert an emergency can take place. The standards to which safe practices are carried out depend on the clarity of organizational authority and its delegation, on the judgments of supervisors, on the competence and experience of specialized teams and on the native abilities, training and morale of all workers. Significant weakness in any dimension of the human element will reduce the working margin of safety and may, as in the loss of the *Ocean Ranger*, contribute directly to a chain of events that ends in catastrophe. For real safety in any technology is a highly human factor and a heavy price is exacted for carelessness, ignorance, or poor judgment on the part of those involved.

The failure of any critical system is of singular concern because these systems provide the means for exercising human control of the drilling rig during normal operations and in emergencies. In complex technologies, such as aerospace, nuclear power and chemical processing, it is customary to protect against failure in critical systems by having backup or redundant means of control, and to instrument the operations so that the fact of failure is made transparently evident to those responsible for intervening. While the offshore oil industry has appropriated the latest technology in seismic exploration, drilling and the structural design of drilling units, it is by no means clear that it has done so to an equivalent level in the instrumentation and redundant control of critical systems. Neither has the industry stimulated the responsible governmental regulators to give leadership in ensuring that more reliable and technically feasible means of escape and survival in emergencies are devised and required.

The rig designer must design a drilling rig that is stable, efficient and seaworthy under all prescribed and foreseeable circumstances. There is no doubt that perfect safety is unattainable in an imperfect world. In the real world, some measure of safety must be surrendered, some degree of risk must be accepted, if an economical and useful drilling unit is to be designed and constructed. What that measure or degree is at any period of time is determined by prevailing economic and social evaluations. If it is deemed to be too high, the activity will not be undertaken. In the actual practice of striking the balance between cost, utility and safety, the key factors are engineering judgment based upon knowledge, experience, and proven technology, and the accountability of those making the decisions.

The overall failure of technological systems to sustain the safety of those who operate them stems from three primary causes: from external environmental disturbances, internal failures of basic structures or critical subsystems, and ill-conceived human action or lack of knowledgeable intervention in response to evidence, real or apparent, of abnormal behaviour. Human competence is at the core of safety in the use of technologies. In the face of external disturbances such as a collision with a

2.2 The Grand Banks present an ever-changing environment in which offshore drilling equipment must function efficiently and safely. When transformed by high winds and seas, such as those encountered on the night of the loss of the *Ocean Ranger*, the Northwest Atlantic challenges even the most recently designed drilling rigs.

supply vessel that punctures a compartment of a pontoon, or of internal failure of air supply to a well control system, competent human intervention may often recover a large part of any potential loss in the margin of overall safety. There is dramatic historical evidence that, as in the loss of the *Ocean Ranger*, incompetent human intervention can destroy margins of safety.

In the operation of a drilling rig, as in all industrial endeavours, safety ultimately depends upon the individual who has been carefully selected and trained for the task that he or she is expected to perform. Individuals have the responsibility of being alert to ensure their own safety and that of others who by their acts of omission or commission may be put at risk. To this end, everyone must know his or her job thoroughly, be physically and mentally fit to perform all assigned tasks even under emergency conditions, and have the intelligence and education, particularly if the position involved is a key one, to know when something goes wrong and what action then to take. Training to the level of knowledgeable intervention, when it is required, is the key to the safety of the individual and of others. The operation of any intricate system of man and machine requires teamwork and the conscious recognition by all members of their responsibility for their own safety and for the safety of the other members of the team. Their safety may be endangered if too many ill-trained or inexperienced persons are inserted into the team at any one time.

There are those who seek reduction of risks through increased regulation. During the past few decades, there has been a great increase in regulatory control without comparable discernible benefit. Regulations do not of themselves ensure safety and may be counterproductive in their consequences. Responsibility for safety may become a complacent acceptance of rules and regulations, and the evolving technology that is applied may be only as good as the rule and the rule formulators. Those who argue for greater regulatory control ignore the ever-present human element. The human element in safety in this context has two basic dimensions. It is expressed in the judgments that determine the characteristics of the equipment and of the personnel coming together to constitute a MODU operating at a particular time and place. Designers, builders, owners, operators and regulators working as part of an evolving industry all influence this outcome. Second, the human element is expressed in the quality of the judgments made in resolving the balance between safety and

2.3 The remote and demanding work environment of an offshore drilling rig requires a commitment to safety by all those involved. The knowledge, judgment and trained responses of the driller form the first line of defence against well control problems.

productivity during operations. These judgments are guided by a fabric of safe practices carried out by the personnel on board. Thus, here too, safety depends fundamentally on human integrity, judgment and competence. Regulation can establish performance standards in critical areas of technology and operating practices but it cannot encompass the many dimensions of human behaviour that contribute to or detract from safety.

Many are involved, upon whom those who work on the rig must depend for their safety – those who may never be identified but whose engineering knowledge and sound judgment are brought to bear in the configuration, detailed design, and construction of a rig capable of meeting performance standards under anticipated environmental conditions. They are the naval architects, metallurgists, steelmakers, welders, and a host of others. They are the designers who create the structural system and who devise specialized subsystems, such as for ballast control, communications, and evacuation. Then there are the inspectors who exercise control during the construction process. All share responsibility and in some way should be held accountable.

A mode of enhancing safety that is likely to be more effective than regulations is a more rigorous enforcement of this principle of accountability; the continuing professional responsibility of those involved in the design and construction of the drilling rig, and their accountability for its structural integrity and for the efficacy of its systems; and the overriding responsibility of the drilling contractor who owns and operates the rig and of the operator who has the permit to drill, both of whom must be held accountable for the safety of the rig and of its crew. There is a risk involved in practically every human activity, and no precautions at any price can make any activity completely safe. The accepted practice in business is to seek a compromise where the level of expenditure on safety reduces risk to a tolerable level, while maintaining potential benefits sufficiently high to make the venture economically attractive. In pursuit of this goal, the decisions in the design and construction process leading to an acceptable compromise are numerous and complex and are made by many professionals, but the chief executive officer of the company owning the rig must accept responsibility and be held accountable for the wisdom of these compromises.

High standards of safety in the workplace are achieved when well-designed equipment is operated properly by well-managed and well-trained persons. Occupational safety is maintained by keeping these factors in a state of positive balance, in what is normally a highly dynamic situation. It requires constant vigilance to ensure that equipment is kept operating within permissible limits, that the persons responsible for each aspect of the operation continue to be well selected for the tasks they do, and that they are knowledgeable about what they are doing. The more demanding the work and the work environment, the more essential it is to ensure that a continuing effort is made to maintain their health, their motivation, their safety consciousness and, thus, their commitment to safety.

When man attempts new ventures in a harsh environment, unforeseen events are bound to occur in spite of the most careful preparation. Harmful effects from these unforeseen events can be kept to a minimum by ensuring that safety is borne in mind throughout the entire process of planning, construction, and operation. The level of safety that is achieved in any rapidly evolving industry depends, more than anything else, on the commitment of the senior management of rig owners and operators. Therein lies the path to greater safety.