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Abstract: The Outer Continental Shelf Lands Act Amendments of 1978 (43 USC 1347) (OCSLAA) mandate specific government actions with regard to the safety of OCS operations, among them a study by the Geological Survey and the Coast Guard of the adequacy of the existing safety and health regulations and of the technology, equipment, and techniques available for offshore exploration, development, and production. In June 1979, the Geological Survey requested that the National Research Council (NRC) undertake an assessment of the adequacy of technologies and regulations as a major contribution to the mandated study. For its part, the NRC appointed the Committee on Assessment of Safety of Outer Continental Shelf Activities to conduct the assessment under the aegis of the Marine Board. Members of the committee were selected for their experience in matters relating to safety engineering, offshore operations, the design of structures, engineering of petroleum drilling and production systems; operations research and management, marine biology, with emphasis on the environmental effects of oil, risk assessment and economic analysis, and regulatory and compliance procedures. The charge to the committee was to review prevailing regulations and technologies and to assess their adequacy in providing for human and environmental safety in OCS drilling and production. The committee was also asked to develop a methodology for assessing the adequacy of regulations and technologies in the future.

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SAFETY AND OFFSHORE OIL

Committee on Assessment of Safety of OCS Activities

Marine Board

Assembly of Engineering

National Research Council

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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance. This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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FOREWORD

This report is based on a study of a timely subject: the adequacy of federal regulations and industrial technology for ensuring the safety of oil and gas operations on the outer continental shelf (OCS).* The findings are specifically intended to be a statement of principal topics that must be addressed in the report to the President by the U.S. Geological Survey and the U.S. Coast Guard on OCS safety and the plan to promote safety, as required by the Outer Continental Shelf Lands Act Amendments of 1978 (P.L. 95-372, Sec. 21(a)).

Since issuing its first report on the safety of petroleum operations on the OCS in 1972, the Marine Board of the National Research Council has performed several studies of the subject. The reports of these studies offer conclusions and recommendations for the improvement of the government's regulation of offshore safety. Consistent with the long-term objective of the Marine Board to contribute to this matter of vital public interest, the present report also includes conclusions and recommendations that are likely to advance the cause of safety in OCS oil and gas operations.

As in all Marine Board studies, members of the committee conducting the investigation and review were drawn from broadly diverse vocations, areas of expertise, and personal interests. The Marine Board and, particularly, the study chairman, are indebted to the committee members for their individual contributions of effort, knowledge, and experience and for the consensus they achieved.

The first Marine Board effort was undertaken in the wake of public reaction to a major oil spill in the Santa Barbara Channel in 1969. During this study the committee was reminded of the implications of major accidents in offshore oil and gas operations by the blowout of Ixtoc-I off Mexico in 1979 and the collapse of the Alexander Kielland platform in the North Sea in 1980.

Several issues and courses of action have been consistently emphasized in the reports of the Marine Board on offshore petroleum operations--e.g., the importance of standards that are supported by a consensus and their industry-wide application. The particular contribution of the participants in this study, many of whom brought their expertise to the OCS for the first time, is their recognition of the overriding importance of human performance in the safety of

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*The OCS is that portion of the submerged continental margin that is subject to U.S. jurisdiction. For the purpose of this report, the OCS is defined to extend from the state's offshore boundary (usually three miles offshore) out to the limit of economic exploitation.

day-to-day operations offshore. The greatest potential for minimizing the risk of future offshore oil and gas development lies neither in technology nor regulation, but in the abilities, training, and performance of the people engaged in the industrial and regulatory activities.

George F. Mechlin
Chairman
Committee on Assessment of Safety
of OCS Activities

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PREFACE

Origin of the Study

The Outer Continental Shelf Lands Act Amendments of 1978 (43 USC 1347) (OCSLAA) mandate specific government actions with regard to the safety of OCS operations, among them a study by the Geological Survey and the Coast Guard of the adequacy of the existing safety and health regulations and of the technology, equipment, and techniques available for offshore exploration, development, and production. In June 1979, the Geological Survey requested that the National Research Council (NRC) undertake an assessment of the adequacy of technologies and regulations as a major contribution to the mandated study.

For its part, the NRC appointed the Committee on Assessment of Safety of Outer Continental Shelf Activities to conduct the assessment under the aegis of the Marine Board. Members of the committee were selected for their experience in matters relating to safety engineering, offshore operations, the design of structures, engineering of petroleum drilling and production systems; operations research and management, marine biology, with emphasis on the environmental effects of oil, risk assessment and economic analysis, and regulatory and compliance procedures. Members also represented public interests in OCS development. The principle guiding the constitution of the committee and its work, consistent with NRC policy, was not to exclude the bias that might accompany expertise vital to the study, but to seek balance and fair treatment.

Scope of the Study

The charge to the committee was to review prevailing regulations and technologies and to assess their adequacy in providing for human and environmental safety in OCS drilling and production. The committee was also asked to develop a methodology for assessing the adequacy of regulations and technologies in the future.

The committee attempted to conduct a comprehensive assessment of safety, taking "safety" to include that of people, the marine environment, and property and encompassing the lessening of risk and the avoidance of accidents.

The committee recognized that its examination of OCS safety provides the technical basis for completing the assessment of OCS safety and preparing the plan to promote safety, that are required by the OCSLAA.

In its deliberations, the committee found it necessary to define "regulation" as a government requirement that demands compliance, regardless of the form it takes--statute, regulation, order, or standard.

Limitations of the Study

The study mandated by Congress is of the safety of the "exploration, development, and production of the minerals of the outer continental shelf" (OCSLAA). The committee interpreted this as an assessment of the safety of oil and gas operations on the OCS: the development of other OCS minerals, such as sand and gravel, was excluded from the study because of limited industrial and regulatory activity.

The law also explicitly calls for the study to be an assessment of the adequacy of the regulations and technology. The committee adhered strictly to this precept. In assessing the adequacy of regulations, the committee directed its attention to regulatory practice and compliance. No attempt was made to broaden the evaluation of regulations into a management audit of government responsibilities and programs.

The committee excluded detailed consideration of the health of offshore workers, air pollution, diving, and transportation of people and materials to and from offshore structures, except for certain aspects of diving and transportation that are unique to the offshore industry (such as offshore loading facilities).

Nor did it attempt to assess the vulnerability of offshore structures to sabotage or attack. While sabotage and attack are important aspects of safety offshore, their investigation is beyond the committee's charge.

The committee sought to document the effects on the marine environment of intentional and accidental discharges of petroleum and drilling fluids from offshore operations, rather than to judge whether the effects are acceptable.

Study Organization

The committee's work involved developing a methodology for gathering information on OCS safety, and analyzing the adequacy of technologies and regulations aimed at providing for the safety of OCS activities. The committee's sources of data on OCS safety incidents are described in Appendix C. Appendix D lists the regulations assessed in the study, and Appendix E reviews the technical and social perspectives that need to be considered in assessing adequacy.

The committee's technical analysis was divided for convenience into five areas of concern--well control, fires and explosions, installation loss, workplace safety, and operational discharges. The committee's technical analysis of OCS safety was conducted primarily in a workshop convened in Avalon, California (Catalina Island), in June 1980 and in a subsequent meeting held in Reston, Virginia, in

SUMMARY

Offshore areas of the United States now provide 12 percent of domestic petroleum, and the government projects that this will grow substantially. It is expected that much of the growth will occur in the hitherto inaccessible regions and harsher environments of the Arctic and the Atlantic.

To advance the contribution of offshore oil and natural gas resources to the national energy supply, the U.S. government takes measures to minimize the risks of their development and ensure the safety of offshore workers, the marine environment, and offshore installations. Serious accidents or damage from chronic discharges during any offshore oil and gas operation could endanger human life, valuable natural resources such as fish, and important coastal areas.

The Outer Continental Shelf Lands Act Amendments of 1978 (43 USC 1801) (OCSLAA) establish a national policy for the conduct of the nation's offshore program, and among their many provisions recognize the importance of safety in offshore development. The amendments call for a comprehensive assessment of the nation's capability to assure the safety of oil and gas development on the outer continental shelf (OCS). If regulations and standards are found to be inadequate or inappropriate to new technologies and conditions and standards, and to the conditions anticipated in frontier regions of the OCS, as new tracts are leased for exploration and production, the Congress, has directed certain federal agencies to modify, replace, or eliminate them. The agencies, among them the U.S. Geological Survey, were required by law to perform a study of the adequacy of existing safety and health regulations in connection with the technology, equipment, and procedures used for exploration, development, and production on the OCS and to report their conclusions to the Congress.

Hence, in June 1979, the U.S. Geological Survey requested that the National Research Council (NRC) assist in its study by undertaking an examination of matters relating to the safety of offshore operations. The NRC convened the Committee on Assessment of Safety of OCS Activities to conduct the study under the aegis of the Marine Board.

The committee conducted a comprehensive assessment of safety on the outer continental shelf, taking "safety" to include that of people, the marine environment, and property, and encompassing the lessening of risk and the avoidance of accidents. In its work, the committee did not attempt to place OCS oil and gas development in perspective with other resource development activities. With regard to assessing the adequacy of regulations, the committee directed its attention to regulatory practice and compliance. No attempt was made to broaden this evaluation into a management audit of government responsibilities and programs.

The committee excluded detailed consideration of the health of offshore workers, air pollution, diving, and transportation of people and materials to and from offshore structures (including tanker transportation), except for certain aspects of diving and transportation that are unique to the offshore industry.

In considering the fates and effects of discharges from oil and gas operations in the marine environment, the committee sought to document the known consequences rather than to judge whether they are harmful or acceptable.

The committee initiated its study with a request for information and opinions on the safety of OCS activities from interested parties. This served to identify sources of public and industrial concerns. The committee then reviewed the historical record of the safety of OCS activities and the conclusions and recommendations of previous studies. The committee then assembled data on OCS technologies and regulations, organizing the data by areas of safety concerns.

The committee described the various technical and social perspectives that must be considered in an assessment of the adequacy of technologies and regulations to provide for OCS safety. The next task in the committee's work was to evaluate the utility of analytical techniques such as benefit-cost analysis and risk assessment. While the usefulness of such techniques was recognized, the committee considered their applicability to its work to be limited. As an alternative, the committee prepared a set of questions on the adequacy of data, technologies, and regulations to provide for the safety of OCS activities. The questions are not in any sense criteria for measuring adequacy. They are, instead, analytical techniques to initiate inquiry into the adequacy of technologies and regulations. The next task of the committee was to prepare for each area of safety a technical description of technologies and regulations for analysis and assessment.

The final assessment of adequacy is a judgment and is the consensus arrived at by the committee through collective evaluation of the technical analysis and discussion.

The committee's findings are reproduced in their entirety in this summary. No priority is implied in the order of presentation.

Underlying Safety Considerations

The Coupling of Resource Discovery and Technological Development (page 223)

Many discrete technologies are used in the exploration, development, and production of oil and gas from beneath the oceans. Failure of any particular technology to provide for the safety of oil and gas operations can have a wide range of consequences to people, property, and the environment.

Technology for offshore development has been forthcoming to date in response to the opening of new OCS areas and the discovery of hydrocarbons. It is not possible for the committee to conclude whether developing technologies will provide adequately for OCS safety in frontier areas until these technologies are known and have been demonstrated. It is also difficult to evaluate fully their environmental risks and economic costs.

Thus, it is especially important that technologies and operational procedures be carefully and continually assessed as operations move into new offshore regions to ensure that they are in line with the environmental conditions. Many existing technical standards for OCS operations were not originally developed for use in the Arctic, in deepwater, and in fragile biological areas. They do not take specific account of the environmental conditions in these areas and require special attention.

The Human Element in OCS Safety (page 234)

The overall experience (and possibly the skill) of the OCS work force appears to be adversely affected by both slack and high demand periods--i.e., by fluctuations in the level of OCS activity. Industry can institute measures to compensate (when necessary) for inexperience in the work force, such as training programs, tighter procedures, and closer management supervision. Management emphasis on safety must be established at the top of the corporate structure, and it must be effected through a system of motivation and responsibility that is unmistakable and that reaches every supervisor and worker.

The present regulatory system is not structured to motivate concern for safety at every level by taking advantage of the whole industrial management structure. As currently constituted, the federal program comprises regulations based on the idea that if a law commands, all will obey or conform and that inspection will ensure compliance.

There are a number of options open to the government that could reasonably be expected to enhance management interest in the safety performance of OCS workers.

> Government agencies should incorporate into the regulatory system alternative techniques that could better utilize the potential of the industrial management structure to promote safe company and worker performance. In developing these, the government should consider such mechanisms as public visibility and accountability, establishing expectations of safety performance, selective enforcement, limited entry, personnel standards, and analytical review of operating experience (page 241).

The Interaction of Regulations, Technologies and The Environment (page 244)

The regime for regulation of OCS petroleum operations is a mixture of four distinct regulatory philosophies. The first comprises general statements of policy to provide direction to the OCS program. The second is equipment-specific or applies specific maxima or minima--e.g., producing wells shall be equipped with a surface-actuated downhole safety device. The third philosophy generates performance-oriented requirements describing the result that must be achieved to comply with the regulation--e.g., the requirement for shutdown of pipeline pumps when abnormally high or low pressures occur. The fourth calls for preparation and submission of equipment and operating plans by the operator, followed by government review and approval. The requirements are usually only generally stated in regulation--e.g., the American Petroleum Institute's recommended practice for fixed platforms transformed into regulation by the Geological Survey.

The committee is aware of a wide range of opinions on which of the regulatory approaches is the most efficient and effective. The committee concludes that no single approach is feasible and that the current regulatory approach of using all four is more likely to be an overall strength than a weakness. While a major overhaul of the OCS regulatory program is not needed to provide for the safety of OCS activities, there is need for improvement in several important areas.

Government regulation, especially that which relies on the review and approval of plans and on inspection and monitoring for compliance with standards, can only be as effective as the technical and enforcement capabilities of government personnel. Since the committee was not equipped to evaluate the capabilities and effectiveness of government personnel (and deliberately did not do so), this critical aspect of the effectiveness of regulation--the adequacy of the numbers, or technical and enforcement capabilities, of those who run the regulatory programs--was not considered in the committee's findings. This determination on a continuing basis does not appear to have been adequately considered or provided for in legislation or in executive action.

Section 21(b) of the OCS Lands Act Amendments (P.L. 95-372), the Best Available and Safest Technologies (BAST) requirement, is intended to provide a focus for the many elements of the OCS safety program. The ability to determine which technologies are the best available and safest is contingent on having adequate safety information. Some type of information reporting, analysis, and utilization system (including environmental information, as discussed in Chapter III) is a central element in the implementation of the BAST requirement. The Failure Inventory and Reporting System (FIRS) is intended to contribute to this purpose; however, as currently constituted and utilized, FIRS is inadequate. Improvements in FIRS data collection and utilization are needed and ought to be based on continuing review of safety information requirements and the performance of FIRS.

The government's procedures and practices are inadequate for developing important information on safety problems and innovations and promoting its dissemination and use. Without a strong safety information component in the OCS regulatory program, it is not readily possible for the government to identify safety problems and courses of action to resolve them, as would seem to be required by the BAST requirement. Nor is the government able to identify the poorer performers and target them for close and continuous scrutiny, while subjecting companies with excellent safety records to less regulatory attention.

> The Department of the Interior, the Coast Guard, and the Environmental Protection Agency should take steps to strengthen the safety information elements of the government's OCS regulatory program. They should:
>
> - Review and revise existing reporting requirements (e.g., those covering accidental discharges, workplace accidents, and fires and explosions) to ensure that the information gathered for safety purposes is limited to what is really necessary for the regulation of safety and is useful in monitoring and analyzing the safety of OCS activities. the information should include causal factors in the reporting of accidental spills. All this is necessary in implementing FIRS.
> - Conduct more comprehensive and frequent investigations of OCS accidents (and near misses) in order to develop information relative to the causes and consequences of accidents.
> - Make use of the safety information that is gathered in the identification, analysis, and resolution of safety problems, in the continuing evaluation of the adequacy of technologies in the application of BAST and in evaluating the efficiency of the regulatory process.
> - Conduct additional research on the fates and effects of discharges on a generic and site-specific basis.

There is an inseparable link in the safety performance of OCS technologies between the interaction of people, equipment, and operating procedures. It is necessary to include the interactions in evaluating technologies to determine whether they are the best available and safest.

> The Geological Survey and the Coast Guard should define the scope of the BAST requirement and program to include the interaction of people, equipment, and operating procedures in the evaluation of OCS technologies and to take account of these interactions in their regulatory actions.

Technical Analysis of OCS Safety

Environmental Effects of OCS Operations (page 63)

Scientists agree that spills and discharges at high concentrations of petroleum, drill cuttings, and drilling fluids produce an adverse effect on marine biota. There is no clear agreement among ocean biologists as to whether low concentrations of petroleum, drilling fluids, and cuttings produce significant effects on marine biota.

While there is a large amount of scientific information on the effects of offshore operations on the marine environment, the data have been acquired piecemeal and often have not been rigorously analyzed. Lack of agreement persists concerning the validity, interpretation, and general acceptance of data. Adequate effort has not been directed to using existing data and structuring scientific programs to achieve a consensus on the fate and effects of petroleum, drilling muds, and drill cuttings on the marine environment.

> Several courses of action should be pursued by the oil and gas industry and the Bureau of Land Management's (BLM) OCS Environmental Studies Program to enhance the possibility of resolving conflicting views regarding effects of discharges, as well as selecting an acceptable environmental data base.
>
> These include the following:
>
> - The conduct of a critical peer review of the existing research concerning the fate and effects of OCS discharges. Among the alternatives available for accomplishing this are establishing a steering group and contract study under the Department of the Interior's Environmental Studies Advisory Board; utilizing the peer review experience of the National Science Foundation by having the review conducted under its auspices; or commissioning an independent study for these purposes.
>
> - Updating of the National Research Council's 1975 study of the fates and effects of petroleum in the marine environment (an update is currently in progress).
>
> - A similar independent comprehensive examination should be conducted of the fates and effects of drilling fluids and cuttings and produced water in the marine environment.
>
> - Additional research to characterize by location, extent, and duration the fate and effects of discharges, particularly in frontier areas of recognized biological importance or sensitivity. Specific studies might include

> analysis of the toxicity, carcinogenicity, and mutagenicity of discharges; the content and distribution of OCS discharges; establishment of circulation patterns in areas of OCS operations and where discharges are disposed of; and documentation of biological effects of discharges. To be effective this research program must include the development of a consensus on research objectives, methodologies, data quality, and method of interpretation, and must be long-term, flexible, well managed, and carefully integrated into the decision-making process.

A great deal of attention has been devoted to the effects of hydrocarbons in the marine environment; however, little study has been devoted to the effects of gas blowouts in environmentally fragile areas.

> The BLM's Environmental Studies Programs should conduct research into the effects of gas blowouts in environmentally sensitive areas where the threat of a gas blowout may exist.

Intentional Discharges (page 72)

Without a sound scientific basis for decision-making about environmental effects, it is not possible to conclude whether the technology now in use to control discharges provides or does not provide adequately for the safety of OCS operations. The leasing program of the Department of the Interior is not structured to establish the scientific basis in a timely fashion.

Three agencies--the Environmental Protection Agency (EPA), the Coast Guard (USCG) and the Geological Survey (USGS)--regulate intentional discharges from OCS operations. The regulations are diverse in form, complex in structure, and overlap within and among agencies. Some important regulatory obligations remain unimplemented or unenforced. Many environmental requirements are imposed after leases or permits have been issued, and these are interpreted and implemented at the regional level in a manner that is often not predictable and/or insulated from public review. Eliminating these flaws of implementation would have a positive effect on environmental protection and OCS energy development.

The EPA's regulations appear to be the most comprehensive and stringent of any agency. This is particularly true of the ocean discharge criteria. The regulations of the EPA that were examined by the committee are performance-based. They establish water quality or pollution control objectives based on the capabilities of technology, the prevention of environmental harm, and other factors. Operators are permitted to meet the objectives using the techniques or equipment they deem most practicable.

Many BLM and USGS regulations are general and contain undefined terms. This imposes an unacceptable level of uncertainty on both the industry and on those concerned with or affected by pollution.

With the exception of the ocean discharge criteria, regulations applicable to OCS discharges focus on concentration standards and do not limit the quantities and rates of discharges. The regulations also do not set specific standards or definitions for dispersion or mixing zones. As a consequence, variable burdens are imposed on ecosystems without consideration of overall effects on the system.

Existing procedures allow lease stipulations to be altered after a lease sale without an opportunity for public notice and comment.

Regulations of the EPA, BLM, and USGS allow for variability among sites and can be adjusted to reflect special site sensitivities. However, the standards for flexibility have not been stated with specificity and are generally left to the discretion of the regulator involved. Often the application of variation hinges on post-lease sale, post-permit surveys or studies, rather than on identification of special needs if any, including studies of potential effects, before the sale or permit issuance. By structuring flexibility as a post-sale or post-permit process, the regulations introduce uncertainty into the operations and the conditions imposed on them. This creates a difficult planning environment for the companies and for those concerned with potential pollution. It may mean that damage will already have occurred before conditions are imposed. It may also create an agency disincentive for adjusting the regulations post-sale or post-permit.

> The EPA should complete the implementation of its regulatory authorities on the OCS, as required by law. It should: (1) move quickly to implement the National Pollutant Discharge Elimination System program in all OCS areas,and (2) develop and implement best available technology, best conventional technology and new source performance standards for OCS activities.
>
> In implementing regulatory programs, the government agencies should consider the quantities and rates of discharges; their concentration; the abilities of the receiving water to mix, disperse, or absorb the material; and the biological sensitivity of the receiving area.
>
> Government regulation should be made more predictable by providing that necessary background studies are completed and permit conditions established prior to the awarding of OCS permits and leases. In addition, clear standards need to be set to guide post-permit and post-lease sale decisions. Modifications to lease stipulations should receive a level of public review comparable to that of the original lease stipulation.
>
> The EPA and the USGS should expedite the clarification of their respective responsibilities for the regulation of operational discharges, including the implementation and enforcement of regulations.

Well Control (page 84)

In the past 10 years, 55 instances of lost well control have been recorded on the OCS of the U.S.--incidents that range in duration from a few seconds to three weeks. These incidents resulted in 14 lives lost and 34 injuries, spills ranging from trace amounts to 53,000 barrels in one blowout, and 7 lost rigs. The consequences of these blowouts and, by implication, the hazards posed by potential blowouts, for personnel safety, and the safety of the marine environment and property vary with the circumstances of each, particularly the geology of the formation and the location of the accident. Any blowout could have serious consequences, and control is difficult to regain once lost. Thus, both industry and government have strong incentives to prevent them.

The basic physics, hydrodynamics, and chemistry of managing subsurface pressures are understood. However, predictive models of the control of a well have not yet been provided with data adequate for accurate predetermination of all well-control parameters before drilling. Improved measurement of the maintenance of the mud column during all phases of well drilling will contribute to the control of kicks and prevention of blowouts. These measurements include, but are not limited to measurement, of mudflow and downhole pressure.

> Development and application of reliable instrumentation, especially for the measurement of mudflow and downhole pressure, should be a focus in the implementation of the best available and safest technologies requirement by the Geological Survey.

The technology available for well control has developed over time, piece by piece, practice by practice, and is still being improved and tested. When properly selected, installed, maintained, and conscientiously applied, the equipment and practices can prevent blowouts except in the most unusual circumstances.

Well-control accidents are chains of events that usually involve failures in (or by) equipment, people, procedures, and adherence to procedures. There is little factual information about the contribution to accidents of individual elements of the system (i.e., equipment, people, procedures, and adherence to procedures). However, most if not all blowout causes include personnel failures to implement good well-control practices. The pressure of performance (i.e., hole drilled per unit time or stipulated dates for lease development) produces unfavorable effects on the safety of the whole system by contributing to less than satisfactory material condition, operational planning, including recognition of latent or suspect geological factors and choice of equipment; selection, training, and qualification of personnel; and adherence to good procedures.

To the extent that the contribution of equipment and operating procedures to accidents can be isolated and analyzed, there is little evidence that failure to perform as designed is significant. It is not possible, however, for the committee to conclude whether the equipment and operating procedures are optimum for use by personnel acting under fatigue, stress, boredom, or other adverse environmental factors of the workplace.

For individual blowouts, causes in terms of the chain of events that constitutes the causes may be understood in engineering terms by a limited group of people immediately associated with the operators suffering from the accident and also possibly by technical personnel of the Geological Survey. The public availability of the information in a verifiable fashion is severely limited. Subject to constitutional constraints against self-incrimination, the conduct of full-scale investigations under the authority of the OCS Lands Act Amendments of 1978 could bring to light useful facts about the interactions of men, machines, and nature in the loss of well control.

Offshore industry personnel emphasize that the capability and quality of rigs vary. In the chains of events associated with blowouts, marginal rig capabilities or equipment maintenance can be contributors to increased accident risk. Sound well-drilling plans should account for the expected or potential effects of the geology and operating environment in the selection of individual rigs and equipment.

Some companies seem to have better records than others in well control.*

Because of increased drilling and development activity, there has been a reduction in the experience (and possibly the skill) level of personnel involved in drilling and other well-control operations. Further expansion of leasing activity and development in older fields could exacerbate this problem. Although it is difficult to assess in a quantitative way, the committee is concerned that the risk of blowouts will increase unless the industry can compensate for inexperience, for example, through increased training.

> Industry should compensate for inexperience in the work force through improved training, tighter procedures, and closer management surveillance.

The regulation of drilling (including well control) depends heavily on the preparation, submission, approval, and execution of specific plans for each well. The adequacy of this regulatory process depends on a high level of technical knowledge on the part of the individuals in the operating organizations who prepare and implement the plans and those in government who review and enforce them.

Of the 55 blowouts that have occurred on the OCS during the last 10 years, 10 have occurred during workover and remedial operations. No specific training requirements or government-sanctioned operating procedures apply to these operations. The American Petroleum Institute is developing operating and training practices for these operations.

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*See also the findings of "The Human Element" section below.

> The Geological Survey should expand the coverage of its present regulations to include training requirements and operating procedures for well control during workover and remedial operations. It should utilize industry-developed recommended practices for these operations as a basis for regulatory action.

Pipelines (page 106)

Reported oil discharges from OCS pipeline failures over the past 10 years have been small in absolute terms and as compared with the volume handled (approximately 12 bbls per million bbls transported).

Impact below water (anchor-dragging) and corrosion are the leading causes of discharges because of pipeline failures.

Pipelines are vulnerable to anchor-dragging accidents, particularly in the course of OCS construction operations. Standard procedures do not exist that address the documentation of pipeline locations, the transfer of information about the location of pipelines to contractors and others who might anchor in their vicinity, and anchoring operations in the vicinity of pipelines.

Pipeline risers are susceptible to impacts and to internal and external corrosion. Design standards do not exist that address riser location within the platform, method of riser support, and protection from impacts and external corrosion.

Standard procedures do not exist to ensure that operators will not pump into a pipeline network without being certain of its pressure integrity.

> The DOI should require that procedures be established to ensure that operators will not produce into a pipeline network without being certain of its pressure integrity.

The safety benefit of trenching or burial of pipelines depends on the environmental and operational conditions of the pipeline location. Regulations covering pipeline trenching or burial are occasionally implemented without regard to the safety benefit of such action. Trenching or burial does not always protect pipelines from impacts.

Shear sleeves can be used to minimize pipeline failures that occur as the result of pipeline movement induced by such phenomena as mudslides or earthquakes. Check valves used in conjunction with shear sleeves may be beneficial in some instances for keeping pipeline discharges to a minimum in the event of such failures.

Pipeline regulations comprise both performance requirements, which incorporate accepted industry standards, and specific requirements, which are adopted after review and comment by industry and other interested parties. With the exception of requirements for trenching or burial, regulations are flexible enough to take site-specific considerations into account.

Pipeline regulatory requirements have increased the uniformity of application of accepted industry practices. Some specific requirements, notably those requiring drip pans, shut-in valves, pressure sensors, and check valves, have reduced the number of spill incidents. These requirements can be expected to benefit the safety record of operations in frontier areas to a greater extent than in developed areas due to early and total application to every line laid.

The lack of implementation of a memorandum of understanding on pipelines between the Department of the Interior and the Department of Transportation has left operators confused with respect to the allocation of regulatory authority.

> Industry should take steps to improve the safety of pipeline technologies. These should include the development of the following:
>
> o Recommended practices for riser design that address riser location within the platform, the method of riser support on the platform, and protection of the riser from impacts and external corrosion.
>
> o Operating practices that address the documentation of pipeline locations, the transfer of information about the location of pipelines to contractors and others who might anchor in their vicinity, and anchoring operations in the vicinity of pipelines.
>
> The government should expand the coverage of its regulations to include regulations on riser design and the documentation of pipeline locations and anchoring operations in their vicinity. It should utilize industry-developed practices as a basis for regulatory action.

Accidental Spills From Other Sources (page 120)

Precise identification of the causes of accidental discharges generally does not exist. If such information were available, it might be possible to identify and eliminate spurious regulations while improving the effectiveness of others. Present information identifies fuel transfer as a possible source of accidental discharges not presently covered by regulations.

> The Geological Survey and the Coast Guard should coordinate and revise their regulations regarding fuel transfer hoses to ensure full coverage of all contingencies. In particular, regulations should be developed for fuel transfer in situations where all the transfer gear is based on a fixed OCS installation.

There is overlap in the regulations of the Geological Survey, the Coast Guard and the Environmental Protection Agency in the reporting of pipeline breaks and oil spills and also in deck drainage requirements. The usefulness of reported information is limited because it does not include adequate causal information.

> The EPA, USCG, and the USGS should standardize their reporting requirements regarding accidental discharges. The Geological Survey reporting requirements should be revised to meet the needs of other agencies. These requirements should be expanded to include the reporting of specific information on the causes of accidental discharges.

Offshore loading operations, which have been limited to date may be expected to increase as frontier areas are developed. Such operations are inadequately regulated.

> The Coast Guard should develop regulations for offshore loading operations prior to the expansion of such operations.

Oil Spill Containment and Clean-up (page 121)

Current technology to recover spilled oil is severely limited above sea state 3, in rapidly moving ice-bearing waters, and at night. The ability to clean up spills could be negligible during major periods of the year in frontier areas such as the North Atlantic and Alaska. Some of the above conditions may lead to the suspension of oil in the water column; the containment and clean up of oil spills when the oil becomes suspended in the water column is not technologically feasible at this time. Continuing research and development, with incentives for industry, is necessary to advance the state of the art.

> The Coast Guard should continue to support a research and development program and should establish appropriate incentives for industrial research and development, to advance oil spill containment and cleanup equipment and practices, particularly for the North Atlantic and the Arctic.

The Geological Survey approves the adequacy of contingency plans proposed for areas on the OCS. For those areas where the Geological Survey has set site-specific criteria (i.e., source, type and rate of spill, sea states, and response times), the industry has demonstrated technology and equipment to satisfy the criteria. The industry's existing capability generally represents the best available.

The criteria of adequacy for contingency plans will vary, and possibly become more stringent, as new areas of the OCS introduce additional source types (i.e., tanker loading operations) and environmental conditions, such as ice. Wherever these eventualities may occur, criteria are needed in advance of lease sale commitments, and the industry, in turn, needs to demonstrate adequate capability and plans.

The Coast Guard, the Navy, and industry have developed and maintained (for different purposes) complementary oil spill containment and cleanup technology and support equipment. The requirement that industry demonstrate its readiness to contain and clean up oil spills prior to undertaking offshore petroleum development operations should lead to improved ability to respond to oil spills on the open ocean.

The National Contingency Plan and the regulatory practices of the Geological Survey provide some assurance of response within the limitations of existing technology to oil spills on the OCS. The plan's requirements for regional contingency plans, provisions for special forces, and so on have brought together officials of the pertinent agencies and local and state governments and those whose coordinated decisions and actions are necessary to oil spill response. The plan is periodically revised, and the process of planning and practicing for oil spill response is just being established on firm ground. An important limitation of the National Contingency Plan is that its effectiveness depends on timely decisions from external sources to support the on-scene coordinator.

Dispersants, as a means of lessening the environmental effects of spills, have been a controversial issue since the TORREY CANYON incident. They may be used today on the OCS at the discretion of the on-scene coordinator only if danger to human life or limb, or fire, is imminent. There are, however, circumstances in which their use may be warranted for the protection of certain populations of birds or other important biological resources. Although many new dispersants have been developed since the TORREY CANYON incident, EPA has not completed a review of dispersants and oil/dispersant mixtures for toxicity nor has it established which, if any, are acceptable for use in special circumstances. The National Contingency Plan could provide for the rapid acquisition of permission to use those dispersants found acceptable by the EPA in certain circumstances.

> The EPA should review dispersants and oil/dispersants mixtures for toxicity and establish which, if any, are acceptable for use and under what circumstances.

Workplace Safety (page 134)

Workplace safety on the OCS is an area of concern, but not one easily improved by legislation or detailed regulation. Work on the OCS appears no more hazardous than in similar industries ashore. This does not mean that improvements in workplace safety cannot be achieved nor that regulatory agencies should not be concerned.

Both the Geological Survey and the Coast Guard require the reporting of lost-time injuries and fatalities that occur in OCS operations. Industry keeps workplace safety statistics and makes a summary of its data available to the public. These data are collected for different purposes, and the methods of collection and format of presentation vary. This results in workplace safety data that are neither consistent nor comparable between data banks. Also, the data are not necessarily comparable to that of other industries, such as mining and shipyard construction, with which safety comparisons could be useful.

> The Coast Guard and the Geological Survey should coordinate and strengthen the collection of workplace data. A single accident-reporting form collected by a single agency could provide the kind of information needed to gain better understanding of the causal factors and characteristics of workers that could lead to improved safety.

Current technology and engineering systems now in use on the OCS appear to provide adequate workplace safety. Most of the improvement in safety that can be achieved by engineering has already been accomplished. The principal item demanding attention in improving workplace safety is not technology, but improvement in personnel performance.

In drilling operations, entry-level workers account for more than 70 percent of the lost-time accidents, and these typically occur within the first six months of employment. In the experience of the committee, this pattern is similar to that of other industries and typical of other operations on the OCS.

The application of effective workplace safety practices by responsible companies has provided a favorable overall safety record, even though there is no single, comprehensive set of federal regulations being applied specifically to workplace safety on the OCS.

Although some companies exhibit a level of safety performance substantially below the industry average, existing regulations and enforcement practices do not provide a means readily to identify the companies exhibiting the lowest safety records and to target the companies for closer scrutiny to improve their safety performance.

The available data show few qualitative or quantitative differences between North Sea and Gulf of Mexico experience. The committee has found no evidence that more hostile physical environments or more difficult operations, by themselves, lead to more accidents. However, they may indicate a need for special measures--protective gear, general procedures, training, supervision, and personnel selection. The knowledge required to ensure workplace safety in extreme environments is already in hand in the cumulative experience of the oil industry and the military services. There is no evidence that additional regulations regarding workplace safety are needed for frontier areas nor that major developments in workplace safety technology are indicated.

Fires and Explosions and Emergencies Requiring Abandonment of OCS Installations (page 157)

There is a level trend in the incidence rate of fires and explosions per facility on the OCS over the last 10 years. The level incidence rate may indicate the limits of what technological approaches can achieve in mitigating fires and explosions.

The data base on fires and explosions is adequate to depict the overall hazards from such events, but not adequate for detailed analysis of causes and effects and the interactions among such possible factors as poor maintenance, personnel error, poor operating practices, faulty design, and insufficient training. Better incident reporting, more thorough investigation of incidents, and more comprehensive incorporation of cause and effect findings in the data base could provide better insight into the causal factors of fires and explosions.

The development of technology, its incorporation into regulations, and its application are adequate to prevent and control fires and explosions and for emergencies requiring abandonment of OCS installations. The critical problem is ensuring that offshore workers are adequately trained and sufficiently drilled in the individual and team procedures necessary to ensure survival.

Regulations prescribe an adequate level of technology for abandonment of mobile units but not of fixed installations. The Coast Guard has recognized this deficiency and is taking steps to rectify it.

Fire and explosion protection has historically been regulated through the development of highly specific, equipment-oriented requirements. While this approach has merit, there is also room for performance-oriented requirements regarding fire and explosion protection. This is because total reliance on technology-specific regulations can have the effect of locking out new technologies that, while not meeting the regulatory requirements, may offer superior fire protection performance.

There have been some industry complaints that Coast Guard regulations have prohibited application of new technology in the area of fire protection. The committee's review of this issue indicates that the regulations do not prohibit the development nor use of new technologies, but the administrative process for their special approval is not completely understood by the industry and has been insufficiently explained by the Coast Guard. Even when followed, this process in many instances is untimely.

> The Coast Guard should make it easier for new fire protection technologies to be used on the OCS. This can be accomplished by making a special effort to improve the understanding within the offshore industry of the Coast Guard appeal/approval process for fire protection equipment.

Regulations requiring training and drills have not been effective in ensuring that personnel can use the technology and follow the individual and team procedures necessary to ensure survival in an emergency and, therefore, are inadequate. Some drills are performed only perfunctorily for minimal compliance with regulations. Emergency equipment is often not used or demonstrated, and emergency situations are not simulated.

Response during emergencies is often complicated by lack of a well-defined chain of command for emergencies, rapid turnover of personnel in some occupations, and the frequent presence of temporary personnel. Station bills do not by themselves provide adequate organization for effective action in emergencies.

Loss of Installations (page 178)

Fixed Platforms. From 1947 to 1979, fixed-leg platforms on the OCS accounted for approximately 32,870 platform years of operation. There were 37 known installation losses (0.001/year) exclusive of those associated with blowouts, collisions, or other operational incidents. The loss of most of the platforms could have been anticipated and prevented using current 1980 technology and design criteria. All of the failed platforms were designed on the basis of criteria now considered obsolete.

About half of the existing platforms on the Gulf of Mexico OCS were designed prior to 1965 and do not meet contemporary design standards. Some would be lost if exposed to 100-year storm loads associated with current standards. Any such potential losses, would not reflect adversely on the current state of technology or the adequacy of current regulations. Current hurricane warning systems, combined with well shut-in and platform evacuation procedures, justify continued utilization of these important older structures.

The technology of fixed-leg structures is mature and provides adequately for the safety of OCS operations. The technology for the design and installation of subsea well completions, deepwater compliant structures, and fixed polar arctic structures is still developing. It is not possible for the committee to conclude whether these developing technologies for fixed structures are currently adequate to provide for the safety of OCS operations in frontier areas. However, regulatory procedures for the verification of the design of fixed OCS installations should provide adequate assurance for the safety of such OCS installations.

OCS Order No. 8, "Verification of the Design of Fixed OCS Installations, "together with the related documents that it incorporates by reference, establishes adequate procedures for regulating the design and installation of fixed-leg platforms at all OCS locations and at all water depths where this form of construction is practicable. The third-party verification procedures established by OCS Order No. 8 also constitute an adequate framework for regulating the design of new structure concepts, such as guyed towers, and of structures in polar Arctic water, although procedures for arriving at design practices to be used in the verification program are not yet fully established. The structural inspection of fixed platforms is currently being considered in the regulatory process. The Geological Survey should:

- Clarify the procedures by which operators are to submit and seek approval of the design bases they adopt on pioneering projects for which mandatory design requirements have not yet been published.
- Ensure that verification agents for new structural concepts or for frontier areas have specifically applicable expertise.
- Move ahead to implement structural inspection requirements for fixed OCS installations.

Mobile Installations. The following findings relate to mobile offshore drilling Unit (MODU) accident history covering the period 1955 through mid-1980 and exclude those accidents and losses related to blowouts, fires, and explosions. In general, the loss rate for MODUs exceeds that of fixed platforms by almost an order of magnitude. Over the record period, the loss rate steadily diminished in all categories of operation except when in transit or moving on or off location.

Since 1955, the worldwide fleet of MODUs of all types experienced approximately 4,870 platform-years and recorded 86 major accidents (0.017/year). Approximately half of these accidents (42) resulted in total loss of the installation (0.008/year).

Among the different MODU types, jack-up units have experienced the highest accident rate (0.026/year). Their two worst hazard exposures, accounting for 77 percent of jack-up unit accidents, occurred (1) while the units were in transit or (2) when they were moving on or off location.

The high incidence of damage to, or loss of, jack-ups while in transit indicates this to be the largest single accident category for MODUs. The causes of in-transit accidents appear to be related to stability under tow, particularly during storms. Only 5 of the 29 reported accidents resulted from broken towlines. Available reports do not identify the extent to which inadequate weather forecasting and human error were contributing causes in this accident category, but expert opinion identifies both of these as important factors.

The record indicates that jack-up mobile units are vulnerable also when moving on or off location, i.e., when undergoing the transformation from a floating vessel to a bottom-supported platform, or vice versa. Accident reports include numerous indications of leg collapse and also of soil failure beneath the legs. While most accident categories exhibit a clearly declining rate, this category does not. OCS Order No. 2, paragraph 2, "Drilling From Fixed Platforms and Mobile Drilling Units," provides the Geological Survey with the authority to require seabed data at any drilling site.

Using this authority to require a foundation installation plan (and contingency planning) offers a possible means of reducing the risk of installation loss or damage when a jack-up unit moves on or off location.

The jack-up operational phases of transiting and moving on and off location are clearly hazardous and therefore demanding of personnel skill and judgment. The quality of personnel skill and judgment could possibly be improved through the establishment of manning provisions for jack-up units requiring (1) the certification or licensing of persons, through examination, to establish their competence to serve in MODU command positions during specific operation phases and (2) the designation by each MODU operator of the person who has command and control of the unit during all operational phases and the identification of when the command responsibility shifts from one phase to the next.

Semisubmersibles experienced the second-highest accident rate (0.014/year) among the MODU groups. The record shows a vulnerability to structural cracking, resulting from the combined influences of structure configuration, severe cyclic loading, and corrosion fatigue. It is significant, however, that many of the major accidents reported for these structures consisted of storm-related structural cracking that was detected and repaired without installation loss. There were only five total losses of semisubmersibles (0.005/year), which is roughly comparable to the loss experience of floaters (0.004/year) and submersibles (0.005/year).

MODU accident frequency is serious enough to warrant continued industry efforts to seek technological and operational improvements.

There is an adequate regulatory basis for administering the safety of mobile installations. Within the framework, specific regulatory steps can be taken by the Coast Guard and the Geological Survey to improve the safety of jack-up rigs.

> It is recommended that the Coast Guard consider establishment of manning provisions for jack-up units requiring the following:
>
> - Clear designation by each MODU operator of the person who has command and control of the unit during all operational phases and identification of when the command responsibility shifts from one phase to the next.
>
> - Certification or licensing of persons, through examination, to establish their competence to serve in MODU command positions during specific operational phases.
>
> It is recommended that the Geological Survey consider extending its authority under OCS Order No. 2, paragraph 2, to include requirements for a foundation installation plan

> compatible with the reported seabed conditions and a contingency plan to be followed if actual conditions are found to differ from those anticipated.

Operational Accidents. The causes of blowouts, fires, and explosions that result in major damage to or loss of installations roughly parallel the causes of all blowouts, fires, and explosions. It is more practicable to prevent operational accidents than to attempt to design OCS installations that can withstand them.

The likelihood of the use of tankers in some frontier areas raises the possibility of increased risk of collision between vessels and OCS installations.

Experience suggests that collisions between vessels and OCS installations result from willful or careless disregard of both voluntary and mandatory navigation restrictions and that a problem exists with respect to identifying and penalizing violators.

There is insufficient evidence to conclude that either improved technology or regulatory changes in the absence of improved attentiveness and compliance by ship operators would reduce the incidence of collisions of ships with OCS installations.

I. THE OUTER CONTINENTAL SHELF AS A NATIONAL ENERGY RESOURCE

The Contribution of OCS Oil and Gas to the U.S. Petroleum Supply

This section evaluates the past, present and possible future contribution of OCS oil and gas to the total U.S. petroleum supply. It is based on available industry and government data and estimates. Estimates of future production have been described as "educated guesswork,"[1] because the presence of resources cannot be confirmed until they are discovered by drilling wells. This section is narrow of scope. It does not rank the importance of this particular energy source as compared to all other energy sources. Nor does it place this resource development activity in perspective with other oceanic resources such as fish and other forms of wildlife.*

There is a broad range of public opinion on national energy supply alternatives and on the relative social and economic values of the living and nonliving resources of the OCS. The committee has not attempted to reach a consensus on which of these broad alternatives and values are preferred, nor was the committee charged or constituted for this. No inference is intended as to the desirability (or lack thereof) of any energy source alternative nor of the relative value to be placed on any ostensibly competing uses of the OCS. By law, the balancing of the many competing uses is an integral part of government decision-making concerning resource development.

Perspective

The oil and gas resources of the OCS contributed about 9 percent of domestic oil and condensate production and 24 percent of domestic gas production in 1979.

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*Despite this limitation on the committee's work, committee members recognized that some OCS areas were important because of their endowment of living resources, and for other reasons. For example, Georges Bank off Massachusetts is a fishery of enormous productivity. The maximum sustainable yield is estimated to be 420,000 metric tons per year, and the value of the landings at dockside is about $229 million per year.[2] The total contribution of the fishery to the U.S. econony is estimated to be several times this.[3] The value of OCS areas for multiple purposes including the development and harvest of living resources makes it especially important that the oil and gas drilling operations be conducted safely.

The OCS has not been nearly as fully explored as land areas, leaving open the possibility that significant resources await discovery and that OCS resources could play a relatively larger role in the future than they have in the past. It is important to emphasize that this course of events is not inevitable, but it is possible. The magnitude of the future contribution of the OCS to the national energy supply will depend on federal policies towards OCS development, the extent of actual discoveries of resources, the economics of developing and producing OCS oil and gas, and other factors.

To the extent that the U.S. continues to be dependent on petroleum, attention will be directed to the OCS because domestic production of petroleum from land sources is declining.

The Present

The offshore oil and gas industry is a mid-twentieth century phenomenon. Although wells were drilled from piers as early as the 1890's in Southern California, modern offshore oil and gas operations were first undertaken in the Louisiana bayous in the 1930's and extended outward incrementally into the Louisiana Marsh and to the shallow waters of the Gulf of Mexico. The first oil well out of sight of land was drilled off the coast of Louisiana in 1947. The industry has moved progressively further offshore since, to deeper waters and to harsher environments.

The government is the trustee for the resources of the OCS and has the duty under law to balance a number of conflicting but equally important national objectives in their development: expedited energy development, environmental protection, national security, assuring economic competition, a fair return to the public, and cooperation with affected coastal states.

From 1980-1985, the federal government proposes to lease more than 20 million acres of the OCS for exploration and development. This will be undertaken through a program of 36 lease sales covering all OCS areas, including 17 sales in all 14 of the so-called frontier areas (Table I-1 and Figures I-1-A and I-1-B). The frontier regions include the Alaska, California (outside the Santa Barbara Channel), and Atlantic Outer Continental Shelf, and also all portions of the OCS overlain by deep water (over 1,000 feet). Characterized largely by harsher environmental conditions and/or deeper water, these regions are termed "frontier" precisely because the likelihood of finding oil and gas in them and the risks to be encountered in offshore operations there are not well established.

Exploration of some frontier areas in the U.S. is already under way. Commercial discoveries have been made in the deep water areas in the Gulf of Mexico and the Santa Barbara Channel. However, the initial exploratory efforts in the Mid and South Atlantic, and in Cook Inlet and the Gulf of Alaska, have been disappointing. In two

TABLE I-1

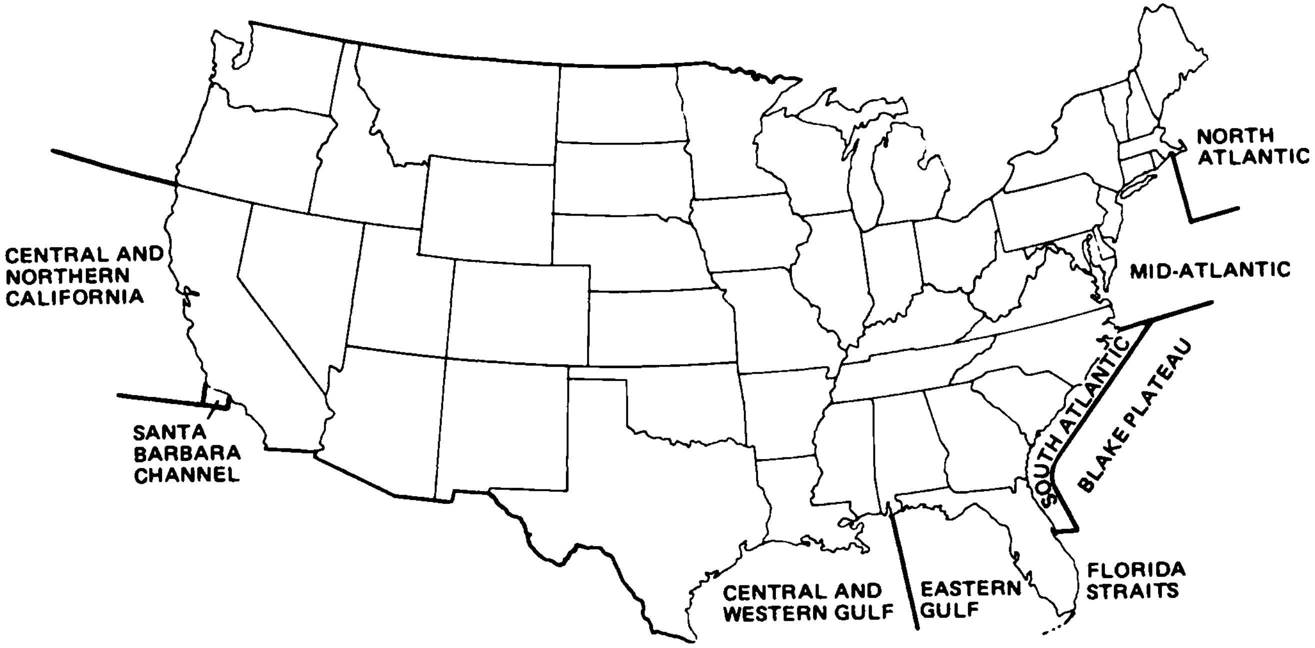
OCS Frontier Areas Scheduled for Leasing 1980-1985

Sale Area	1980	1981	1982	1983	1984	1985
Gulf of Alaska	X					
Central and Northern California		X				
South Atlantic		X			X	
Mid-Atlantic		X		X		
Cook Inlet		X				
Norton Basin			X			
St. George Basin			X			
North Atlantic			X		X	
Beaufort Sea	X			X		
Kodiak				X		
No. Aleutian Shelf				X		
Navarin Basin					X	
Chukchi Sea						X
Hope Basin						X

X = Lease Sale

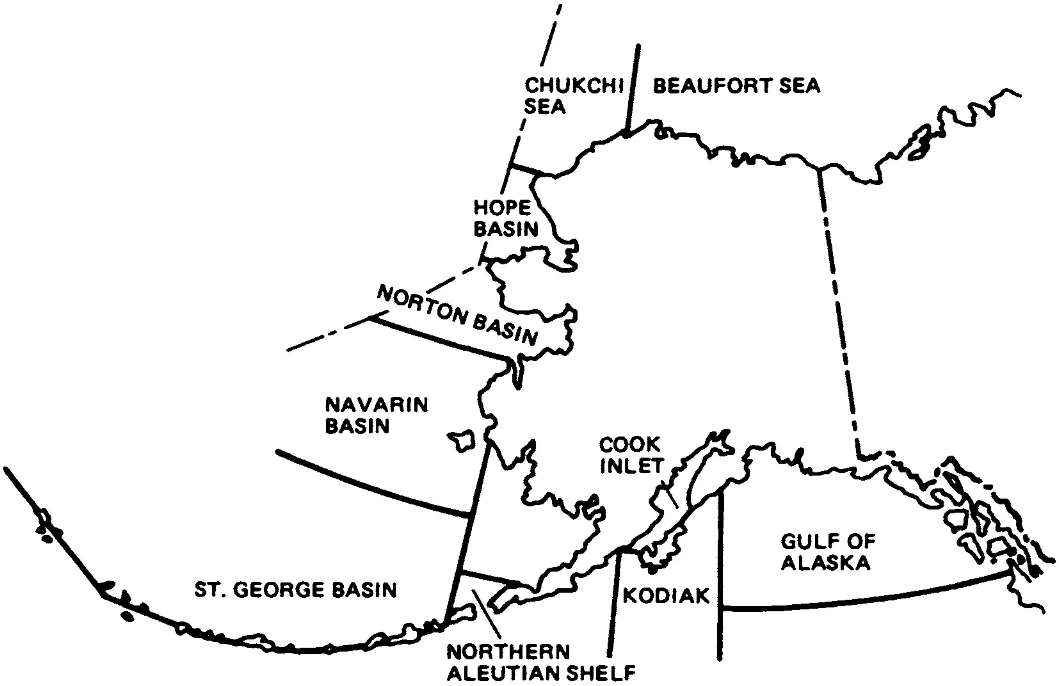
Source: Department of the Interior News Release, March 28, 1980

Outer Continental Shelf Areas Under Consideration for Leasing



Source: U.S. Department of the Interior

Figure I-1-A



Source: U.S. Department of the Interior

Figure I-1-B

other frontier areas, outlying regions off Southern California, and Georges Bank, leases for exploration and development have been awarded, but exploratory drilling has yet to be conducted.

The overwhelming proportion of the offshore industry's operating experience in U.S. waters comes from more than 30 years of operations in the Gulf of Mexico. Of approximately 37 million OCS acres that have been offered for lease, nearly 28 million acres have been in the Gulf of Mexico. The role of the Gulf of Mexico as the source of OCS operating experience is demonstrated in Figure I-2, which shows the share of OCS production that has come from the Gulf of Mexico, as compared to all OCS production. In addition to its Gulf of Mexico experience, the offshore oil and gas industry has acquired operating experience in the Canadian Arctic, the North Sea, and elsewhere where environmental conditions may be relevant to U.S. frontier areas.

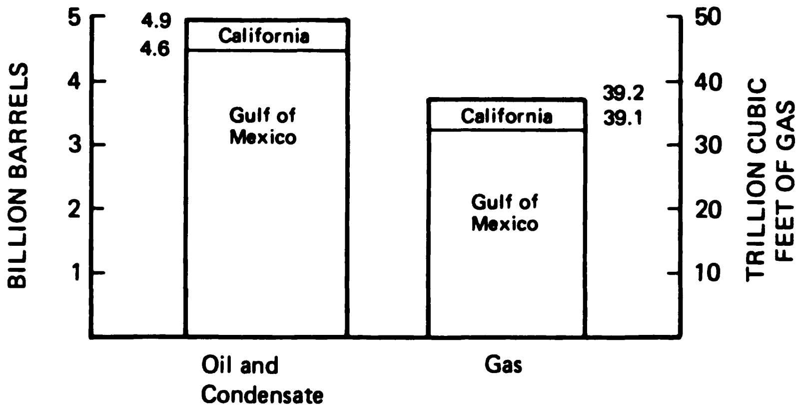
With the exception of hurricanes, the Gulf provides a moderate operating environment as compared to the frontier areas such as Alaska and the North Atlantic. Furthermore, the government's OCS regulatory program was originally tailored to the Gulf of Mexico. The overwhelming majority of all professional personnel concerned with OCS operations in both government and industry including those working in foreign waters have developed their job skills dealing with Gulf of Mexico problems. Similarly, OCS technology has evolved from the Gulf of Mexico. Its extension to new operating environments is recent (10-15 years). Considering government regulatory activity and industry operations as a single system, the bulk of U.S. experience comes primarily from the Gulf of Mexico.

The Future

Total domestic production of oil and gas is declining and is expected to continue to decline. Production of offshore resources has increased and has been projected by industry analysts to increase further (Figure I-3).

An estimate of undiscovered OCS resources is uncertain in the absence of actual exploratory drilling and must be based on statistical estimates derived from models. The USGS estimates of OCS resources are 12.5-38 billion barrels of oil and 61.5 to 139 trillion cubic feet of gas (75 percent and 25 percent probability, respectively) (Table I-2). These estimates have been described by the Department of the Interior as "educated guesswork." Actual discoveries may prove significantly higher or lower than these figures. It must be realized that the actual reserves in total or in any given area are unknown and could be significantly greater or less than these estimates.

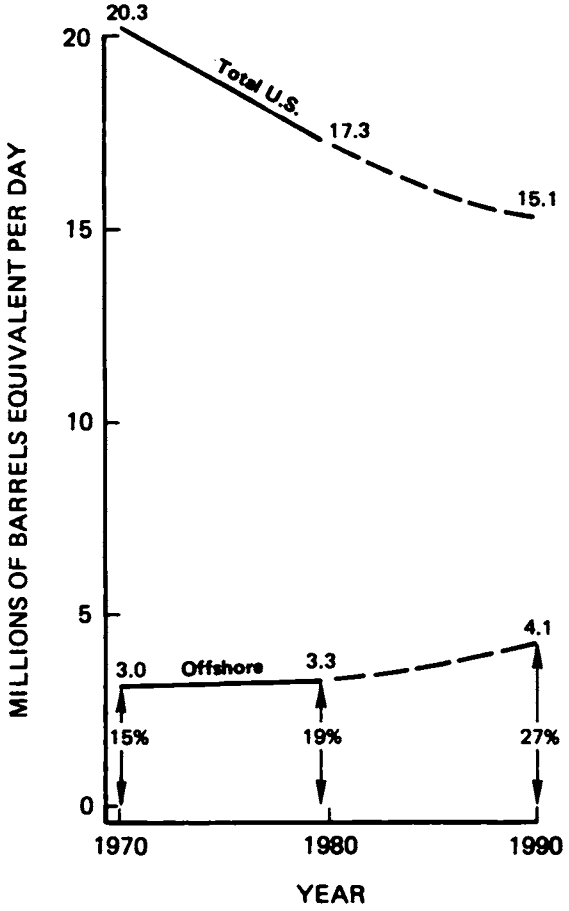
The role of potential offshore resources in the domestic energy supply could be important. In 1977, about 75 percent of the energy consumed in the United States came from petroleum and natural gas.[4] Natural gas production peaked in 1973; oil production peaked in 1972. Analysts estimate total U.S. oil production for



Source: Data from the U.S. Geological Survey

Figure I-2 Estimated Accumulated Production from the OCS: 1947-1978

Actual and Estimated U.S. Production of Oil and Gas



5.61 X 10 cubic feet of gas = 1.00 Barrel of oil

(1) These estimates are for all offshore lands under U.S. jurisdiction, both state and federal.

Source: "Outer Continental Shelf Frontier Technology: Proceedings of a Symposium," National Academy of Sciences, Washington, D.C., 1980. Based on U.S. Geological Survey estimates.

Figure I-3

TABLE I-2

OCS Resources*

	Oil (Billion Barrels) Probability			Gas (Trillion Cubic Feet) Probability		
Area	95%	5%	Mean	95%	5%	Mean
ATLANTIC						
North Atlantic	0	2.5	0.89	0	13.2	4.44
Mid-Atlantic (0-200m)	0	1.6	0.4	0	8.1	2.6
South Atlantic	0	1.2	0.3	0	2.5	0.7
Blake Plateau (200-2500m)	0	2.6	0.6	0	3.8	1.2
GULF OF MEXICO						
Florida Straits	Negligible			Negligible		
E. Gulf of Mexico (0-200m)	0	2.1	0.5	0	2.1	0.5
Gulf of Mexico	0.6	4.3	1.9	11.1	49.1	25.8
ALASKA						
Gulf of Alaska (0-200m)	0	0.7	0.1	0	1.9	0.4
Kodiak Basin	0	1.1	0.23	0	3.5	0.69
Lower Cook Inlet	0.1	1.5	0.5	0.4	3.3	1.5
S. Aleutian Shelf	0	0.2	0.04	0	0.5	0.08
N. Aleutian Shelf (0-200m)	0	1.0	0.2	0	3.2	0.8
St. George Basin (0-200m)	0	5.8	1.6	0	15.7	6.2
Navarin Basin (0-200m)	0	11.8	3.8	0	38.3	14.2
Norton Basin (0-200m)	0	1.3	0.3	0	3.8	1.2
Hope Basin	0	0.6	0.13	0	3.3	0.86
Chukchi Sea	0	14.5	6.4	0	38.8	19.8
Beaufort Sea (0-200m)	0	10.4	4.3	4.1	32.0	16.5
PACIFIC (0-200m)						
S. California Borderland (200-2500m)	0.2	2.3	0.9	0.2	2.3	0.0
Santa Barbara Channel	0.6	3.0	1.5	0.7	3.3	1.7
Central & Northern California	0	0.8	0.4	0	0.8	0.4
Washington-Oregon	0	0.7	0.2	0	1.7	0.3

*Unconditional estimates of undiscovered recoverable resources

Source: Adapted from U.S. Geological Survey data, March 5, 1980.

1979 at about 10.2 million barrels per day. Despite increased investments in exploration and enhanced recovery in the lower 48 states since 1973, reserves have continued to fall. Furthermore, additions to the reserve have been only about half as large as production in the last decade. Domestic production is projected to drop by more than 10 percent between 1979 and 1985.[5]

Viewed in this light, the policy of accelerated OCS development that has been adopted by the U.S. takes on more significance. An important share of the U.S. effort will be expended in such environments as in the Arctic, where offshore experience is scant and where, frequently, there are competing activities such as fishing. Yet this is also where the resource potential is more promising (Figure I-4). Successful exploration of the untried and untested areas will involve meeting technical and economic challenges, without negating the government and industry's responsibilities for ensuring worker safety and environmental protection. The future contribution of the OCS to the U.S. energy supply depends upon successfully meeting these challenges.

The Offshore Oil and Gas Industry

The offshore oil and gas industry comprises many elements that provide management and financing, scientific and technical expertise, and specialized services or goods. The companies range from the largest corporations in the world to one-man enterprises vending special skills.

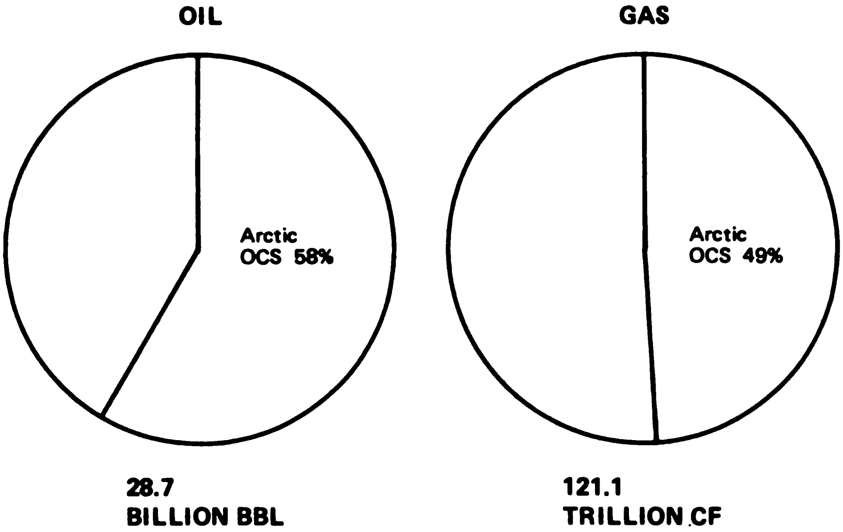
The responsibility to bring the many diverse activities together in the development of OCS resources falls on the offshore operator. The offshore operator may be the holder of a federal OCS exploration and development lease, or the company may have had operating authority delegated to it by a leaseholder. There are about 70 offshore operators in the Gulf of Mexico, whereas about 800 companies are said to comprise the entire offshore industry.[6]

Two organizational arrangements are key to understanding the offshore industry. These are (1) the financial arrangements under which leases are acquired and costs are distributed for exploration and development and (2) the organizational arrangement between the operator and various contractors to perform the physical operations on the OCS.

Financial Organization

Any individual, group of individuals, company, or group of companies (except for constraints on joint bidding by major companies) may bid on an offshore lease. If the bid presented is the highest received by government, and the government elects to award the lease, the bidding entity acquires the right to explore and develop that lease. If the successful bidder is an individual or a single company, the financial arrangement is simple. All costs are borne by the bidder.

PROPORTION OF ESTIMATED OCS RESOURCES LOCATED IN THE ARCTIC(1)



(1) Mean Estimate of Undiscovered Recoverable Resources in OCS

Source: Data from U.S. Geological Survey (1979)

Figure I-4

In recent years, joint bidding by two or more companies has become more common for two reasons. First, the acquisition of leases and the exploration and development of OCS prospects require large amounts of capital and most bidders, even major companies, find it desirable to share this risk. Second, each bidder is likely to have limited funds to commit to a given OCS sale and there is a large degree of uncertainty as to which prospects in a given sale might ultimately prove to be of greatest value. Bidders may wish to spread the funds allocated to a sale among several of the more attractive prospects. In such arrangements where a number of companies bid jointly at a sale, one of the companies is normally identified as the "lead" company. The lead company generally is a large firm with substantial financial resources and technical expertise in OCS operations. The lead company will, in most instances, be designated as the operator if the bidding partnership is successful in acquiring leases in the sale. Other companies bidding with the lead company may consist of other operators on the OCS, companies from other industries, or others who wish to make a financial investment in OCS development. The partnership is bound by contract as to the proportion of lease bonus and subsequent operating costs that each will pay and as to the proportion of production or revenue each will receive from a venture. The contractual arrangements include provisions to compensate the operator for utilization of his technical and operational manpower and may include financial leverage (i.e., an operating interest somewhat higher than financial investment) to the operator. The financial arrangement thus established is intended to last for the life of the project, although each party to the contract usually has the right to dispose of an interest at any time.

Operating Organization

The financial organization described above provides a basis for OCS development. The lead bidder is now designated the operator for the lease. The conduct of all field operations is under the supervision of the operator. For the exploratory drilling phase, the operator will select a contractor-owned drilling rig and an individual employee will be continuously present on the rig. Such an employee is designated as the "operator's representative" and normally will have experience in drilling comparable to that of the level of the drilling foreman (toolpusher). The drilling contractor is responsible for supplying the drilling rig with the equipment and personnel necessary to conduct the drilling operation. The operator's representative is in charge of the overall operation and is charged with responsibility for the successful completion of the well. During the drilling operation, all necessary equipment and services other than for repair of the drilling rig are normally arranged for by the operator's representative. Such equipment and services include casing, casing crews, cementing services, well-logging services, and so forth. Problems associated with well control are the responsibility of the operator's representative although he must utilize the drilling contractor's equipment and personnel to perform the necessary functions.

Various other contractual arrangements necessary to the conduct of offshore operations are the responsibility of the operator. Such arrangements include transportation for equipment and supplies; onshore support facilities; and various engineering, technical and logistic services.

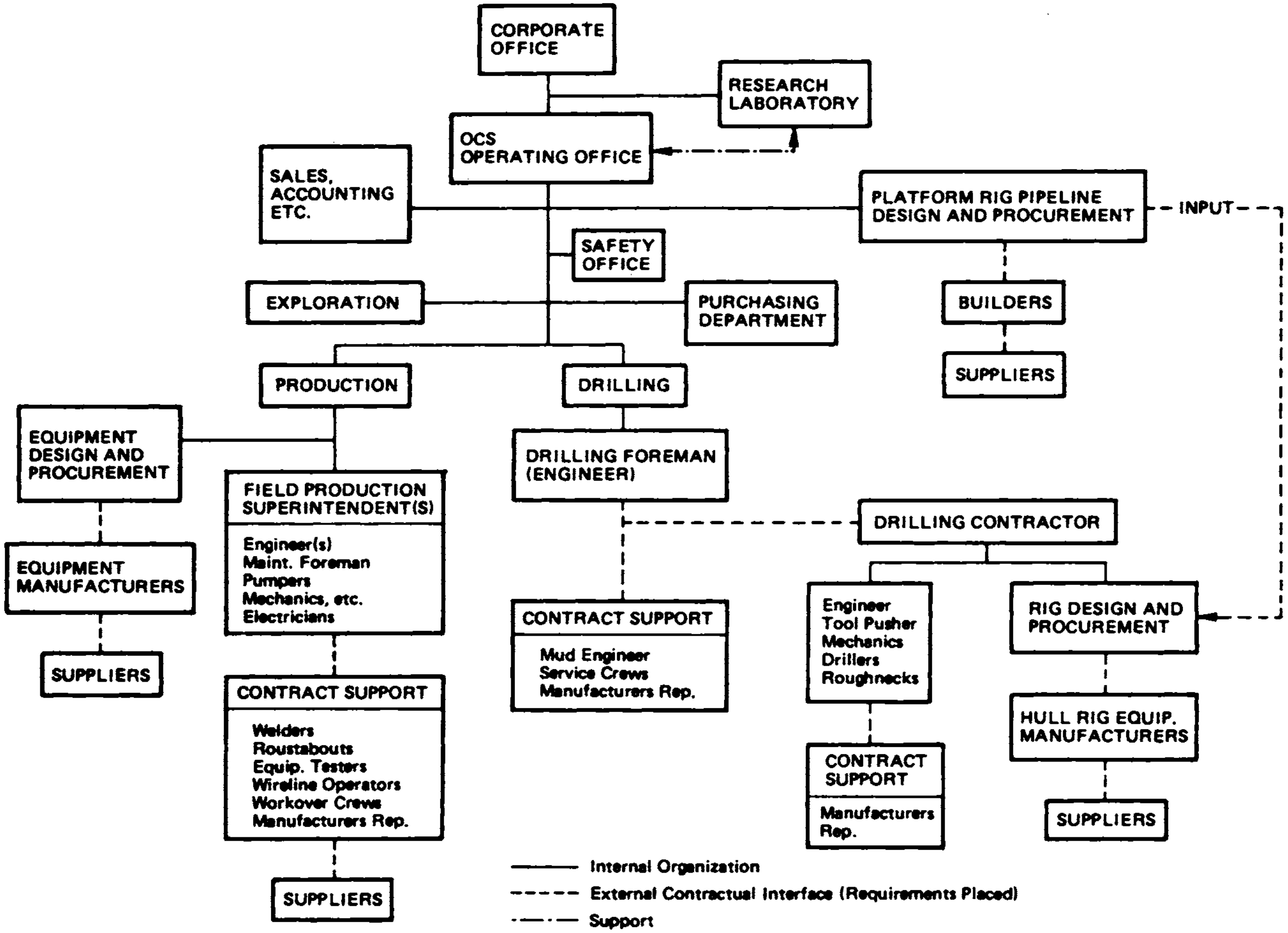
The operating organization for development and production is similar to that utilized during exploratory drilling. The financial partnership utilized to acquire the lease continues to pay the respective shares of capital costs incurred in development and production. The operator continues to bear responsibility for recommending to the leaseholding group the manner in which the lease is to be developed, including the number of platforms to be installed, the number of wells to be drilled, and other matters relating to recovery of the reserves from the lease. The operator continues to be responsible for all operations, including selection of contractors to fabricate and install necessary platforms, selection of a drilling contractor to drill the development wells, and obtaining other contractors to install necessary production handling equipment. One distinct difference in the production phase is that the operator is more likely to use his own employees to conduct the production operation as opposed to the greater reliance upon contractors during drilling and development operations.

The OCS leaseholder is ultimately responsible for the safety of operations, including compliance with government regulations, on government leases. This responsibility is passed through to the OCS operator and his contractors in the conduct of OCS operations.

Figure I-5 depicts the typical operating structure of an OCS operator and indicates the nature of contractual relationships. In the context of the organization chart, it is important to understand the industrial management structure in which offshore operations are conducted. Headquarters' personnel onshore maintain close oversight of offshore operations. Often, the shoreside supervisory personnel are in frequent radio contact with the offshore personnel. Operational strategies are conceived onshore and conveyed to the supervisory personnel on the rig for implementation. When the field personnel exercise independent judgement, it is usually in response to conditions requiring quick action, such as a kick in the well (a sudden fluid incursion into the wellbore). Even in these instances, field personnel may seek approval of actions from shoreside supervisors if there is time.

More than 60,000 people work on the OCS in skilled, semiskilled, and unskilled positions. And it is very hard work indeed. It is common practice for workers to spend a week or more at a time offshore, working 12-hour shifts. The composition of the offshore work force changes, as necessary, in the course of operations. Typically, drilling operations employ on the order of a hundred or more people on a ship or platform and; production operations employ a few tens of people on the production structure.

Representative Oil and Gas Company Organization
And Interfaces for OCS Operation



Source: "Applicability of NASA Contract Quality Management and Failure Mode Effects Analysis Procedures to the USGS Oil and Gas Lease Management Program," I. Dyer, et al., November 1971.

Figure I-5

The Government's OCS Regulatory Program

The natural resources in the OCS are under the jurisdiction of the U.S. government. The federal government is responsible for managing the resources in a manner that benefits the nation as a whole. The government decides which OCS resources to offer for exploration and development and establishes the time frame for development. It sets the conditions under which industry will be allowed to explore and develop OCS resources--e.g., requiring bonuses to be paid for the opportunity to explore and develop and payment of royalties to the federal government if production is obtained. Government also sets the rules under which operations will be conducted taking into account safety considerations, environmental concerns, and potential conflicts with other ocean industries such as fishing and shipping.

Agencies that Regulate OCS Safety

As many as 18 federal agencies have an active interest in some aspects of OCS operations.[7] Of these, six (housed in four executive departments or agencies) have statutory authorities that require them to regulate the day-to-day operations on the OCS. The four agencies are as follows:

- Department of the Interior
    - Bureau of Land Management
    - Geological Survey

- Department of Transportation
    - Coast Guard
    - Materials Transportation Bureau/Office of Pipeline Safety

- Environmental Protection Agency
- Department of Defense (U.S. Army Corps of Engineers)

The roles of these agencies in OCS activities are discussed below.

Department of the Interior. The Department of the Interior (DOI) has general responsibility for managing mineral leasing on the OCS, including coordination of federal activities. Within the DOI, the Bureau of Land Management (BLM) and the Geological Survey are the two principal units charged with OCS regulatory responsibilities. Under the authority of the OCS Lands Act of 1953, the Secretary of the Interior has delegated to the BLM the responsibility to administer the leasing procedures for OCS tracts. The BLM issues lease stipulations that set forth the terms guiding development and the constraints and procedures that are to be observed.

The Secretary of the Interior has delegated to the Geological Survey, Conservation Division, responsibility for the regulation of all mineral exploration, drilling, and production operations on leased or leasable OCS land. The Geological Survey issues regulations for oil and gas operations on the OCS, which are carried out on a nationwide or area basis as appropriate. Regulations are proposed, written, implemented, and enforced by the Geological Survey to ensure that operations under federal oil and gas leases and permits on the OCS emphasize the safety of operations, prevention of pollution, and protection of life and property and minimize the risk of environmental damage.

Department of Transportation. The principal units in the Department of Transportation with regulatory responsibilities for oil and gas on the OCS are the Coast Guard and the Office of Pipeline Safety of the Materials Transportation Bureau.

The Coast Guard's regulatory authority relates generally to its responsibility for maritime safety and for the safe operation of vessels and floating ocean structures. Some Coast Guard regulatory authorities for maritime safety date back at least 100 years. Under the OCS Lands Act Amendments of 1978, the Coast Guard promulgates and enforces regulations to promote the safety of life and property on OCS facilities and vessels engaged in OCS activities. Included under this broad legislative authority are safety of life and property on offshore structures; inspection and/or certification of commercial vessels that engage in OCS operations, including mobile offshore drilling units; licensing of certain marine personnel; supervision of the cleanup of discharges of oil and other hazardous substances from facilities engaged in OCS activities and, in some instances, control of discharges; and safety of life in diving operations, submersibles, and other underwater operations.

The Natural Gas Pipeline Safety Act of 1968 provides the Office of Pipeline Safety Regulation with jurisdiction over gathering lines and transmission pipelines offshore and onshore. Pipelines of an oil- or gas-producing facility are under the jurisdiction of the Geological Survey up to the flange connected to the transmission pipeline.

Environmental Protection Agency. The Environmental Protection Agency's (EPA) major authorities on the OCS are those sections of the Clean Water Act of 1972 as amended that authorize the setting of effluent standards and ocean discharge criteria and the issuing of discharge permits that reflect the standards and criteria. While the EPA is responsible for regulating air quality on land, the OCS Lands Act Amendments specifically charge the Geological Survey with regulating the air emissions of OCS installations.

Department of the Army. Under the Rivers and Harbors Act of 1899, Department of the Army permits are required for the construction of any structure in or over the navigable waters of the U.S. This responsibility is carried out by the U.S. Army Corps of Engineers. The OCS Lands Act of 1953 extended this authority to cover construction of artificial islands and fixed structures on the OCS.

In accordance with this legislation, the Department of the Army has occasionally established shipping safety fairways and anchorages on the OCS to control the erection of structures in order to provide safe passage for vessels through areas of mineral exploration and development. However, the Ports and Waterways Safety Act of 1978 gave the Coast Guard the authority to establish, operate, and maintain routing systems and fairways. Nevertheless, the Department of the Army retains responsibility for shipping safety fairways and anchorage areas in the Gulf of Mexico and in the Pacific Ocean at Port Hueneme, California. It has also established regulations that authorize drilling in the Gulf of Santa Catalina, California.

Administration of OCS Development

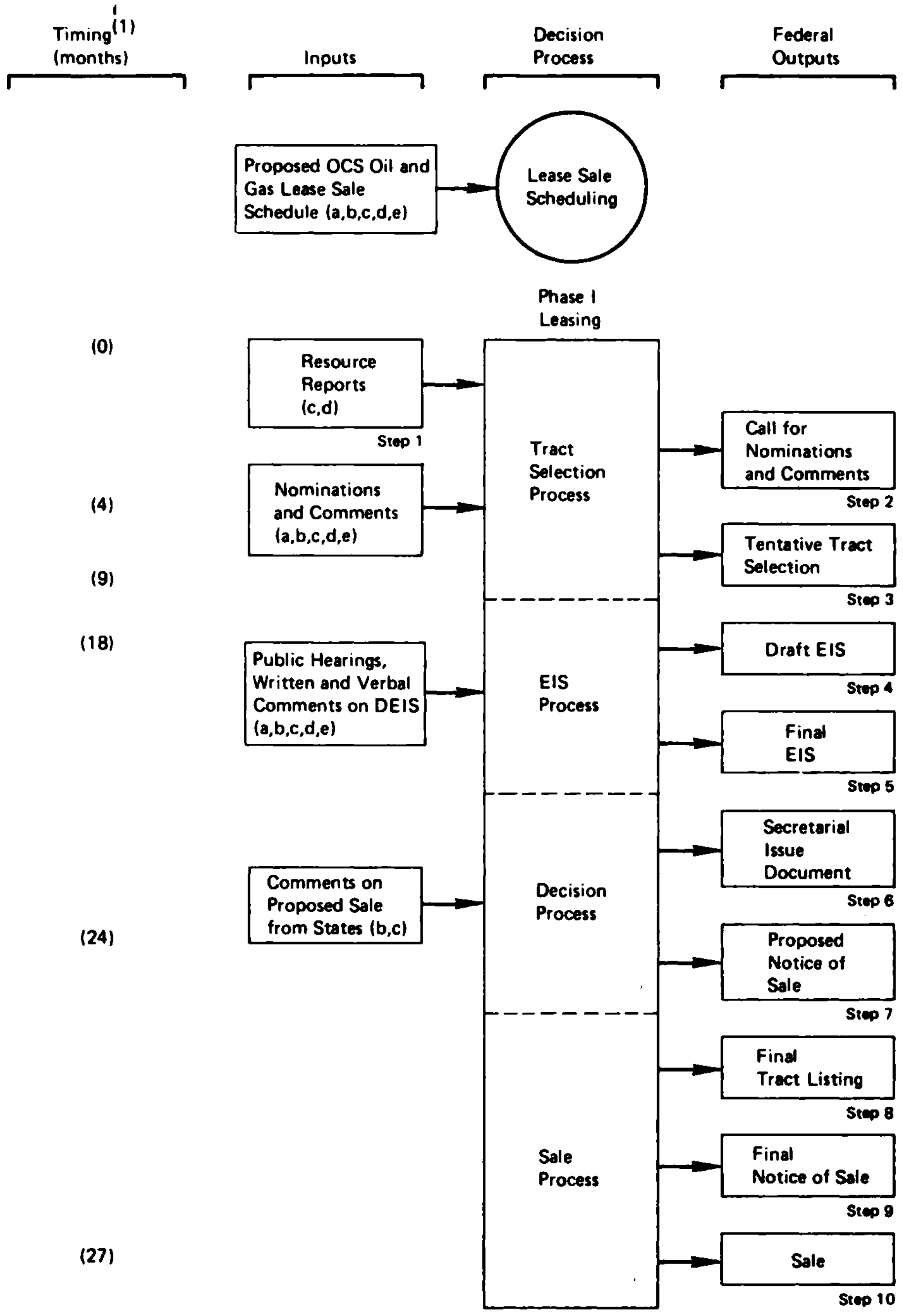
Government administration of OCS development commences with the preparation of a five-year leasing plan and continues through the leasing, exploration, development, production, and abandonment phases of OCS oil and gas activities. While it is convenient to present the OCS program in terms of these phases of activity, it is important to understand that in any geographic area these activities can proceed simultaneously although they are regulated separately.

OCS Leasing. The Department of the Interior is the leader and coordinator of OCS leasing activity. A schematic of the OCS leasing process is provided in Figure I-6.

The initial step in the leasing process is the preparation of a five-year planning schedule listing anticipated OCS lease sales. Once in effect, the schedule may be updated and revised by the Department as conditions affecting the lease areas change. The schedule is developed with industry and public review and is intended to serve as a planning tool for all levels of government and for industry.

Planning for a specific lease sale begins 2 - 3 1/2 years prior to the holding of the sale. An early action taken by the Secretary of the Interior, through appropriate BLM regional offices, is to request technical resource reports from pertinent federal agencies on the broad geographic OCS area under consideration for a lease sale. The information contained in these reports may relate to aspects of safety such as the identification of sensitive environmental areas. After reviewing the resource reports, the BLM and the Geological Survey define the general geographic area proposed to be covered in the sale (the area unit used in OCS leasing and development is a square block (or tract) three miles on each side, or 5,760 acres). Public comments are solicited on the nominated tracts, of which there may be several hundred at a time. When the nominations and comments have been received, a tentative selection of tracts is made for site-specific environmental study and possible lease offering. A draft environmental impact statement is then prepared and public hearings are held.

The OCS Leasing Process



(1) Months from the onset of lease sale planning.

Source: Outer Continental Shelf Oil and Gas Information Program, Directory to Federal, State, and Local OCS Related Activities and Contacts, U.S. Geological Survey, Reston, Va., 1979. Open File Report 79-1481.

Figure I-6

After oral and written comments have been evaluated, a final environmental impact statement is prepared that incorporates new findings, substantive comments, and recommendations. An additional input into the environmental impact statement process is the hazards report prepared by the Geological Survey. This report identifies potential geological hazards for each tract included in the lease sale. Based on this report, tracts with known hazards are either recommended for deletion from the sale or are included with stipulations for their development. After the analyses have been completed, a tentative decision on whether to hold a sale is made by the Secretary of the Interior. To assist the Secretary in this regard, the BLM prepares a decision document identifying the significant factors associated with the proposed action. If the Secretary decides to proceed with the sale, a proposed notice of sale is prepared by the BLM. Following a 60-day comment period on the sale notice, a final selection is made of tracts to be offered. The BLM then prepares a public notice of sale. Finally, a public lease sale is held for the purpose of receiving and publicly opening all bids, whereupon a series of agency procedures is initiated to evaluate bid offers and grant leases.

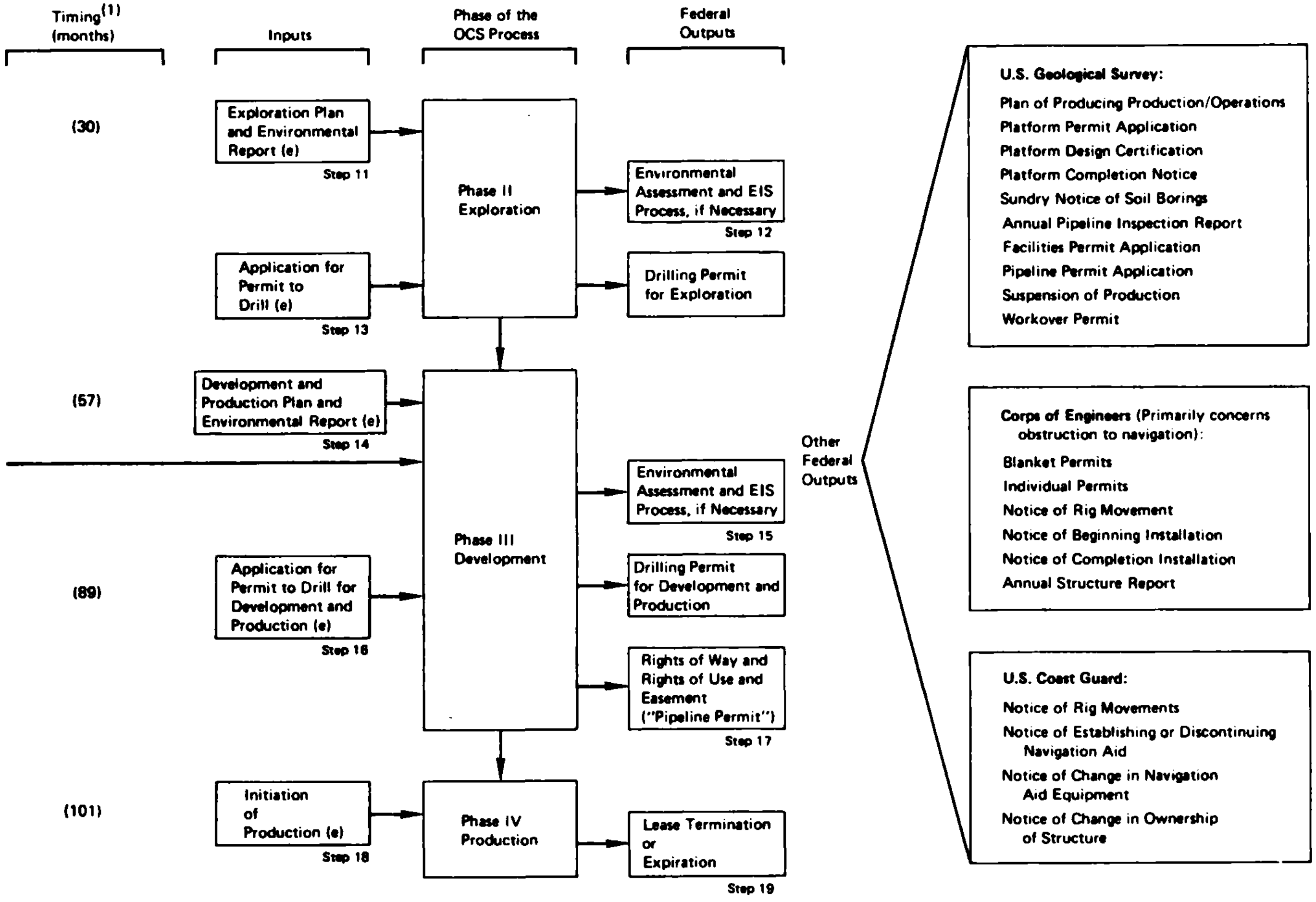
Throughout the pre-lease phase, safety-related concerns can be raised by any public or private party. Safety-related concerns may relate to the adequacy of technology or regulations or to site-specific environmental or other concerns. The raising of concerns can result in the deletion of specific tracts from the sale offering or in the stipulation of specific actions that must be taken in exploration and development to provide for OCS safety.

What should be an important source of planning and management information for the federal government throughout the leasing and developing of OCS lands is the BLM's Environmental Studies Program. Congress mission for the program was "To establish information needed for prediction, assessment, and management of impacts on the human, marine, and coastal environments of the outer continental shelf and nearshore area which may be affected...."[8] The program was intended by Congress to identify information needs well before leasing activities begin and to develop studies that address the needs.

OCS Exploration. An outline of OCS exploration activity is contained in Figure I-7. The Geological Survey, the Coast Guard, the EPA, and the U.S. Army Corps of Engineers all oversee aspects of OCS exploration operations. The Geological Survey has the most extensive responsibility for regulating operations on OCS tracts.

Before a lessee may begin exploratory drilling, an exploration plan and an accompanying environmental report must be prepared and submitted for approval to the Geological Survey. These documents provide information on the methods to be used in exploration and provide assurance of effective and environmentally sound exploration activities. The exploration plan includes the type and sequence of

OCS Exploration, Development and Production



(1) Months from the onset of lease sale planning.

Source: Adapted from Outer Continental Shelf Oil and Gas Information Program, Directory to Federal, State, and Local OCS-Related Activities and Contacts, U.S. Geological Survey, Reston, Va., 1979. Open File Report 79-1481.

Figure I-7

exploration activities and a tentative timetable of activities; a description of drilling vessels, platforms, or other offshore structures, and features such as safety and pollution prevention and control measures; and the approximate location of each well.

The environmental report for exploration contains descriptions of the affected ocean area and environmentally sensitive areas and procedures for oil or waste spill prevention and cleanup, as well as information on demands and impacts on offshore and onshore environments, personnel requirements, company points of contact, etc. Some of the information in the exploration plan and environmental report is germane to OCS safety.

An environmental assessment is prepared by the Geological Survey based on all available environmental information, including the exploration plan and the environmental report. If the environmental assessment indicates that approval of the plan would constitute a major federal action significantly affecting the human environment, an environmental impact statement must be prepared. On the basis of the environmental assessment or the environmental impact statement findings and the technical review by the Geological Survey, the exploration plan will be approved, disapproved, or modified.

After approval of the exploration plan and environmental report, the lessee may obtain a drilling permit for exploration by filing an application for permit to drill (APD). The APD is approved by the Geological Survey after a completion of detailed review of the application and a hazard analysis of the drill site. Other permits required prior to exploratory drilling include those for aids to navigation from the Coast Guard, navigation permits from the U.S. Army Corps of Engineers, and National Pollutant Discharge Elimination System (NPDES) permits from the EPA.

Throughout exploration, the four agencies with direct responsibility for aspects of OCS safety are required by law to administer safety requirements by requiring that lessees address aspects of OCS safety in plans, reports, and permit applications. During operations, the Geological Survey, the Coast Guard, and the Environmental Protection Agency are supposed to monitor and inspect operations to ensure that they are being conducted in conformance with the plans, reports, and permits.

OCS Development. The same four agencies continue to oversee OCS operations in the development phase of OCS activity. Prior to development and production, the lessee must prepare a development and production plan and an accompanying environmental report (Figure I-7). The plan describes all development and production activities planned by the lessee for a specific lease(s) and the timing of these activities. The plan includes a description of the activities to be performed; a proposed schedule for development and production; descriptions of drilling vessels, platforms, and other offshore structures, their locations and safety and pollution control features; the approximate well location(s); current interpretations of geological and geophysical data (proprietary information); and safety standards to be met and implementation procedures.

The environmental report analyzes the impacts that may occur as a result of implementation of the plan. The report considers both offshore and onshore impacts, transportation routes; discharges generated, resource requirements; biological, physical, and human environments; and contingency plans and equipment. After receiving the development and production plan and the environmental report, the Geological Survey prepares an environmental assessment which is reviewed and processed in a manner similar to that prepared in the exploration phase.

If the development and production plan is approved, the operator submits an application for permit to drill to the Geological Survey for approval. Additional permits that may be required in the course of OCS operations are listed in Figure I-7.

For pipeline transportation across the OCS, a grant of right of way (issued by the BLM) or a grant of right of use or easement (issued by the Geological Survey) may be required. The Department of Transportation's Materials Transportation Bureau is responsible for issuing regulations for pipelines on the OCS, whereas the Geological Survey performs a technical review and makes a hazard analysis of the proposed pipeline route. In addition, the U.S. Army Corps of Engineers issues permits for the construction of pipelines in navigable waters, the Fish and Wildlife Service (DOI) reviews all pipeline applications, and state and local agencies are responsible for regulation of pipelines in state waters.

During the course of development of OCS leases, the government provides for OCS safety through the submission and review of plans, reports, and permit applications, and through monitoring and inspection to ensure that procedures are being conducted in conformance with the plans, reports, and permits.

OCS Production. The duration and amount of production is dependent upon the reserves discovered, the number of wells drilled, and their respective rates of flow. Rates of production for each well are established by OCS operators and reviewed and approved by the Geological Survey under OCS Order No. 11. Once production begins, certain federal regulatory requirements must be met, including monthly reports of production and submittal of royalty payments to the Geological Survey; lessee compliance with all safety and operating requirements, including periodic inspection by both the Geological Survey and the Coast Guard; and obtaining Geological Survey's approval of any significant modification to production equipment or procedures.

For various reasons, lease termination proceedings may be initiated by the Department of the Interior or by the lessee. In this case, or when a lease expires, all piping and platform legs (for exploration, development, and production) must be cut off below the surface of the ocean floor and other bottom obstructions must be removed. The BLM is responsible for all official record title actions.

Other Program Elements. The Geological Survey and the Coast Guard are supposed to conduct separate extensive field inspection programs throughout exploration, development and production to ensure that operations comply with regulations and permit conditions. The Geological Survey's drilling and production compliance inspection program is intended to ensure that all operations are in compliance with safety and pollution prevention requirements. Checklists containing pertinent requirements of OCS orders and regulations are developed prior to commencement of compliance inspections and serve as the basic inspection guide. Subject to possible personnel limitations that the committee did not investigate, inspections are specifically tailored to each facility and operation; therefore, accompanying the checklist is information on the specific facilities and operations to be inspected, such as permit conditions, system schematics, and prior inspection reports. The applicable questions are answered by inspection personnel during the inspection, and the prescribed enforcement action is taken if noncompliance conditions are discovered.

The Coast Guard developed its OCS inspection practices as an outgrowth of extensive marine inspection activities. Marine (ship) inspectors are indoctrinated in OCS systems and operations and then detailed to inspect OCS installations. Many systems on OCS installations are similar to those on ships. Examples are the hulls, fire fighting equipment, and machinery and electrical installations. Like the Geological Survey, Coast Guard inspectors use an extensive check-off form in their OCS inspections.

Other important components of the administration of the OCS are the "diligence" and "prompt and efficient development" requirements.[9] The thrust of these requirements is that no offshore operator should be able to withhold resources by improperly shutting-in wells or delaying exploration or production. In deliberating the 1978 Amendments to the OCS Lands Act, Congress indicated that, if lessees act in conformance with their exploration and development plans, as defined by regulation and approved by the Secretary of the Interior, they would be acting with due diligence and would not be deprived of their leases; and furthermore, in the case of joint ventures, innocent parties would not be punished by the activities of their partners.[10] The DOI has general regulations on diligence and a policy on prompt and efficient development. The policy is that, upon conclusion of the first lease term, the lessee shall have begun development operations (as evidenced by the obligation of funds) or else run the risk of not having the lease renewed. The Department of Energy has the authority to issue diligence regulations that could duplicate and possibly supersede the DOI's regulations.

How the OCS Safety Program is Implemented

The actual implementation of the government's OCS safety program works something like the following. Regulations promulgated at the national level with occasional interpreting guidance at the regional levels establish rules, procedures, and standards for OCS development. These regulations are implemented at the federal regional and district levels and complied with by industry. In order to implement and comply with the regulations, both the government regional offices and industry interpret the regulations in order to apply them appropriately to the specific conditions on the OCS, which are conditioned by the physical environment, including the marine and coastal environment and its biota, and by the technologies available to the operator. The implementation of regulations is also affected by the technical capabilities of government personnel. This is discussed in Chapter IV.

Another strong influence on implementation of the OCS program has been the numerous duplicative authorities. As has been described, the EPA is responsible for the quality of ocean water and for setting standards for allowable discharges; the Geological Survey oversees the expeditious and safe production of natural resources; the Coast Guard has responsibility over the safety of life at sea, navigation, actual or threatened water pollution, and the integrity of vessels; the BLM specifies the terms of the use of federal lands; and the U.S. Army Corps of Engineers permits the placement of offshore structures.

Recognizing the overlap in authorities, the agencies have attempted to negotiate memoranda of understanding (MOU). MOUs are used by agencies to resolve conflicts in authority and to improve efficiency. They are published in the Federal Register. For example, the Occupational Safety and Health Administration (OSHA) and the Coast Guard resolved confusion over responsibility for workplace safety on the OCS by concluding a MOU that specifies that the Coast Guard will have the major operating responsibility for regulating workplace safety. In exercising this authority, the Coast Guard will take due account of OSHA's general standards and will report any violations of OSHA regulations. MOUs follow practical considerations of enforcement. The OSHA/USCG MOU, for example, acknowledges the Coast Guard's long history of responsibility for maritime safety and (not explicitly stated) practical ability to conduct workplace safety inspections on the OCS.

A memorandum of understanding between the Geological Survey and the Coast Guard recognizes the expertise and experience of the Geological Survey in regulating drilling and production and that of the Coast Guard in maritime safety. An example of how this division of responsibility is translated in the implementation of responsibilities as stipulated in the MOU is that the Coast Guard is responsible for a mobile offshore drilling unit (MODU) as a vessel, while the Geological Survey is responsible for the MODU as a drilling operation.

Because of the number of responsibilities that the Geological Survey has that transect the responsibilities of other agencies, both within the DOI and elsewhere in the federal government, the Geological Survey has drawn up a number of MOUs between agencies to clarify jurisdiction and to avoid duplication and overlaps. Within the DOI, the USGS has negotiated MOU's with the BLM and the Fish and Wildlife Service. Outside the DOI, MOUs have been (or are being) concluded (or expanded) with the EPA, the DOT, and the USCG.

NOTES

1. Department of the Interior, "Secretarial Issue Document on the Five Year Leasing Program," Department of the Interior, Washington, D.C., February 14, 1980, p. 17.
2. National Oceanic and Atmospheric Administration, "Comments on the Final Environmental Statement on Georges Bank, OCS Sale 42," National Oceanic and Atmospheric Administration, Washington, D.C., July 16, 1979, p. 20.
3. Callaghan and Comerford, "Economic Impact of Commercial Fishing," University of Rhode Island, College of Business Administration, Kingston, R.I., October 15, 1976, p. 1.
4. Federal Leasing and Outer Continental Shelf Energy Production Goals, U.S. Department of Energy, Washington, D.C., June 1979.
5. See, for example: "Oil and Gas Journal," Vol. 77, No. 36, September 3, 1979, p. 50 (discussion of CIA research); and, Shell Oil Company, "The National Energy Outlook 1980-1990," Shell Oil Company, Houston, Texas, 1980.
6. These estimates are based on discussions with informed company personnel and trade association executives.
7. Office of Technology Assessment, "Addendum to Staff Paper on Federal Role in OCS Oil and Gas Development," Washington, D.C., 1977. These agencies are the Bureau of Indian Affairs (primarily Alaska involvement), Bureau of Land Management, Bureau of Mines, Bureau of Outdoor Recreation, Coast Guard, U.S. Army Corps of Engineers, Council on Environmental Quality, Department of Defense, Department of Energy, Environmental Protection Agency, Federal Aviation Administration, Fish and Wildlife Service, Geological Survey, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Park Service, Occupational Safety and Health Administration, and the Office of Pipeline Safety.
8. 43 CFR 3301.7, 197.8.
9. See P.L. 95-91, Department of Energy Act, Sec. 302(b), and P.L. 95-372, OCSLAA, Sec. 204(c) and (d).
10. U.S. Congress, House of Representatives, Select Committee on the Outer Continental Shelf, Report, 95-590, p. 143.

II. METHODOLOGY FOR EVALUATING THE ADEQUACY OF OCS SAFETY

One objective of this study was to review and develop methods to assess the adequacy of regulations and technologies to provide for OCS safety as a guide for the government. This chapter presents the analytical process followed in this study.

Considerations in Developing Methodology to Assess the Adequacy of OCS Safety

Any analytical methodology must be appropriate for the context in which it will be used. For example, the methodology must be compatible with available data. It must also take into account the perspectives and needs of its users on the matters being assessed.

Since one purpose of the methodology is to assess the adequacy of regulations, it is important to determine the limitations and effectiveness of regulatory approaches to problem solving. An incremental increase in regulation to promote safety may not necessarily result in a commensurate safety improvement. Occasionally, government action to promote safety can inhibit technological development and industrial activity. Furthermore, the actions the government takes to promote safety need to be balanced against other concerns, such as national energy and environmental goals. A related matter is that regulation needs to be equitable and predictable if it is to be defensible and in the public interest.

A consideration in framing a methodology to assess the adequacy of technology and regulations to provide for OCS safety is the fact that the government's OCS safety program is only effective to the extent that it is complied with. It is far easier (and in the long run more effective) to obtain compliance by fostering a climate of cooperation rather than coercion. To this end, the government may choose to pursue safety by allowing, encouraging, or requiring the development of performance standards in order to promote creative or economic responses to acceptable boundary conditions on OCS operations. Such flexibility may prove critical in addressing the specific needs and sensitivities of each of the OCS regions. For example, technologies that may be entirely adequate in the Gulf of Mexico may not be suitable for use in Arctic operations.

Another item of importance in assessing the adequacy of technological or regulatory innovations is the capability to monitor their effectiveness, i.e., to attribute specific safety improvements to identifiable innovations. To be useful, a methodology needs to incorporate such a mechanism.

The assessment of adequacy is necessarily a judgment that takes all points of view into account. To assess the adequacy of technologies and regulations, therefore, it is necessary to have a clear understanding of all the various attitudes toward OCS safety. Appendix E attempts to portray the many points of view regarding OCS safety that were presented to and defended before the committee in the course of its deliberations.

Alternative Analytical Approaches

Alternative analytical approaches include engineering design review; failure modes and effects analysis; logic diagramming; consequence evaluation; risk studies; comparative analysis; and benefit-cost analysis.

Methods to Assess the Level of Safety

Engineering Design Review. An engineering design review is a systematic evaluation of the performance of each component and subsystem of an engineered system against a specified set of requirements. Included in the review is verification of the validity and applicability of the specified requirements, including an examination to determine any that may be missing.

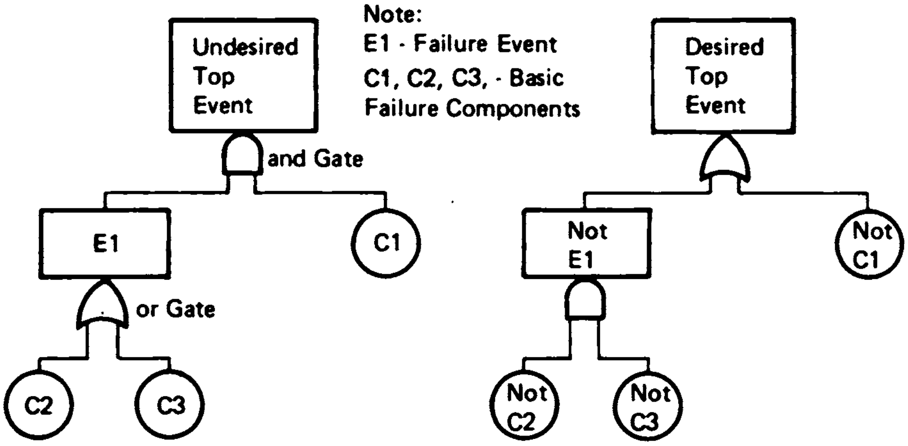
Failure Modes and Effects Analysis. Failure modes and effects analysis (FMEA) is a commonly applied method of system safety analysis. It is used to assess the safety of equipment, processes, and operating procedures that involve the interaction of people and equipment. A table is constructed as the format for searching a system for hazards. As a typical example, such as that shown in Figure II-1, the first column lists the system component, (or it may specify a procedure performed by an individual). The next column typically asks the question "How can this fail or what can be done wrong?" Subsequent columns describe the chain of events leading to the ultimate effect on the system. Those consequences that are not acceptable are highlighted, and corrective actions are derived for the corresponding chain of events.

Logic Diagramming. Fault tree and event tree analyses involve the diagramming of engineered systems and human interaction with them and considers the effect of the failures at all points in the system. In these methods, a logic diagram is developed describing those combinations of events that will cause the occurrence of a specified "undesired top event."

A similar technique, success tree analysis, considers desirable events instead of failures. In both cases Boolean algebra is used to reduce the complex logic diagram to its basic elements and probability theory is used to evaluate the importance of basic events and sets of events that combine to cause the undesired top event to occur (see Figure II-1).

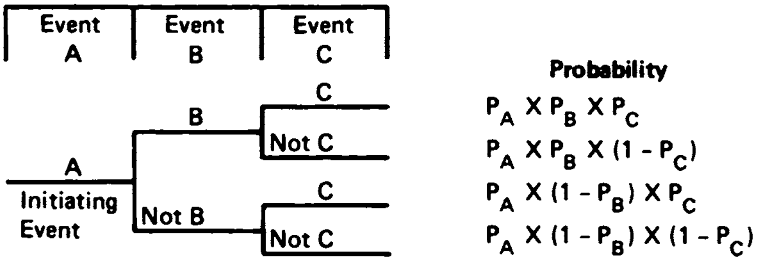
System Component	Failure Mode	Direct Effect	Effect on System	Hazard Level	Corrective Actions

Example FMEA Format



Fault Tree

Equivalent Success Tree



Event Tree

Failure Modes and Effects Analysis

Source: Pape, R., H. Napadensky, and T. Waterman, "Evaluating Hazards of Manufacturing and Handling Pyrotechnic Materials," Proceedings of the Seventh Pyrotechnics Seminar, Vail, Colorado, July 14-18, 1980, pp. 505-528.

Figure II-1

Event trees and decision trees are other types of logic trees. Conditional probability chains, usually used when historical accident data are available for similar situations or systems, is yet another technique of system safety analysis. The specific technique that is used to determine failure paths and probabilities of undesired events depends upon the purpose of the analysis and the nature of the data or information available to the analyst.

Consequence Evaluation. Once an undesired event is found to be credible in terms of probability of occurrence, it is usually desirable to ascertain the severity of the potential consequence. In a consequence analysis, the phenomena are modelled analytically or experimentally. For example, the damage potential of an explosion is determined by first assessing the explosion effects in terms of airblast overpressure and impulse and the radiated heat flux. Next, the consequences of these explosion effects on people and property are calculated.

Risk Studies. Risk assessment generally combines several of the methods previously described. These methods are not sharply discontinuous; there are similarities and overlaps. In assessing risk it is necessary to consider two factors: the likelihood that an undesired event will occur and the magnitude of the consequences of the event.

When failure rate data are available for the basic events on a logic tree, and the technology base exists for determining the consequences of undesired events, then risk analysis has the potential to pinpoint the weak elements in systems, define the sequences of events leading to undesired events, predict the frequency with which undesired events will occur, and identify methods to reduce the frequency of their occurrence or the magnitude of the consequences. The consequences of undesired events can be described in as much detail as the technology base permits.

Most of the above results of risk assessments can be obtained even if the data base is small or incomplete; however, the confidence level of the results will be low. In these instances, the probabilities assigned to individual events may be judgmental or synthesized from similar systems or components. They may stray far from mathematical certainty. In such a situation sensitivity analysis is performed, but is technique also is subject to judgmental errors.

Analyses that do not use logic trees but use conditional probabilities based on historical data can provide guidance as to the seriousness (from a frequency standpoint) of undesired events.

The accuracy and completeness of the physical models used in logic trees and consequence analyses directly impact the validity of the results. Incomplete logic trees can lead to incorrect conclusions. Incompleteness may be due to the analyst not considering all significant failures and failure paths. This may result from an incomplete understanding of how the system functions or simply from oversight.

Since a detailed risk assessment can be costly, it is important to balance the level of detail sought against the adequacy of the data base and the technology base. Because adequate input data (e.g., failure rates) are often lacking, numerical probability predictions should not be taken literally.

A drawback of these several techniques for the purpose of assessing OCS safety is that they are more capable of dealing with technological factors than with regulatory nuances. Further, these methods require substantial detail specific to individual installations. To use them in assessing the safety of all operations on the OCS would require a number of separate analyses, which would have been completely beyond the scope of the committee's capability.

Risk assessment requires data that are frequently lacking. Data needs fall into two broad categories: failure rate data (e.g., equipment and people) and consequences data. The mere existence of data weaknesses should not prevent the assessment of risks. Much can be learned through use of these analytical techniques, at any level of detail.

Although the calculation of a level of risk may be a straightforward scientific problem, the acceptability of a given level of risk is often a judgment.

Risk assessment is not the definitive answer to the methodological needs of the OCS Safety Program. However, it has in selected situations the potential to increase the government's understanding of OCS safety problems and mitigation measures. Risk assessments or other analytical tools that use a logical and systematic structure have their greatest value in evaluating new technologies and innovations.

Methods to Assess Adequacy

Comparative Analysis. An analytical tool that is useful in certain instances to assess adequacy is to compare OCS safety with safety in analogous onshore or other maritime situations or to compare it with an activity that produces similar benefits (e.g., energy resource development). The committee used the first two approaches in aspects of its work, especially in analyzing workplace safety. While the approach is useful in such specific applications, it is neither comprehensive nor rigorous.

Benefit-Cost Analysis. Stripped to its essentials, benefit-cost analysis is a method that can be applied to determine whether a given activity should be continued or a contemplated activity undertaken. In principle, the benefit-cost ratio is straightforward. For example, let \$B equal the dollar value of the gross benefits per year of an activity and \$C equal the total costs (operating costs and capital costs) per year of the activity. Then, \$B - \$C is the net benefit per year and the net benefit-cost ratio is (\$B - \$C)/\$C. In this sense, the net benefit-cost ratio resembles a net rate of return on total costs per period.

The technique seems simple, yet it is embroiled with confusion and controversy that make the resulting quantitative evaluation uncertain. Furthermore, the usefulness of the technique is limited in analytical situations typical of those encountered in the administration of a regulatory program to ensure OCS safety; for example, determining whether a specific regulation, or a set of reasonably well-focused regulations (e.g., those governing crane design or crane operation), has increased OCS safety by reducing accident frequencies.

Assuming that the required data are available in abundance and recorded without error, and that the proper statistical tests are designed and conducted, several outcomes are possible.

- The hypothesis that regulations have reduced accident frequency can be rejected with a high degree of confidence. In this instance, the gross benefit ($B) of existing regulations is zero, the net benefit is -$C, and the net benefit-cost ratio is -1. The policy implication is clear: the regulations should be scrapped. If the specific accident frequency is nonetheless "unacceptably high," some other regulations, or perhaps certain forms of penalizing the occurrence of accidents, should be considered. The insurance market, of course, provides penalties for certain kinds of accidents as insurance premiums adjust in response to accident severities and frequencies.

- The hypothesis that the regulations have reduced accident frequency cannot be rejected (in looser terms, some positive, desirable effects of the regulations are apparently present). In this instance we are faced with the problems of identifying direct and indirect benefits, and of placing dollar values on each type, and of identifying direct and indirect costs, and evaluating each in dollar terms.

Even if it were possible to identify the true components of all benefits and all costs, the formidable task of evaluating them in dollar terms remains.

If extensive analysis yields a correct value of ($B - $C)/$C, criteria are required to gauge whether a specific, numerical benefit-cost ratio is "sufficiently high" to merit a program's continuation. If the ratio were negative, then the benefits would be less than the costs of enforcing and complying with the regulations. But if the ratio were positive, the thorny problem would arise of deciding whether the net rate of return over costs is high enough to justify continuing the regulation.

A related limitation is that, if several analysts (each with different perspectives) conduct similar benefit-cost analyses independently, different benefit-cost ratios will probably result.

Another consideration in reliance on benefit-cost analysis to measure the adequacy of safety of regulations and technologies is that the data and computational requirements are severe. As a practical matter, the OCS data base is neither extensive nor reliable enough to support the regular use of benefit-cost analysis in administering the OCS regulatory program.

The conclusion that can be drawn from this brief review is that while benefit-cost analysis has the potential of being a valuable tool in the administration of the OCS program, there are practical limitations to its use.

Safety Data and Areas of Safety Concern

An important task in methodology design is gaining an understanding of available data, including its scope, limitations, and organization.

Data on the Cost of OCS Regulation

The committee attempted to compile information on the cost of OCS regulation and regulatory compliance. The American Petroleum Institute has conducted a study of "the Economic Impact of Environmental Regulations on the Petroleum Industry."[1] This study presents estimates of environmental control costs to the petroleum industry through 1990. The Geological Survey is estimating the economic impact of its OCS regulations.[2] As a contribution to the committee's work, the Offshore Operators Committee provided data on the amount of effort and cost of personnel devoted to regulatory activities.[3] In addition to these studies, the committee requested information from federal agencies on their OCS regulatory development, implementation, and enforcement budgets. Another source of information on the cost of regulation that the committee consulted was a study conducted by Arthur Anderson & Co. for the Business Roundtable, which included a study of the direct incremental cost incurred by 48 companies in complying with the regulations of six federal agencies for calendar year 1977.[4]

While these studies provided many interesting points of discussion relative to the cost of OCS regulation, they furnished little verifiable data for assessing adequacy. As a consequence, it was not possible to use a methodology that called for any rigorous analysis or estimate of costs.

Technological and Regulatory Data

A data base on OCS safety was prepared in this study. The sources of technological and regulatory data used in the study, including their scope and limitations, are presented in Appendixes C and D of this report. The Geological Survey and the Coast Guard both participated in establishing this data base. The present data set is but a first step toward a system to support continuing assessment of OCS safety.

The technological and regulatory data have been organized around five areas of concern: workplace safety; fires, explosions, and emergencies requiring abandonment of OCS installations; loss of OCS installations; well control; and operational discharges. These groupings provide a convenient way of categorizing safety data according to their human or environmental consequences and also the authority and interests of the federal agencies. Table II-1 shows how analysis by areas of concern covers the range of possible safety consequences and also government regulatory agency interests. In the frame of reference of Table II-1, it is convenient to consider all aspects of human safety and, therefore, the primary set of interests of the Coast Guard, under the workplace safety, fires, etc., and installation loss areas of concern. The major portion of the Geological Survey's regulatory program that is concerned with regulating drilling and production operations is covered under "well control." The bulk of the environmental aspects of OCS safety, including acute and chronic pollution from petroleum, drilling fluids, "household wastes," pipelines, and spill containment and cleanup, fall under the "operational discharges" area of concern. As indicated in Table II-1, the areas of concern reflect the types of events that have occurred in the past and also the types of safety problems that are likely to occur in the future.

The Committee's Methodology

The committee recognized that all of the analytical techniques discussed here can contribute in one way or another to assessing the adequacy of technologies and regulations to provide for OCS safety. However, none of the techniques is adequate to stand alone as an analytical basis for assessing OCS safety, which is due either to limitations inherent in the techniques or in the data base.

The committee employed an analytical method that was tailored to its purpose and that took account of the fact that OCS safety data have not to date been rigorously and comprehensively collected and analyzed. The committee initiated its OCS safety inquiry by requesting information and opinions on the safety of OCS activities from all interested parties (Appendix B). This served to identify sources of public concern or frustration. The committee then reviewed the historical record of the safety of OCS activities, including the conclusions and recommendations of prior studies. The product of these investigations was the preliminary identification of areas of safety concern.

The committee assembled a data base on OCS technologies and regulations, organized by area of safety concern (Appendices C and D). This was reviewed for internal consistency. The committee also described the various technical and social perspectives that must be considered in an assessment of the adequacy of OCS safety (Appendix E).

TABLE II-1

The Coverage of Areas of Concern

Area of Concern	Consequences		Cognizant Federal Agency		
	Human	Environmental	USGS	USCG	EPA
Workplace Safety	X		X	X	
Fires, Explosions, Emergencies	X		X	X	
Installation Loss	X		X	X	
Well Control		X	X		
Operational Discharges		X	X	X	X

Source: Committee on Assessment of Safety of OCS Activities

The next task was to generate and refine a set of questions on the adequacy of data and technologies and regulations to provide for the safety of OCS activities. The questions are not in any sense criteria by which to measure adequacy. They are, instead, analytical triggers that initiate inquiry into the adequacy of technologies and regulations. The assessment of adequacy is a judgment (in this case, the collective judgment of the committee). It is the product of the melding through review, analysis and discussion of individual points of view.

The final task to enable the assessment of the adequacy of OCS safety was preparation of technical descriptions of areas of OCS safety concern sufficient to support the committee's technical analysis.

Following is the list of questions on the adequacy of data and technologies and regulations that the committee developed and employed.

Adequacy of the Data to Support the Analysis

1. Are the data adequate in terms of quality and quantity to support the analysis? Is the volume of data sufficient to support statistical analysis and to determine cause-effect relationships?

2. Are the preliminary analyses consistent with the data?

3. Can events that emerge from the data be characterized as regards:

   - causes of events and their frequency, as well as probable causes of events in frontier areas?
   - consequences of events, including probable consequences of anticipated events in frontier areas?
   - concerns that are unique to specific operating regions?
   - mitigation strategies to prevent untoward occurrences?

Adequacy of Existing Regulations to Cope with Classes of Events

1. What are the regulations related to the area of concern? When did they come into force? For the purpose of analysis, should incidents that preceded crucial regulations be analyzed separately from those that occurred after crucial regulations were in force?

2. To what extent are the causes of events unidentified and why? To what extent are the identified causes and consequences of these events covered by regulation? For the causes and consequences addressed by regulation, why did the regulations not succeed? What is the implication with regard to the adequacy of the regulation? Do regulations have the

flexibility to address site-specific needs? Are new regulations indicated? Would a performance-oriented regulation be more effective than a detailed technical specification? Is better enforcement needed? What urgency is indicated for these actions?

3. For causes and consequences not covered, is it clear that regulations would help eliminate causes or reduce consequences? What would be the nature of additional regulations? How would they operate so as to achieve the desired results? To what extent could they be expected to reduce the causes or consequences?

4. For both existing and needed regulations: (a) Does technology exist that permits them to be carried out? If not, can it be developed? What action is indicated?
   (b) Are procedures and means in existence, or could they be established, for ensuring compliance with the regulations? Are there economic or other private sector incentives for compliance or resolution of problems? (c) Are the costs of compliance commensurate with the severity of the events? What data are available or needed to support such decisions? What criteria are there for making such decisions?
   (d) Are the costs of enforcement commensurate with the projected results?

Adequacy of Existing Regulations from the Standpoint of Promoting OCS Safety

1. Do overlapping agency authorities or duplicative regulations inhibit the effectiveness and enforceability of specific regulations and industry's compliance with specific recommendations?

2. Are specific regulations clearly aimed at enhancing some aspect of safety in OCS operations? Are they aimed at preventing specific types of undesirable events that have actually occurred? Are these types of events peculiar to OCS operations and likely to recur?

3. If not aimed at a specific type of event, how do specific regulations act to enhance safety? To what extent is the effect of each regulation definable or predictable if it is carried out?

4. If aimed at specific events, do the regulations require actions that reduce event frequency or severity if carried out? What is the basis for this conclusion? Are there any historical data that indicate that the regulation has already had an effect or has not been effective? What are the implications with regard to the adequacy of specific regulations?

5. To what extent do specific regulations deal with the causes or consequences of events?

6. To what extent do specific regulations address hardware, procedures, or personnel concerns? Are there specific, identifiable gaps in regulatory coverage?

7. Is each regulation enforceable? What steps do the government agencies take to ensure compliance? Can industry compliance with the regulation be demonstated? What conclusions can be drawn about the overall effectiveness of each regulation?

8. Are the costs to government and industry of implementing, enforcing, and complying with specific regulations commensurate with the ensuing improvement in safety? What is the basis for this conclusion?

Adequacy of Technology Utilization to Provide for OCS Safety

1. What are the specific attributes of existing technologies that promote OCS safety? Are these attributes in the area of hardware, operating procedures, or human factors? How are these attributes related to the causes or consequences of events?

2. Are alternate technologies or utilizations of technologies immediately available, the application of which to OCS operations would promote safety? Are these related to hardware, operating procedures, or human factors? How would their use address the causes or consequences of events? What specific steps would have to be taken to utilize alternate technologies to promote OCS safety?

3. Are there specific opportunities to promote safety that hinge on new technological developments? Are these opportunities related to hardware, operating procedures, or human factors? How would the development and application of new technologies relate to the causes or consequences of classes of events? What specific steps would have to be taken to develop needed technologies and utilize them to promote OCS safety?

NOTES

1. Sheppard, W. J. et al., The Economic Impact of Environmental Regulations on the Petroleum Industry--Phase III, Battelle Columbus Laboratories, Columbus, Ohio, March 1980.
2. Arthur D. Little, Co., Inc., Cost of U.S. Geological Survey OCS Regulations in the Western Gulf of Mexico, Arthur D. Little, Inc., Draft report to the U.S. Geological Survey, Contract No. 84434, Cambridge, Massachusetts, September 18, 1980.
3. Shirley, O. J. "The Cost of Regulatory Compliance on the Outer Continental Shelf: Report on an Industry Survey." In National Research Council, Safety and Offshore Oil: Background Papers of the Committee on Assessment of Safety of OCS Activities, National Academy of Sciences, Washington, D.C., 1981.
4. Anderson, Arthur and Co., Cost of Government Regulation Study, Executive Summary, The Business Roundtable, New York, N.Y., March 1979.

III. SAFETY OF OCS OIL AND GAS OPERATIONS

This chapter presents a technical analysis of safety on the OCS. In doing this, it concentrates on reviewing, analyzing, and discussing data to determine the extent of safety problems and reviews technological and regulatory approaches for controlling and improving OCS safety. Findings about the adequacy of technologies and regulations and recommendations for specific improvements are also noted.

This chapter is organized in the following way. Environmental safety is analyzed, then human safety and the safety of structures. The environmental section commences with a description of the sources of discharges from OCS operations. This is followed by a review of the environmental effects of discharges. The technologies and regulations are assessed individually in the areas of intentional discharges from OCS installations, well control, pipelines, accidental discharges from other sources, and spill containment and cleanup.

Human safety and the safety of structures are analyzed from the standpoint of workplace safety, fires and explosions, emergencies requiring abandonment of installations, and loss of installations.

Environmental Safety

Sources of Accidental and Intentional Discharges to the Marine Environment

Discharges incident to OCS operations include the accidental spilling and the intentional release of oil, hydrocarbon-contaminated produced water, drilling fluids, and other materials and debris into the ocean. Excluded are releases from other oil and gas activities in the ocean, such as marine transportation of petroleum products. Also excluded are hydrocarbons from terrestrial runoff and natural seeps of oil.

Estimated data on discharges from OCS operations have been developed by the Geological Survey and the offshore oil industry. Table III-1 presents annual estimates, based on a three-year period, of the total quantities of material discharged into the Gulf of Mexico in the course of OCS operations. The data on petroleum discharges in the table are based on spills reported to the Geological Survey by OCS operators. In this data spills of less than one barrel are recorded as one barrel spills.

The "produced water" and "oil from produced water" estimates are based on the assumptions that all produced water is treated to separate most of the oil and then discharged overboard. The oil content of this effluent was estimated in two ways: as an average, (25 ppm)

TABLE III-3

Estimated Inputs of Petroleum Hydrocarbons in the World's Oceans During the Early 1980s[a]

Estimated Magnitude (mta)b

Input Source	Quantity
Natural Seeps	0.6[c]
Offshore Production	0.2[d]
Transportation	0.8[d]
Coastal Refineries	0.02[d]
Atmosphere	0.16[e]
Municipal and Industrial	0.45[d]
Urban Runoff	0.13[c]
River Runoff	1.6[c]
TOTAL	4.57

[a] Input values are directly subject to global output values that may experience major shifts because of political, financial, economic, or exploration/production considerations.

[b] Millions of tons per annum

[c] Estimated with modest confidence

[d] Estimated with high confidence

[e] Estimated with low confidence

SOURCE: Adapted from Farrington, J. W., " An Overview of the Biogeochemistry of Fossil Fuel Hydrocarbons in the Marine Environment," in Petrakis, L., and Fred T. Weiss, Petroleum in the Marine Environment, American Chemical Society, Washington, D.C., 1980.

and as the maximum concentration permitted by regulation.[1] The drilling fluids and well-cuttings estimates are based on "average" data per well multiplied by the number of wells drilled on the OCS. The data should be viewed as lacking precision but representing an appropriate order of magnitude.

Drilling fluids are a large source of intentional discharges: approximately 110,000 tons per year. Table III-2 describes the composition (excluding water) of a typical drilling fluid. The constituents listed in the table are the approximate dry weights of materials added to water to form a typical drilling fluid. It is important to recognize that, at temperatures and pressures encountered in geological formations, chemical reactions may alter the composition or structure of the drilling fluid. Also, fine material from cuttings, as well as fluids encountered in drilling, add unknown quantities of dissolved and suspended materials to the drilling fluid. Further, the composition of the drilling fluid changes (and is manipulated) in response to downhole conditions. Because of these factors, drilling fluids should be regarded as a system whose characteristics vary, rather than as a single entity consisting of known components. It is the modified, spent, or used drilling fluids that are discharged and have the potential of impacting the marine environment.

Another accidental discharge source is gas blowouts. In some instances, the rapid uncontrolled release of large amounts of gas at the sea floor has caused great quantities of sediment to be suspended in the water column.[2]

In considering the significance of both intentional and unintentional discharges into the ocean from oil and gas drilling and production activities, it is important to have a sense of the background, or ambient, levels of petroleum hydrocarbons in the oceans from all known sources. Table III-3 lists these sources and estimates their magnitude.

From 1975 to 1978, OCS oil and gas operations resulted in an estimated 57,000 barrels of oil entering the marine environment.* Of this, about one third occurs accidentally, whereas two thirds is discharged along with waste waters that flow from wells in the course of oil and gas production. The accidental discharges are caused by identifiable incidents such as blowouts, pipeline and pump accidents, and other operational failures, whereas intentional discharges accompany producing wells.

Environmental Effects of OCS Operations

In recent years, marine scientists have been applying more sophisticated techniques to gather information and data on the fate and effects of oil spills and the release of organic and inorganic

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*In this calculation, intentional discharges of oil have been estimated to be the maximum allowed by regulation. Accidental spills include only those spills that were reported.

TABLE III-2

Composition of Drilling Fluid

			Quantity (Tons)		
Components	Example Materials	Concentration Range (lbs/bbl)	0-3,500 Feet	10,000 Feet	5,000 Feet
Weighing Agents and Viscofiers	Barite	25-700	6	535	1,160
	Bentonite Clays	5-35	20	56	65
	Attapolgite Clays	10-30	10	10	10
Dispersants and Thinners	Lignites and Lignosulfates	1-25		26	95
Fluid Loss Reducers	Starch	2-15			
	Cellulose and Acrylic Polymers	0.25-5	1	4	4
Lubricants, Detergents, Emulsifiers	Processed Hydrocarbons (asphalt)	1-50			
	Detergents	0.05-15	1	3	3
	Surfactants (fatty acids, etc.)				
Defoamers, Flocculants, Bactericides	Organic Sulfates and Sufonates	0.05-6			
	Parafoamaldehyde	.02-2			
	Sodium Penta Chlorophenate				
Lost Circulation Materials	Fibrous and Coarse Materials	5-50			
Special Purpose Additives					
Corrosion Inhibitor	Sodium Chromate	0.1-2			
Surfactants					
ph Control	Caustic Soda				
Resistivity Control	Salts				
Coatings	Formulating Compounds	10-125			

Source: Adapted from "Oil and Gas Well Drilling Fluid Chemicals," API Bulletin 13F, American Petroleum Institute, Dallas, Texas, 1978.

TABLE III-1
Estimated Quantities of Discharges Annually into the Gulf of Mexico, 1975-1978

Discharge	Quantity (Average per year)	
Drilling Fluids & Solids		
Drilling Fluids Constituents(1)		110.21 x 10^3 tons(2)
Drill Cuttings		3.31 x 10^6 tons(2)
Petroleum		
Accidental Discharges		3631 Barrels (bbls)(3) (494 tons)
Blowouts	(one 10 bbl spill in 1978)(3) (1.36 tons)	
Pipeline and Pump Accidents	1701 bbls (231 tons)	
Other Accidental Discharges	1930 bbls (262 tons)	
Intentional Discharges		
Produced Water		220 x 10^6 bbls (29.93 x 10^6 tons)
Oil from Produced Water		5,500 bbls[4] (748 tons)
Deck Drainage		Not Available
Sewage		Not Available
Chlorine/Biocides		Not Available
Debris		Not Available

1. Barites, Bentonites, Lignosulfates.
2. Estimates based on the total amount of feet drilled (USGS) and usage rates (National Petroleum Council).
3. Does not include seepage from Santa Barbara at approximately 1,450 bbls/year (197 tons/yr).
4. Estimate based on average discharge. The regulated maximum permits a discharge of 10,560 bbls (1,436 tons).

SOURCE: Committee on Assessment of Safety of OCS Activities.

substances to the ocean environment at specific sites. Scientists agree that petroleum spills and discharges of high concentration produce an adverse effect on marine biota. There is no clear agreement among ocean biologists as to whether low concentrations of petroleum or drilling fluids and cuttings produce significant effects on marine biota. Nor is there agreement about the cumulative effects of low levels of discharges or of disturbances caused by drilling operations to natural ecosystems, both being difficult to detect and measure quantitatively. Moreover, the long-term effect of the discharges on an ecosystem or community has not been established adequately. Thus, while there is general agreement that the toxicity and smothering effects of large quantities of oil and drilling fluids and cuttings are harmful to pelagic birds, benthic organisms, and coral reefs, there is less agreement on the ability of those life forms to recover after a time.

Some of the difficulty of achieving consensus on these matters is that there is considerable case by case variation in field studies. Three marine scientists who have conducted research on the fates and effects of hydrocarbons in the marine environment critiqued some of the pertinent scientific reports for the committee.[3, 4, 5] These papers indicate that marine scientists differ on the adequacy of the research that has been conducted, from the standpoint of uncertainties in the data as well as the validity of research methodologies.

It is possible that the safety of OCS oil and gas operations could be improved (or regulatory standards relaxed) if the environmental consequences of specific discharges were better understood and generally accepted. Evaluations acceptable to the entire scientific community need to be made about the fate of petroleum, drill cuttings, and drilling fluids and their effects on the water quality and biological populations of the ocean. The effects of oil and drilling fluids and cuttings in different environments may vary considerably because of the sensitivities of different species and possible synergistic interactions. The effects will also vary as the result of variations in discharge concentrations, discharge volumes, and the accumulation of discharges in an ecosystem. Fate and effects evaluations will require accurate, standardized techniques for chemical analyses and for biological studies in controlled laboratory conditions as well as in the ocean environment. Meeting this need is very difficult because of the exceedingly complex and varied nature of the biological species and environmental conditions likely to be involved.

There has been considerable scientific concern and public discussion on this subject. Interested parties--scientists, environmental representatives, and the oil industry--agree that the scientific data on which each of the positions are based should be subjected to rigorous peer review.

In the past a number of investigations sponsored by industry or government to elucidate the fate and effects of discharges on the OCS have lacked effective peer review of methods, results, and conclusions. In the conduct of this study, the committee learned variously from individual scientists that existing data demonstrate no significant effects or that significant effects on the marine environment are occurring.

Several ongoing scientific programs have contributed to the debate on the fate and effects of OCS discharges, and offer the prospect of continuing research and (perhaps in the future) bringing the debate closer to resolution. These include the planning for ocean pollution research, development, and monitoring coordinated by the National Oceanic and Atmospheric Administration pursuant to P.L. 95-273,[6] and the Environmental Studies Program of the Department of the Interior. Another scientific activity has recently commenced that offers the possibility of bringing the scientific debate on the fates and effects of some discharges from OCS operations closer to resolution. The National Research Council's Ocean Science Board is updating its 1975 report on the fate and effects of petroleum in the marine environment, utilizing more recent research on biological and chemical actions of oil spills and other discharges in the ocean.[7] This study does not extend to drill cuttings and drilling fluids.

The next paragraphs identify considerations in the design of a program whose objective would be to develop consensus on research objectives, methodologies, data quality, and method of interpretation applicable for research on discharges from OCS operations in the marine environment.

Considerations in Achieving Consensus. Existing information on environmental conditions and the fate and effects of discharged materials in the marine environment are inadequate for operational standards, even though in the absence of adequate data environmental standards are still required by law. The requirements of the law necessitate that federal efforts to promote environmental safety be based on a well-conceived fate and effects research program that produces a reasonable level of scientific concensus on research objectives, methodologies, data quality, and methods of interpretation. The research methodology for such a program needs to emphasize the highest quality of scientific endeavor in order to come to grips with the complex environmental cause-effect relationships. Inasmuch as leasing and regulatory decisions are based in part on research programs, it appears necessary to correlate research programs with oil and gas activities in a timely way. At each stage of a research program (program design, experiment design, data quality, and conclusions) adequate levels of peer review need to be provided.

Emphasis should be placed on comprehensive experimental design, with commitment to long-term (life of oil field) data acquisition coupled with analysis, and continuity in program management and coordination among federal agencies to foster acceptable and useful data. The variability of natural ecosystems makes commitment to long term studies particularly important.

Because of the variety of conditions in OCS areas, there is a need to allow for an element of variability in research design to accommodate local differences and needs. The concept of flexibility needs to be extended to the research design to allow for modification of the methodology during the studies in order to accommodate new and useful information. This element of flexibility needs to be reflected in the overall management scheme to allow for innovative and comprehensive research. In this connection, model contract terms that build flexibility into federal research programs are now used by the Office of Naval Research, the Air Force Office of Scientific Research, and the Army Research Office.

It must be recognized that the problem of developing scientific information adequate to serve as the basis for regulation, as required by law, is one of extraordinary difficulty. The task is made easier if environmental data is acquired before oil activity begins, opening the possibility of altering the ecosystem. The many variables that are encountered include the background or natural levels of materials in the water column and in the sediments prior to the start of drilling and production operations; the extent of living resources in the area, their value, and their sensitivity to discharged material; the estuarine or oceanic circulation, including seasonal variability, which drives currents at the site; the equipment necessary to drill and produce in the environmental conditions (e.g., water depth, weather, ice cover) at the site; the rate of discharge of either drilling fluids, drill cuttings or produced water; the concentration of given constituents in either of these source discharges; and the effectiveness of spill control, containment, removal, and disposal.

Site-specific discharge studies need to address three levels of concern: local concentrations (read also volumes, and rates of discharge and dispersion) of discharged materials at a specific drilling or production site; area concentrations of discharged materials in regions of oil or gas activity where the effects of discharges from several drilling and production sites may be additive; and concentration levels of discharged materials in the estuarine or oceanic circulation system that drive water past oil and gas operations.

Two types of discharged materials are important to consider at each level of concern: (1) dissolved materials that persist in the water column while possibly reacting, being assimilated, or otherwise changing form over long periods of time and (2) insoluble materials, such as solids, that are transported different distances from the site of operations, depending on their particle size and specific gravity, the current regime at the site, the bathymetry, and the disposal technology used by the operator.

Specific concerns about effects may be manifested in observable and measurable phenomena. These are identified and arranged in Table III-4.

Two general classes of studies may be envisioned as making up the scope of the needed technical effort.

- o Fate Studies. Fate studies are concerned with the physical and chemical distribution or diffusion of discharges in the marine environment. First, it is necessary to characterize the estuarine and oceanic circulation system that drives water past the operational site. Because there are so many variables involved in oceanic circulation systems, site specificity is very important. The missing features of the circulation system need to be defined so that the dispersion and long-term concentrations of discharged materials can be determined at all points in the circulation system. This makes it possible to define the flow patterns of discharges at particular sites and over entire areas of operations. A three-dimensional quantification is needed. This is recognized to be a large and difficult task to carry out with mathematical precision, supported by reliable verification in the ocean. Even so, dependable calculations can ultimately be made of the behavior of cuttings and undissolved materials that settle to the bottom at some distance from the operational discharges site, dissolved materials that diminish in concentration at greater distances from the discharge point, and potential additive effects from more than one drilling or production facility of both undissolved and dissolved materials in the circulation system.

- o Biological Studies. Biological investigations are needed to characterize existing biota in discharge areas (including identifying seasonal variations and sensitive periods, such as spawning times); determine the community structure in order to understand the ecological or economic value of each species; and establish relationships between specific operational discharges and biological changes. Studies of benthic ecology are an especially important biological area. Biological studies are most helpful if a baseline is established prior to the onset of industrial activity.

A knowledge of these three parameters will foster the identification of ecologically sensitive areas, potential disposal sites of mud and cuttings for minimal impact, and acceptable concentrations, volumes, and rates of discharges.

Where commercially important living marine resources are involved, it may be necessary to analyze trends in fish catch and species composition, as well as spawning success and the strength of particular year classes.

TABLE III-4

Observable Or Measurable Phenomena Which May Be Associated With Intentional Discharges

Effects	Physical	Chemical
Acute	o Turbidity o Smothering	o Toxicity o Bioaccumulation
Chronic	o Changes in Substrate o Biological Community Changes	o Depuration o Physiological Parameters o Reproductive Effects o Behavioral Effects o Reduced Growth

Source: Committee on Assessment of Safety of OCS Activities

In addition, appropriate laboratory studies of toxicity and biological effects should be undertaken to assist or strengthen field observations and research.

The Importance of Achieving a Scientific Consensus. The development of a scientific consensus on objectives and methods for research on the fates and effects of petroleum, drilling fluids and drill cuttings in and on the marine environment could be a positive inducement of environmentally satisfactory OCS energy development because it would provide a basis for making the leasing of OCS lands and the regulation of OCS activities more environmentally sensitive and also more predictable. It would enable the regulatory agencies to establish permit conditions at the onset of OCS activities.

These actions would be looked on favorably by both the environmental community and the offshore industry. For the environmental community, greater predictability would allow them to target real areas of concern for public scrutiny. For industry, greater leasing and permit predictability would reduce the financial unknowns that must be contended with.

The absence of a scientific consensus on the effect of OCS activities on the marine environment leaves questions of environmental risk unanswered and impedes the evaluation of the adequacy of regulations. It contributes to unpredictability in the course of operations since lease stipulations and permit conditions applicable to discharges are not known at the time that OCS leases are awarded.

Findings and Recommendations on the Environmental Effects of OCS Operations

Scientists agree that spills and discharges at high concentrations of petroleum, drill cuttings, and drilling fluids produce an adverse effect on marine biota. There is no clear agreement among ocean biologists as to whether low concentrations of petroleum, drilling fluids, and cuttings produce significant effects on marine biota.

While there is a large amount of scientific information on the effects of offshore operations on the marine environment, the data have been acquired piecemeal and often have not been rigorously analyzed. Lack of agreement persists concerning the validity, interpretation, and general acceptance of data. Adequate effort has not been directed to using existing data and structuring scientific programs to achieve a consensus on the fate and effects of petroleum, drilling muds, and drill cuttings on the marine environment.

> Several courses of action should be pursued by the oil and gas industry and the Bureau of Land Management's (BLM) OCS Environmental Studies Program to enhance the possibility of resolving conflicting views regarding effects of discharges, as well as selecting an acceptable environmental data base.

These include the following:

- The conduct of a critical peer review of the existing research concerning the fate and effects of OCS discharges. Among the alternatives available for accomplishing this are establishing a steering group and contract study under the Department of the Interior's Environmental Studies Advisory Board; utilizing the peer review experience of the National Science Foundation by having the review conducted under its auspices; or commissioning an independent study for these purposes.

- Updating of the National Research Council's 1975 study of the fates and effects of petroleum in the marine environment (an update is currently in progress).

- A similar independent comprehensive examination should be conducted of the fates and effects of drilling fluids and cuttings and produced water in the marine environment.

- Additional research to characterize by location, extent and duration the fate and effects of discharges, particularly in frontier areas of recognized biological importance or sensitivity. Specific studies might include analysis of the toxicity, carcinogenicity, and mutagenicity of discharges; the content and distribution of OCS discharges; establishment of circulation patterns in areas of OCS operations and where discharges are disposed of; and documentation of biological effects of discharges. To be effective, this research program must include the development of a consensus on research objectives, methodologies, data quality, and method of interpretation, and must be long-term, flexible, well managed, and carefully integrated into the decision-making process.

A great deal of attention has been devoted to the effects of hydrocarbons in the marine environment; however, little study has been devoted to the effects of gas blowouts in environmentally fragile areas.

> The BLM's Environmental Studies Programs should conduct research into the effects of gas blowouts in environmentally sensitive areas where the threat of a gas blowout may exist.

Intentional Discharges From OCS Installations

Intentional discharges from OCS installations comprise drilling fluids, solids such as well cuttings, and produced water.

In drilling a deep well on the OCS, 10,000-30,000 barrels of spent fluid of varying chemical composition may be discharged at various times. The greatest volume of fluid is used during the final stages of drilling when the hole is deepest. This final lot of fluid --1,000 to 2,500 barrels--is either disposed of when the hole is completed or, in drilling in well-known areas, it is stored in a barge for use in other wells. The most common method of disposal is overboard dumping. Alternative spent fluid disposal methods that exist but that are not widely used include diffuser systems that reduce the concentration of fluids in the seawater or shunting systems that direct discharges to different locations on or near the sea floor; transportation systems that include ships and barges to haul materials from the drilling site to other locations for disposal; onboard treatment and holding systems; and less toxic, possibly reusable chemical constituents for drilling fluids.

Each alternative must be evaluated against overboard disposal in terms of logistic and economic feasibility and environmental and safety considerations. A concern in evaluation is that fluids moved from the drilling site still have to end up somewhere, with possible consequences for environmental or human harm. While industry studies argue that drilling fluids and cuttings have very little toxicity and can be released safely in the marine environment, other scientists have identified certain constituents, such as biocides and heavy metals, that may be toxic. Research conducted by the industry has resulted in substituting or modifying certain chemical constituents in drilling fluids for use in environmentally sensitive areas. Government regulation has encouraged this trend.

The solids that are generated on the OCS consist of drill cuttings and other materials that enter the hole from the formation being drilled. A 10,000-foot well in the Gulf of Mexico may generate 1,800-2,000 barrels of cuttings. Such solids are normally denser than water and sink to the bottom. If the underwater currents are strong near the site, the solids may disperse over a wide area and settle to the bottom some distance from the point of discharge.

During production, a volume of water from the hydrocarbon-bearing formation may be produced along with the hydrocarbons. The produced water is normally separated from the oil on the production platform or nearby, and then is intentionally discharged into the sea. In mature wells, the produced water may comprise 60 percent or more of the fluids pumped. The water passes through separators, which reduce the oil concentration to an average of 25 ppm, with a regulated maximum of 48 ppm.[8] One characteristic of the separation process is that, while it separates most of the petroleum from the associated water, the fraction of petroleum that remains associated with the water is discharged and tends to have a high concentration of the more toxic petroleum compounds (many of which remain dissolved in the water column).*

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*The concentrations of discharged materials after their release to the water column is a separate subject and was not addressed by the committee.

Intentional discharges and other minor discharges, such as deck washings and household wastes, associated with OCS operations are regulated through numerous technical and administrative requirements. The technical requirements comprise pollution control standards and discharge evaluation guidelines established by the Clean Water Act of 1972, as amended, (33 USC 466 et seq.) and include the following:

- Best Practicable Control Technology Currently Available (BPT). This best practicable technology (BPT) standard is set for particular pollutants and is based on the capabilities of existing pollution control technologies. Relative to OCS operations, BPT standards have been established concerning the discharge of chlorine and oil and grease into the marine environment.

- Best Available Technology (BAT) and Best Conventional Technology (BCT) Economically Achievable. These standards are designed to move the nation further along the course to improved water quality than BPT. The BCT standards are pertinent to all discharges and will be applied to all discharges for which they are developed. BAT standards will be developed for certain toxic substances. In the development of BCT and BAT standards, a technical and economic assessment is required relative to how much an industry can afford to pay to remove pollutants from effluents and the technical feasibility of reducing the discharge of the pollutants. In some instances, the BCT and BAT standards are established at a level that forces industry to make additional investments in pollution control. No BCT or BAT standards have yet been established that are applicable to the OCS.

- New Source Performance Standards (NSPS). Whereas the previous two standards apply to pollutants from existing sources, NSPS apply to discharges from new installations. It represents the Environmental Protection Agency's (EPA) determination of the greatest degree of effluent reduction that can be achieved by demonstrated technology on a type of installation. In establishing NSPS, the EPA sets individual standards for the effluent concentration of numerous pollutants that may be present. Once NSPS are established, all new installations of the type regulated must comply. NSPS for offshore oil and gas operations are currently under development and are slated for promulgation by June 1981.

- Ocean Discharge Criteria. The ocean discharge criteria are guidelines for use in the National Pollutant Discharge Elimination System (see below) for evaluating the environmental effect of the discharge of pollutants from a point source into the ocean. The guidelines call for an evaluation of the effect of the proposed discharge on human health and welfare; marine life; aesthetic, recreation, and economic values; and alternate ocean uses. The persistence of the effects of the pollutants must also be assessed. Alternative methods, rates, and locations of discharge must be also considered. The ocean discharge criteria were established in 1980.

Following are the administrative requirements pertinent to intentional discharges.

- National Pollutant Discharge Elimination System (NPDES). Under this program, the EPA regulates the continuous discharge of pollutants from point sources into U.S. waters. The permit is the regulatory vehicle for the implementation of EPA's technical pollution control standards (see above). The implementation of the NPDES on the OCS varies from region to region. The EPA is developing a general permit for operations in the Gulf of Mexico. In environmentally sensitive areas, such as the Flower Garden Banks, special permits will be issued. In the Atlantic, NPDES permits have been issued to specific exploratory rigs while they operate within a permittee's lease area. Off Southern California, NPDES permits have been issued to rigs and platforms for the duration of a plan of operations, which may include several wells. One NPDES permit has been extended to cover all OCS operations in the Cook Inlet region of Alaska.

- Ocean Dumping Criteria and Permit. The Marine Protection, Research, and Sanctuaries Act of 1972 established a permit for "one-time" dumping of pollutants into the ocean. The Act also included a set of criteria for use in evaluating the effect of the proposed dumping on the marine environment. While day-to-day OCS operators would be regulated by the NPDES system (including effluent limitation standards and evaluation guidelines), the ocean dumping permit and evaluation criteria apply to one-time dumping, such as the occasional ocean disposal of a barge-load of spent drilling fluid.

- Environmental Report. The Geological Survey requires that exploration, development, and production plans be accompanied by an environmental report. This report is supposed to include a description of the operator's proposed methods for controlling or treating operational discharges to comply with regulations. However, if an environmental report is prepared prior to the obtaining of an NPDES permit, the environmental report may not contain adequate information on operational discharges.

- Lease Stipulations. The BLM may include clauses in OCS leases that stipulate how waste materials, such as spent drilling fluid, are to be disposed of.

o Other Requirements. See Table III-5.

A matrix was fashioned by the committee to better assess the adequacy of regulations in this area (Table III-5). The matrix displays the salient traits of each regulatory requirement. Evaluation of the matrix indicates that the controlling regulations are diverse in form, complex in structure, and overlap.

A number of legally required regulations have not been promulgated. The EPA has not promulgated the full range of effluent limitation guidelines based on best available technology, best conventional technology, and new source performance standards.

Most regulations focus only on limiting the concentration of effluents. Only the ocean discharge criteria limit the quantity and rate of discharges. The regulations also do not set specific standards for mixing zones. The consequences of this are that variable burdens can be imposed on ecosystems without consideration of the overall effects on those systems.

The Environmental Protection Agency, Bureau of Land Management, and U.S. Geological Survey regulations allow for variability among sites and may be adjusted to address special site sensitivities at the discretion of the regional supervisor of the regulatory agency. However, the standards for varying regulatory or permit conditions are often not stated with specificity and are left to the discretion of the regulator involved--USGS area supervisor, EPA regional administrator. Often the application of variation hinges on post-lease sale or post-permit surveys or studies, rather than on identification of the special needs, including studies of potential effects, before the sale or permit issuance. By structuring flexibility as a post-sale or post-permit process, the regulations introduce uncertainty into the operations and the conditions imposed on them. This creates a difficult planning environment for the companies and for those concerned with potential pollution. It may mean that damage will already have occurred before conditions are imposed. It may also create an agency disincentive for adjusting the regulations post-sale or post-permit.

The EPA's regulations appear to be the most comprehensive and stringent of any agency with regard to water quality (this is particularly true of the ocean discharge criteria). In contrast, some of the USGS and BLM requirements are very general and impose uncertainty on both the industry and on those concerned with or affected by pollution.

Findings and Recommendations on Intentional Discharges from OCS Operations

Without a sound scientific basis for decision-making about environmental effects, it is not possible to conclude whether the technology now in use to control discharges provides or does not provide adequately for the safety of OCS operations. The leasing program of the Department of the Interior is not structured to establish that scientific basis in a timely fashion.

Three agencies, the EPA, the USCG and the USGS, regulate intentional discharges from OCS operations. The regulations are diverse in form, complex in structure, and overlap within and among agencies. Some important regulatory obligations remain unimplemented or unenforced. Many environmental requirements are imposed after leases or permits have been issued, and they are interpreted and implemented at the regional level in a manner that is often not predictable and/or insulated from public review. Eliminating these flaws of implementation would have a positive effect on environmental protection and OCS energy development.

The EPA's regulations appear to be the most comprehensive and stringent of any agency. This is particularly true of the ocean discharge criteria. The regulations of the EPA that were examined by the committee are performance based. They establish water quality or pollution control objectives based on the capabilities of technology, the prevention of environmental harm, and other factors. Operators are permitted to meet the objectives using the techniques or equipment they deem most practicable.

Many BLM and USGS regulations are general and contain undefined terms. This imposes an unacceptable level of uncertainty on both the industry and on those concerned with or affected by pollution.

With the exception of the ocean discharge criteria, regulations applicable to OCS discharges focus on concentration standards and do not limit the quantities and rates of discharges. The regulations also do not set specific standards or definitions for dispersion or mixing zones. As a consequence, variable burdens are imposed on ecosystems without consideration of overall effects on the system.

Existing procedures allow lease stipulations to be altered after a lease sale without an opportunity for public notice and comment.

Regulations of the EPA, BLM, and USGS allow for variability among sites and can be adjusted to reflect special site sensitivities. However, the standards for flexibility have not been stated with specificity and are generally left to the discretion of the regulator involved. Often the application of variation hinges on post-lease sale, post-permit surveys or studies, rather than on identification of the special needs, including studies of potential effects, before the sale or permit issuance. By structuring flexibility as a post-sale or post-permit process, the regulations introduce uncertainty into the operations and the conditions imposed on them. This creates a difficult planning environment for the companies and for those concerned with potential pollution. It may mean that damage will already have occurred before conditions are imposed. It may also create an agency disincentive for adjusting the regulations post-sale or post-permit.

> The EPA should complete the implementation of its regulatory authorities on the OCS, as required by law. It should: (1) move quickly to implement the NPDES program in all OCS areas, and (2) develop and implement best available technology, best conventional technology and new source performance standards for OCS activities.

TABLE III-5

Characteristics of Operational Discharges Regulations

Drilling Fluids and Cuttings

AGENCY	REGULATION	METHODS OF CONTROL	(1) SITE FLEXIBILITY	(2) PRESUMPTION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
EPA	Effluent limitations, (BPT)	Applies to continuous point source discharges into the ocean. Technology-based performance standard --permissible concentration of effluent in discharge waters applies to oil and chlorine only.	No	Discharge acceptable unless proven harmful	Effluent not monitored	No	NPDES permit and inspections BAT, BCT, NSPS not implemented
	Ocean discharge criteria, 40 CFR 125	Applies to continuous point source discharge into the ocean. Technology-based performance standard. o No feasible land-based alternatives. o No feasible alternative method for reducing pollution. o Dilution required with no biological effects. o No feasible diffuser system resulting in reduced impact. o No measurable adverse impact. o Program to reduce toxic pollutants o Adequate monitoring.	Regional interpretations	Discharge prohibited unless demonstrated to be: o not persistent in suspension; o not interfering materially with fish, esthetics.	Description of mixing zone. Analysis of alternatives. Impact evaluation. Chemical analysis of toxics. Monitoring of effects.	No	NPDES and inspections

AGENCY	REGULATION	METHODS OF CONTROL	(1) SITE FLEXIBILITY	(2) PRESUMPTION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
	Consolidated permits including NPDES 40 CFR 122-125	Implementation mechanism for effluent limitations and ocean discharge criteria	Yes		Drilling Plan and chemical inventory may be required. Effects studies optional Monitoring required.	No	Inspection
	Ocean dumping criteria 40 CFR 220-230	Only applies to occasional one-time dumping of materials into the ocean. Effects-based performance standards. o Prohibits dumping of some components in other than trace amounts (3). o No acceptable adverse effects. o Limits imiscible slightly soluble components to soluble level. o Limits based on depressing oxygen levels.	Yes		Against dumping certain materials in favor of dumping all other substances.	Effects studies prior to dumping.	
USGS	Pollution and waste disposal 30 CFR 250.43	General prohibition of pollution and harm to aquatic life.					

TABLE III-5 (cont'd)

Characteristics of Operational Discharges Regulations

Drilling Fluids and Cuttings

AGENCY	REGULATION	METHODS OF CONTROL	(1) SITE FLEX-IBILITY	(2) PRESUMP-TION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
USGS	Production and Safety Systems--OCS Order 5, BAST requirement.	General definition of Best Available and Safest Technology is currently required/employed technology. Decisions on matters not currently regulated are left to the discretion of area supervisors. Decisions to be made on a case by case basis without specific standards.	Yes				
	Pollution Prevention and Control —OCS Order 7	Case by case review of disposal method. References NPDES where that program has been implemented. In those areas where NPDES is not operative, there is a general allowance of overboard discharge.	Yes	Yes			Detailed list of chemical components.
	Exploration Development, and Production Plan 30 CFR 250.34	General Standards for approval, disapproval, or modification of plan. Standards include: o Threat of serious harm which will not abate over time. o State certification of coastal zone management consistency.	Yes		Optional monitoring. Environmental Report.		

AGENCY	REGULATION	METHODS OF CONTROL	(1) SITE FLEXIBILITY	(2) PRESUMPTION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
BLM	Stipulations	A variety of stipulations may be included in leases at the discretion of BLM. Examples: o Biological studies may be required. o Overboard disposal may be prohibited.	Yes				

Notes:

1. Provide information of whether or not the implementation of a regulation can be tailored to reflect the sensitivities of specific OCS areas.
2. Provide information on whether or not a regulation presumes that discharges are acceptable unless proven harmful, or unacceptable unless proven not harmful
3. These materials include the following: organo-halogens, mercury, cadmium, suspected carcinogens, mutagens, teratogens; trace amount is defined as present in a form and amount which does not lead to significant undesirable effects including danger from bioaccumulation. Bioassays used to determine potential effects.

TABLE III-5 (cont'd)

Characteristics of Operational Discharges Regulations

Produced Waters

AGENCY	REGULATION	METHODS OF CONTROL	SITE FLEXIBILITY	PRESUMPTION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
EPA	Effluent limitations. 40 CFR 435 (BPT, BAT, BCT, NSPS)	Technically based performance standard--48 ppm as monthly average.	No		Monitoring		See above
	Ocean discharge criteria. NPDES 40 CFR 122-125	Same as drilling fluids and cuttings.					
	Ocean dumping criteria. 40 CFR 220-230	Same as drilling fluids and cuttings.					
USGS	Pollution and waste disposal. 30 CFR 250.43						
	Production and safety systems--OCS Order 5, BAST requirement.	Same as drilling fluids and cuttings.					
	Pollution prevention and control. OCS Order 7						
	Exploration, development, and production plans. 30 CFR 250.34						

Produced Waters

AGENCY	REGULATION	METHODS OF CONTROL	SITE FLEX-IBILITY	PRESUMP-TION	ENVIRONMENTAL STUDIES REQUIREMENT	TRAINING ASPECTS	COMPLIANCE METHODS
BLM	Lease Stipulations.	See drilling fluids and cuttings. Examples: o Permission for overboard disposal tied to studies. None parmitted if adverse effects are indicated. o Reinjection may be required, based on the results of studies.					

Source: Committee on Assessment of Safety of OCS Activities

In implementing regulatory programs, the government agencies should consider the quantities and rates of discharges; their concentration; the abilities of the receiving water to mix, disperse, or absorb the material; and the biological sensitivity of the receiving area.

Government regulation should be made more predictable by providing that necessary background studies are completed and permit conditions established prior to the awarding of OCS permits and leases. In addition, clear standards need to be set to guide post-permit and post-lease sale decisions. Modifications to lease stipulations should receive a level of public review comparable to that of the original lease stipulation.

The EPA and the USGS should expedite the clarification of their respective responsibilities for the regulation of operational discharges, including the implementation and enforcement of regulations.

Well Control

One of the most important aspects of safety in oil and gas operations on the OCS is well control. In drilling, pressures of the formation fluids (oil, gas, water, or various mixtures) present the hazard that these fluids may enter the well bore (a "kick"). In production, equipment damage or failure may lead to the release of hydrocarbons. If uncontrolled, the fluids will be released to the ocean or the air (a "blowout") or they may fracture other underground formations (a "subsurface blowout"). The release of hydrocarbons in a blowout may result in fires or explosions, reduction of buoyancy of the water under mobile rigs, cratering of the seafloor, and/or pollution.

Blowouts endanger workers, property, equipment, and the marine environment. The prevention of blowouts has understandably commanded the attention of the oil and gas industry since the first oil field discovery and, increasingly in recent years, that of the public and regulatory agencies.

The Well Control Safety Record. Reports of blowouts on the OCS have been filed with the Geological Survey. A total of 88 events of lost well control were recorded from 1956 through the end of 1979. In the past 10 years, there have been 55 events: 36 in drilling; 4 in completion; 5 in production; and 10 in workover, repair, or recompletion. The principal causes named in these events were "shallow gas" (17); equipment (15); personnel (12); unknown (8); and natural events (storms) (3).

The 55 blowouts recorded in the last 10 years occasioned 14 fatalities, 34 injuries, 7 lost drill rigs or platforms, and spills ranging from trace amounts to 1 spill of 53,000 barrels.

In most cases (28), the blowouts were brought under control by natural bridging (some while relief measures were being taken); 11 were killed with mud; 4 were controlled by relief wells (in one case the well was reentered); 2 were depleted naturally; 1 was plugged with a snubbing unit--snubbing units force pipe or other items such as tools into wells against pressure--and another was diverted and closed in. The remaining accounts are sketchy or ambiguous.

The rates of blowouts for the 10-year period are 1 per 264 wells drilled; 1 per 485 major workovers; 1 per 1,484 completions; and 1 blowout for each 3,100 producing wells. (This latter ratio may be misleading; a better ratio might be number of blowouts to well-years, but this figure cannot be calculated from available information.)

The simple attribution of an accident to a single cause is rarely helpful in understanding the accident itself or in preventing similar accidents. Well control and loss of well control involve several sequential and simultaneous interactions among men, machines, and nature. Detailed investigations of such incidents (and also incidents in which kicks or fires on production platforms were experienced but well control was not lost) can bring to light what might be considered many causes leading to loss of well control and several that might be selected to receive further attention. The Geological Survey's authority to conduct such investigations was limited in the past by lack of legislative authority. The OCS Lands Act Amendments of 1978 (P.L. 95-372) grant this authority (for cases resulting in fatalities or in significant property loss or injuries) and subpoena powers to the Geological Survey and the Coast Guard. However, it is possible that constitutional provisions protecting individuals from self-incrimination could limit the effectiveness of this new investigative authority. These limitations can be ameliorated if immunity from prosecution is granted. This immunity can be obtained from the Department of Justice on a case-by-case basis.

Well Control Technology. Well control depends on information, judgment, and vigilance--on "taking an intelligent approach that will lead to logical control of the well."[9] The first step to an intelligent approach is acquiring the best possible geophysical and geological data about the area of operations. The next step is selecting the proper equipment and ensuring that it is properly installed and used. Maintaining well control depends on constant supervision and attention to the signals that action must be taken to maintain or regain control. While none of the equipment used for these purposes in a marine environment can be delicate or temperamental, it all requires maintenance, and some parts need special care. Care and maintenance are part of an intelligent approach.

The conditions encountered and the technology used to maintain well control differ with the phase of operations: drilling, production (including workover), and (should control be lost) attempts to regain control or lessen the consequences of blowouts. In each of these phases, the committee investigated the conditions affecting well control; responses to changes in conditions; and the people, equipment, and practices that are used.

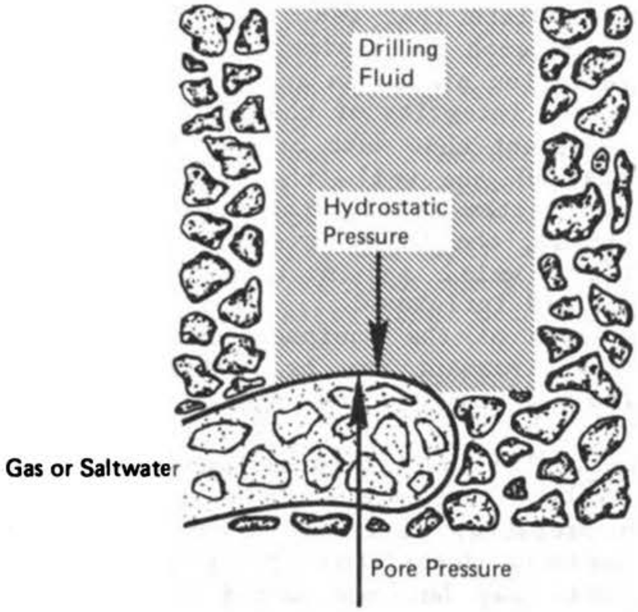
The fundamental principle of well control is the management of pressure. To maintain control while drilling, for instance, the pressure exerted by the drilling mud must at least balance that exerted by fluids in the exposed formation (Figure III-1). In production, the well is flowing and the major concern is ability to shut off its flow whenever necessary. These conditions and technologies are briefly described below by phase of operations.

- Drilling. The major well control concern in drilling is balance of the formation pressure encountered--the constant ability to prevent the well from flowing, by ensuring that the balance of pressures favors that of drilling mud.

  The concept of pressure gradient--the increase in pressure exerted on an area of the same size with the increase in depth --is vital to the management of the pressure in drilling. The characteristics of formations and their trapped fluids determine their sensitivity to the hydrostatic pressure exerted by the column of drilling fluid and the ease with which fluid can escape from its circulating path into a permeable formation. The addition of a drilling fluid column's hydrostatic pressure to the pressures borne by a particular zone (especially at depth or in loose formations) may be sufficient to fracture or part the formation, and fluid may be lost. The drilling fluid weights used in many wells drilled on the OCS today are near the balance of expected formation pressures. This sounds alarming, but in reality the important principle of well control through the use of drilling fluid is balance, not shear weight. Overweight fluid, with attendant potential for lost circulation, poses a hazard equally serious to that of underweight fluid. Often it is possible to deduce the pressures to be encountered in the drilling operation from seismic surveys and other samplings of geophysical and geochemical evidence, and analysis.

  Providing well control in drilling necessitates designing the well taking into account all pertinent geological and other data and then selecting the equipment that fits the plan and using it properly in order to maintain the pressure balance in the well. The primary tool for the maintenance of pressure balance is the drilling fluid. Drilling fluids used on the OCS are complex mixtures of water and solids (Table III-2). Drilling fluid serves other functions: it cools and lubricates the bit, enhances penetration, and carries away cuttings. Drilling fluid is a constantly circulating medium of communication to the surface of downhole conditions carrying warnings or evidence of impending kicks, or lost circulation. The fluid system also provides the means of killing the well or regaining control. This sounds simple, and in principle it is simple, but in practice, maintaining the pressure balance requires constant attention, judgment, and the correct response to the warning signals carried by the drilling fluids.

  Careful design of the well and its programs of operation establish the foundation and guidelines for maintaining the pressure balance. Using geophysical, geochemical and geological information, it is necessary to construct as accurate a



Formation Pressure Balanced by Hydrostatic Pressure of Drilling Fluid

Figure III-1

picture as possible of anticipated downhole conditions and a plan of operations appropriate and adequate to those conditions. This includes the design of well casing, cementing and drilling fluid programs, and the selection of equipment.* The plans of operations are bolstered with plans to cope with conditions deviating from those anticipated (such as encounters with shallow gas).

The plans also specify operating procedures. For example, plans may stipulate that tests be conducted in the course of drilling below each successive casing shoe to check or establish the formation pressures and fracture gradients and possibly to test the integrity of the casing.

The equipment that must be specified and used in drilling includes that of the well (the casing and its cementing), a reliable mud system (calibrated tanks, measuring devices and accurate pumps), the means to seal the drill pipe and annular spaces in the well, and systems to effect the controlled removal of fluid influxes.

While none of the equipment used for these purposes in the marine environment can be delicate or temperamental, it all requires maintenance, and some parts need special care.

oo Equipment. The initial formations penetrated in drilling a subsea well often have fracture gradients insufficient to contain pressures that may be encountered. In areas of rapid sediment deposition, relatively small, high-pressure gas pockets may be encountered in the first few hundred feet. Until sediments of sufficient strength are penetrated, the full complement of blowout preventers (described subsequently) cannot be installed. Diverter systems consist of large-diameter pipes and one-way, full-opening valves. They are used to vent gas that may be encountered away from the platform or mobile drilling unit. It is particularly important to divert kicks from mobile installations.

The diverter system does not guarantee complete well control; rather, as the set of API recommended practices for blowout prevention systems states, "It provides a degree of protection prior to setting the casing string upon which the blowout preventer (BOP) stack and choke

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*"Casing" is steel pipe that is cemented into a hole as drilling progresses to prevent the hole from fracturing or caving during drilling and to provide a means of sealing the well from subsea formations. The casing also provides means of extracting petroleum if the well is productive.

manifold will be installed."[10] The design and maintenance of this system is important: the pressure of a gas influx and the particles that might accompany it can act as sandblasting.

BOPs are mechanical closures that prevent the escape (at the surface) of downhole pressure through the annular space between the casing and the drill pipe or from an open hole during drilling, completion, and workover operations. BOPs are installed on surface or conductor casing, which is set in the well as soon as the formation fracture gradients are sufficiently high to contain the pressures that may be encountered.

Valve-equipped control lines (called choke and kill lines) are installed. These allow fluids to be pumped into the well or circulated out under controlled conditions. A kick entering the well expands as it rises. The rate of its removal from the well and mud system is controlled by throttling the mud through the choke manifold.

The BOPs, and kill and choke line equipment must be assembled and used as a system. The particular arrangement of BOPs is left up to the operator, subject to the Geological Survey's review of the operator's plans. All parts of the choke assembly, kill line, and related parts should have a working pressure at least equal to that of the BOP stack.

Several valve mechanisms are used to shut in the drill string. These valves include manually operated systems on the top of the drill string and one-way check valves inside the drill string.

oo <u>Use of the Equipment: Critical Operations, Warning, Signals, and Response</u>. From reports of lost well control and reviews of experience, two operations are particularly critical: drilling shallow gas and tripping (running the drill pipe in and out of the hole to change bits or to perform specialized downhole operations such as logging). Tripping is an essential operation; drilling through shallow gas deposits is avoided if possible. Nevertheless, the evidence of such deposits in the geological and geophysical surveys is not always unequivocal. Where suspected or encountered, these deposits are dealt with by checking for kicks continuously, keeping the bit on the bottom, and drilling at moderate speed. The diverter system is particularly important in preventing the leaking of gas around the surface pipe or the carrying of gas to the platform or rig.

Raising or lowering the drill string too rapidly may trigger an imbalance in downhole pressures. Even if the correct amount of mud is pumped downhole to compensate for the volumetric displacement of the drill stem (and particularly of the bit and collars), it may not fall at a sufficiently fast rate as the pipe moves upward to fill the space created below the bit and around the collars. Another hazard is that the drill cuttings and fluid may adhere to the pipe, collars, and the sides of the hole, effectively creating a piston. A possible result, called swabbing, is that of formation fluids being drawn into the wellbore. The opposite effect--surging--can occur if the drill stem is lowered too quickly. The qualities, cleaning, and conditioning of the mud are obviously important. Nevertheless, the most important factor in minimizing swabbing and surging is tripping at a moderate speed. This is prudent for other reasons: it allows time, should warnings be received, to check for problems that may have developed, to sort out simultaneous problems, and to take action to maintain (or regain) control. The farther the bit and pipe move off the bottom, the fewer the options for remedial action, should it be required.

Keeping the hole full while tripping is vital. Knowing that the volume of fluid pumped in is exactly equal to the volume of pipe displaced is crucial. To enable this comparison to be made, trip tanks and constant monitoring are used. A trip tank is a small drilling fluid holding tank, calibrated so that changes in level (volume) can be noted quickly. Another important indicator used in keeping the hole full is the measure of drilling fluid displacement, as evidenced by a count of the drilling fluid pump strokes. Techniques for direct measurement of drilling fluid flow exist but are still under development, and are not widely used at present.

A well signals its intention to flow. Some early signals of a kick are sloughing formations, a momentary increase (followed by a decrease) in drilling fluid pump pressure, and an increase in flow at the drilling fluid flowline. These early signals are frequently fleeting or slight. Impending kicks are never unannounced and give the following additional warnings at the surface:

- Gain in pit volume--the entry of formation fluid into the wellbore forces more fluid from the annulus than was pumped down the drill string.

- Increased flow from the annulus--at a constant pump rate, the flow from the annulus should equal that of the fluid into the drill pipe. If greater, it is being augmented by formation fluid.

- Increase in penetration rate--the penetration rate changes with the type of formation being drilled. A sudden change indicates a formation change, possibly increased porosity or high permeability. It sometimes indicates increasing pore pressure. The increase in penetration rate experienced as naturally occurring formations of higher pore pressure are encountered is usually more gradual, but it must not go unrecognized. Clear evidence of increased pore pressure can often be seen in the plotted curve of penetration rate vs. depth.

- Decreased pump pressure, increased pump speed--this follows the momentary increase in pump pressure mentioned as an early signal. As lighter formation fluids enter the wellbore, the hydrostatic pressure of the annular drilling fluid column drops and the fluid in the drilling string flows into the annulus. The pump pressure drops, and the drilling fluid pump speeds up. The same effect may be observed if the fluid is leaking through a hole in the drill string (a "washout").

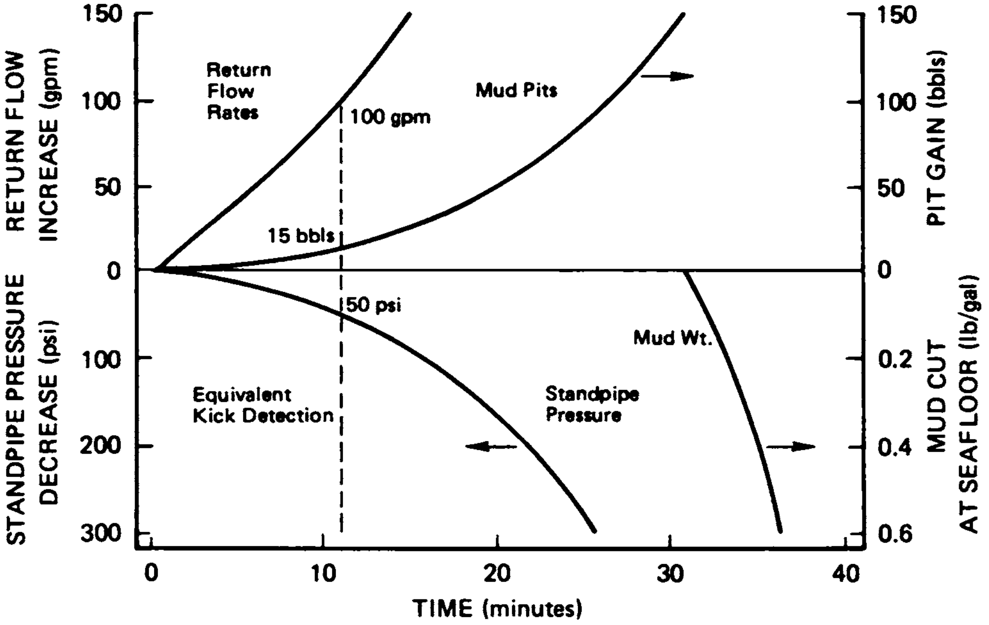
- Gas-cut fluid--while gas-cut fluid may have a distinctly different appearance from the fluid that entered the drill string, it may result from a number of causes downhole that may or may not indicate an impending kick. One such cause may be gas introduced into the drilling fluid by the bit's crushing of hydrocarbon-bearing rock. Gas-cut fluid expands as it encounters reduced pressures as it rises in the wellbore. This results in reductions of the density of drilling fluid.

- Water-cut fluid--if the formation is permeable, water may flow into the wellbore and reduce the weight of the drilling fluid. Because water does not expand as it rises, it is more easily handled than gas, depending on the pressure of the formation.

- Volume required to fill hole less than volumetric displacement of drill pipe (tripping)--as previously mentioned, this signal usually indicates that formation fluid is flowing into the wellbore.

Quick and accurate response to warning signals is imperative. Figure III-2 compares response times associated with various methods of detecting kicks. It indicates that the measurement of the rate of return of drilling fluid is the most accurate and timely sensor

Response Times for Various Methods of Detecting Kicks



Source: Maus, L. D., et al., "Instrumentation Requirements for Kick Detection in Deep Water," Offshore Technology Conference, Houston, Texas, OTC Contribution No. OTC 3240, 1978.

Figure III-2 .

of kicks. The technologies used are reliable but unsophisticated. Improved devices are under development for continuous and reliable measurement while drilling, including better, continuous metering of mud flow.

In all cases of warning signals received at the surface, except that of signals from shallow-gas formations (discussed previously), the practices followed are to shut down the pump, lift the drill bit slightly off the bottom, close the annular or pipe preventer, and check for flow.

oo Well Control in Deep Water. In deep water, the fracture pressure of subsurface formations, as a function of depth below the mudline, decreases as the water depth increases. The problem is severe on initial penetration--the formation can stand a drilling fluid only slightly heavier than seawater (8.55 pounds per gallon). Depending on the drilling rate, the weight of the cuttings circulated could add an additional 0.3 to 0.4 pounds per gallon. The equivalent density of the circulated seawater would approach 9.0 pounds per gallon density.

In 2,000 feet (660 meters) of water, mud much heavier than 9.6 to 10 pounds per gallon would cause lost circulation under the riser. In contrast, the drilling fluid weight in about 300 feet of water off the Louisiana coast could be close to 12 pounds per gallon without losing circulation. Thus, it is necessary to drill without well control equipment until a formation is reached that is strong enough to withstand the hydrostatic pressure of a column of drilling fluid.*[11]

Mobile offshore drilling rigs are usually preferred for deepwater exploratory drilling. While well-control equipment--BOPs, choke and kill lines, and so forth--is ordinarily mounted directly on platforms and jack up rigs, it is usually installed on the seafloor when mobile drilling rigs are employed. Subsea systems are likely to have long control lines. This configuration poses important differences for operations. The longer lines make detection of kick warning signals more difficult and shut-in procedures more complicated and time-consuming. Therefore, for the same conditions, the volume of the formation fluid entering the wellbore may be greater in the subsea than in the surface-controlled system.

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*In very deep water, this situation may require revision of OCS Operating Order No. 2 which requires that conductor and surface pipe be set and a full complement of blowout preventers be installed prior to drilling below 9,600 feet (2,900 m) below the sea floor.

Long choke lines increase circulating-pressure losses, lowering the maximum allowable casing pressure. On floating rigs, the movement of the rig also increases the wear on drill pipes and the BOPs.

o Production. While drilling operations seek to prevent the flow of formation fluids into the well, production operations seek their controlled extraction and delivery to a transmission system.

oo Preparing a Well for Production. Wells drilled for exploratory purposes and found capable of production may be completed by observing the regulatory requirements of OCS Order No. 6 and any specifications added in granting a drilling permit. Wells drilled for development (i.e, intended especially for production of oil or gas) have at least three strings of casing set: drive, surface, and oil-producing (most deep wells offshore have at least one intermediate string of casing). The decision whether to set the string above or in the producing formation and decisions about how to initiate flow are made after the well has been systematically analyzed.

After the casing is completely cemented, and assuming that analysis of the well justifies proceeding with completion, the casing is perforated by a special assembly that either fires projectiles through the casing at predetermined locations or detonates shaped charges, and the final string of tubing is run into the well. As the drilling fluid remains in the casing after cementing, this column holds back formation pressure after the casing is perforated. Fluid in the tubing is displaced with water or a lighter fluid and a packer is set that seals the space between the tubing and casing. As the fluid is replaced, the pressure of the formation may exceed that of the column of water and the well will flow if the valves are opened. Production equipment is run during completion. Portions of this equipment can be changed or manipulated by wireline or pumpdown operations. These operations have evolved from the simple running of a wire in the early years of oil drilling and production to measure feet drilled. Many wireline operations are performed without the advantage of an overbalance of pressure on the well, and the wireline operators have adapted and developed their own well-control equipment and procedures. As an example, perforating devices have been developed that are small enough to be run through the tubing and powerful enough to accomplish the task on arrival. Pumpdown tools are also used for work on production wells.

Several operations are used to induce flow from a formation that does not respond to the lessening of hydrostatic pressure--deliberate swabbing with special equipment, well-stimulation treatments such as hydraulic or explosive fracturing, and acid dissolution--and to continue production from wells that show declining returns from particular formations--drilling deeper, plugging the well back at a higher point and perforating, etc. The same kinds of hazards exist for well-stimulation treatments as for drilling: gas may escape from the formation that is not flowing, for example, and enter the tubing. The equipment and kick-circulation procedures employed are similar to those used in drilling. Special BOPs are used to seal around the specialty rig or unit's equipment, and the valves in the wellhead can be used to control pressure at the surface.

oo Control of Producing Wells. Production wells can be completed on the ocean floor or on a platform. During drilling operations, the casing strings on subsea wells are suspended from the mudline by a system of hangers, and this system is connected to a subsea stack of BOPs, or the strings of casing are extended up to the stack of BOPs just below the rig floor of fixed platforms. When the well has been drilled and tested, the BOP stack (and marine conductor from the mudline to the surface) is removed and the well is capped. After the well is completed, casing strings may be extended back to a fixed platform and the wellhead installed there or it may be installed at the seafloor. The wellhead consists of a series of valves, pressure gauges, and chokes that seal off various annular spaces and pipes and control the flow of oil and gas.

The technology of subsea completions has advanced toward systems that can be installed and maintained without the assistance of divers and that will function reliably over long periods with a minimum of attention. These systems employ various combinations of electrohydraulic controls and multiplexed communications (several signals, transmitted by a single circuit) with the surface or with subsea control units. The advantage of multiplex systems is that microprocessors can be employed to originate and receive signals, and programmed to order a number of simple or complex operations. The system can be reprogrammed easily, which offers a range of flexibility in operations without changing the system's hardware.

All production tubing open to hydrocarbon-bearing zones on the OCS must be equipped with "a subsurface-safety device such as a Surface-Controlled Subsurface-Safety Valve, a Subsurface-Controlled Subsurface-Safety

Valve, an injection valve, a tubing plug, or a tubular/annular subsurface safety device, . . . 30 meters (98 feet) or more below the ocean floor within two days after production is stabilized" (OCS Order No. 5-3), unless it can be demonstrated that the well is incapable of flowing. The devices prevent pollution if the wellhead fails (or if the well must be abandoned) for any reason. These valves have been designed to function in response to hydraulic, electrical, and sonic commands. The design, installation, and operation of surface safety devices are also specified by regulation, as well as a reliability and quality-control system, referencing API standards for testing and certification. All production workers who inspect, maintain, or repair these devices must be trained in a program certified by the American Petroleum Institute.

The government requires reliability and quality-control programs for production equipment (this requirement became effective in January 1980). The programs must include testing of valves at specified intervals, reporting every replacement and failure (the failure inventory and reporting system) maintenance of a complete operating and reliability history for every safety device on every installation.

The relationship of sensors to detect fire, smoke, leaks, and changes in pressure to the location of the valves is important to the rapid shut-in of wells in case of accidents or threatened accidents. These systems are redundant in those instances where many wells are controlled from one platform.

A principal threat to well control on production platforms is fire. The industry and the Geological Survey have given attention to the kinds of operations (such as welding) and the processing machinery that present fire hazards.

oo <u>Special Well Control Considerations in Workover</u>. "Workover" includes operations to retrieve tools from the wellbore, to perform repairs, and to restore or stimulate production. These operations may involve forcing lines of tools and tubing into the well under pressure and/or lowering them into the well on wirelines.

The special equipment used in workover operations includes measuring devices to locate the tools and pipe relative to the wellhead and other reference points. When tools are lowered on wire line into a well under pressure, the wire line is threaded through a packing gland mounted at the top of the wellhead. Specially designed BOPs may be attached during these operations.

Even though the well-service industry that performs completion, repair, recompletion, and workover operations uses specially developed equipment and trains its own work force, this phase of activity has the second highest rate of blowouts on the OCS. The data are too sparse to indicate much about these accidents.

- Fighting Blowouts. Blowouts deplete themselves or bridge naturally, or they may require deliberate efforts to bring them under control. Methods to control blowouts are "Expensive, difficult to implement, and not always successful."[12] Control methods are also time-consuming. The hydrocarbons and other fluids released (and among them may be toxic gases) can ignite or explode on reaching the surface. The underground blowout or migration of formation fluids may cause other blowouts or instabilities, complicating remedial efforts. Remedial efforts themselves may initiate or compound these problems; therefore, such efforts are usually carried out by specialists in wild well control, in collaboration with the operators and other affected parties and representatives of the responsible regulatory agencies.

  If fire is present, extinguishing it may take precedence or the blowout may be ignited to flare H_2S (yielding the combustion product SO_2, which is also toxic but is more readily recognizable in harmful concentrations).

  After a well has blown out, a plan to regain control is developed. Often, several control methods are undertaken simultaneously to enhance the chances of regaining control in a timely manner. Some of the methods that have been used to bring wild wells under control rely on the principles of maintaining well control in drilling: balancing the pressures of the flowing well by pumping in mud, cement, or special materials. This method depends on access to the well's casing, and the casing's ability to withstand the pressure of being shut in with the original BOP equipment (if operable or repairable) or special equipment. Other methods resemble natural extinguishment, such as plugging the passages of the fluids' escape by injection (in imitation of natural bridging).

  If access can be gained to the casing from the surface, but shutting in the well is contraindicated, it may be capped with a special unit consisting of a BOP and valves capable of completely closing the well that is installed above diverter lines. The well is allowed to flow. Pipe or tubing can then be snubbed into the well and heavy mud circulated.

  Cases that obviate killing the blowout from the surface such as underground blowouts, and other considerations may call for drilling a directional relief well. The purpose of the directional well is to intersect the flowing well and inject sufficiently heavy mud into it at a rate greater than its lifting capacity until the well is brought under control. Relief wells are often drilled to minimize pollution.

There are also diver-activated methods for bringing a wild subsea well under control. Filling the well with sufficiently heavy mud is necessary after a relief well, diver-activated methods, or natural bridging has brought the lower part of the well to a pressure that can be diminished.

The Regulation of Well Control. This section is intended only to provide an overview of the regulation of well-control. The application of individual requirements to specific well control operations, and the committee's assessment of their adequacy, is given in the "Adequacy of Technologies and Regulations" section.

The regulation of well control is entirely under the purview of the Geological Survey. Requirements for well control are contained in OCS Operating Orders 2, 5, and 6.

OCS Order No. 2 provides guidance and establishes requirements for the conduct of drilling operations. Provisions that are pertinent to well control include requirements for detailed surveys of the drilling site; plan and permit review; technical requirements for drilling fluid and casing programs, for equipment and procedures; and for the training of drilling crews.

OCS Order No.5 is directed to production operations. It stipulates procedures for the design, installation, and operation of production systems and for the prevention and detection of fires. It also requires certain sensors, the filing of plans, the keeping of records, training and qualification of certain operators in accordance with industry standards, and the use of the best available and safest technologies.

OCS Order No. 6 regulates the completion of oil and gas wells. With the exception of the deepening or plugging back of wells (30 CFR 250.36), the specialized operations that occasionally must be performed in the course of completion, repair, recompletion, and workover are not described in the regulations in explicit detail.

The Training and Qualification of Workers in Well Control. As indicated by a representative of the Offshore Operators Committee, well control requires teamwork: "the relationship may appear to shift back and forth during a well-control situation; however, in fact, a team is generally always there and even includes onshore office personnel--depending on the severity of the problem."[13] A high turnover rate, particularly in entry-level positions, brings to the rig new workers who must be trained and coached and who may then be lost and replaced.

o Training. The importance of well control led major operators to implement training programs long before they were required by government regulation. "Every effort is made," a text published in 1939 states, "to reduce accidents by educational work of various sorts. Occasional group meetings are held at which accident prevention in general is discussed, specific accidents being analyzed by individual demonstration, or with the aid of motion pictures."[14] In the early 1930's, a number of companies designated engineers in their employ to serve on a drilling practices committee that distributed useful information throughout the industry. Schools of engineering at several universities developed and taught sound drilling practices.

The Geological Survey issued requirements (as part of OCS Order No. 2, "Drilling," and OCS Order No. 5, "Production") for training in well control, and, in 1977, published a standard for the training of drilling personnel. The required training closely follows the well-control practices the industry has developed and considers sound. Well-control training for drilling must be provided in schools approved by the Geological Survey, whereas training for production is provided in schools certified by the American Petroleum Institute. There are now more than 100 well-control training programs approved by the Geological Survey.

The job classification level at which training in well control is required is that of rotary helper, which is above entry-level. To the level of rotary helper, the worker is trained on the job. At the level of rotary helper and beyond, training in an approved well-control school is supplemented by training on the rig (and perhaps in some other programs, on the rig and off).

The training that production workers receive is similarly a combination of that received on the job, in company or external schools and programs, and training required by the Geological Survey. The government training requirements apply at about the same level of advancement as those that apply to drilling personnel. For drilling, the Geological Survey writes and distributes the standard. In the case of production personnel, the Geological Survey references the standards written and distributed by the American Petroleum Institute.[15] The well-control training required for production personnel is in the use, inspection, maintenance, and testing of anti-pollution safety devices. These devices include high- and low-pressure, level, and temperature sensors; combustible gas detectors; pressure relief devices; flowline check valves, surface valves; shutdown valves; flame detectors; and surface control equipment for surfacecontrolled subsurface safety devices.

Production and drilling personnel must be tested during the required training. The Geological Survey certifies the schools for drillers; the American Petroleum Institute certifies training programs for production personnel.

The training required by regulation for drilling and production workers on the OCS is similar in seeking to make the workers understand the importance of maintaining well control, but different in its objectives. In the case of drilling personnel, the objectives of training are to be alert to the warning signals of situations that could lead to loss of well control and to respond intelligently. In the case of production personnel, the objectives are correct maintenance, inspection, repair, and so on. Response to the kinds of emergencies (such as fires) that can threaten control of wells is not addressed. In the API recommended practice for training of production personnel (which applies to all personnel working offshore) training in fire prevention and firefighting is recommended.[16] The training provided by operators displays a broad range. One large operator uses three working rigs primarily for training. As the supervisor of training of a large offshore operator reports, "Well control is not a process that can be memorized. It is an art, or skill. And it's a team skill."[17]

Adequacy of Technologies and Regulations. Table III-6 presents the equipment, practices, and regulations for well control as responses to (or action taken in anticipation of) a hierarchy of well-control problems and makes explicit a number of well-control issues that have been identified.

Blowout prevention equipment is tested every day, and the results are recorded. The manufacturers conduct standard reliability analyses on the parts and whole, as well as any tests requested by the operators or required by regulations (such as resistance to embrittlement in the presence of H_2S).

The manufacturers follow what they believe are the dictates of 24-hour/day, heavy working demands in the marine environment: make it simple, make it rugged, make it dependable, and make sure it does what it is supposed to do.

The committee found little evidence (particularly in drilling, where the system and workers constantly interact) that the interaction of technology and personnel is carefully addressed in the design of well control systems. However, some failure modes and effects analyses have been conducted for subsea production systems.

This does not mean that there is no attempt to think through the entire program of well control for each operation, and for drilling in general. A most important aspect of well control is the design of the well, and this aspect has received increasing emphasis as drilling moves to more difficult locations offshore. Operators maintain that kicks represent deviations from the conditions or the practices for which a well was designed and that a properly designed and implemented well-control program provides for a safe response to these deviations. In addition, the equipment and its arrangement have evolved over many years of the practical application of field engineering and accumulated knowledge.

The accumulation of field engineering experience is perhaps the most valuable resource that can be drawn on in assuring that operations meet the standards of accepted good practice. The application

TABLE III-6

Well Control Safety: Drilling

Potential Well Control Problem	Design and Execution: Good Practice	Equipment and Instruments	Regulation
Fluid pressures, mud weight, fracture pressures	Use best available geological and geophysical data; calculate fracture gradient and pore pressures	Seismic, acoustic, realtime sampling; analysis and interpretation important	Must submit data with application for permit to drill, OCS Order 2-1.1
Casing program: design and intergrity	Set casing at depths to ensure/restore wellbore integrity; to meet needs of deeper penetration	Casing grades, cement to meet maximum pressure needs of kick	Must submit plan and specifications with application for permit to drill OCS Order 2-1.1
	Hydraulically test integrity of casing, cement job, casing-seat formation		Required setting depths for casing, formation fracture gradients, tests, OCS Order 2-3
Maintaining full hole	Adequate mud program		Must submit with application for permit to drill, OCS Order 2-1.1; meet requirements of OCS Order 2-6, "Mud Program"
	Replace pipe volume with and volume in tripping	Trip tank, instrumentation	
	Workers alert to warning signals; understand principles of pressure balance, proper procedures		Training required in well control, OCS Order 2-7; USGS standards for training
	Work to cure lost circulation problems while adding mud to annulus	Standby volume of mud	OCS Order 2-6, "Mud Program," and mud program plan submitted with application for permit to drill OCS Order 2-1.1
	Control rheology of mud to minimize surge and swab, control pipe speed	Observe surge and swab in trip-tanks changes; test if probability of swabbing	Training, mud programs
Shallow gas	Avoid known areas of shallow gas	High-resolution techniques	Shallow hazards survey required, lease stipulations; OCS Order 2.3, "Well Site Survey"

TABLE III-6 (cont'd)

Well Control Safety: Drilling

Potential Well Control Problem	Design and Execution: Good Practice	Equipment and Instruments	Regulation
Shallow gas, continued	Drill slowly, keep bit on bottom, use diverter	Diverter	OCS Order 2-5, BOP requirements, referencing API Standard for diverters
Lost circulation	Awareness of signals and interpretation; formation fracture potential; rheology of mud, drill string clearance, design mud weight Control pipe speed in hole	Pit-level instruments, returns rate Training	OCS Order 2-5, BOP requirements; OCS Order 2-6, mud program OCS Order 2-7 and standard
Gas-cut mud	Flow check: continue drilling if no flow; if flow, shut in, circulate bottoms up through choke line. Stop to check, allow kick to expand, choke as required; raise mud weight as required	Pit-level instruments, returns rate, drill pipe pressure gauge, choke manifold and control console BOP, mud system	As above,
Fluid influx	As above	As above	As above
Equipment operability	Routine function and integrity tests, vigilant inspection and maintenance of well-control equipment		OCS Order 2-5, BOP requirements --testing, actuation specified; inspection and maintenance required
			OCS Order 2-3.6, Pressure testing of casing
	BOP and shut-in drills for crews		OCS Orders 2-7, drills

Potential Well Control Problem	Design and Execution: Good Practice	Equipment and Instruments	Regulation
Fire on the platform	Separate sources of fuel and ignition; preventive measures, strict procedures, fire walls, etc.*	Gas, flame, heat, smoke detectors, piped blow down, pulsation dampeners, etc.*	Engine exhaust insulation, API standard, exhaust piping from diesel engines equipped with spark arresters (OCS Order 5-5.1.5)
			Design, installation, operation of surface production systems, API standard and NEC (OCS Order 5-5.7)
			Pressure vessels--in accordance with ASME Code (OCS Order 5-5.1.5)
Shut-in of piping			All flowlines from wells to be equipped with high- and low- pressure shut-in sensors, API standard (OCS Order 5-5.1.2)
Fire prevention and firefighting training	*	*	Recommended, not required (OCS Order 5-8)
Fire-extinguishing systems and equipment	*	*	Firewater system, rigid pipe, firehouse stations, API standard, (OCS Order 5-5.1.8)
			Portable fire extinguishers as specified by U.S. Coast Guard 33 CFR 145
Other			OCS Order 6, Completion of Oil and Gas Wells

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*Covered in section on fires and explosions

Source: Committee on Assessment of Safety of OCS Activities

of tacit knowledge and sound principles to a complete examination of a drilling rig or production platform (particularly one at work) constitutes a practical hazards survey or basic systems analysis.

- Instrumentation. The basic problems that stand in the way of advanced instrumentation or the addition of instruments to drilling operations are the rigors of the marine and working environment and the reluctance to make the drill string more complicated--to add parts that frequently need special attention or control lines that could become tangled. Advanced instrumentation is being used in controlled directional drilling, and significant research and development is being carried out to apply advances in instrumentation to drilling operations.

  Among the most helpful introductions would be gauges or other instruments offering immediate, continuous monitoring of mud flow, formation pressure, pressure on the bottom of the hole, and the location of the weakest formation.

Findings and Recommendations on the Safety of Well Control

In the past 10 years, 55 instances of lost well control have been recorded on the OCS of the U.S.--incidents that range in duration from a few seconds to three weeks. These incidents resulted in the loss of 14 lives, spills ranging from trace amounts to 53,000 barrels in one blowout, 7 lost rigs, and 34 injuries. The consequences of these blowouts and, by implication, the hazards posed by potential blowouts, for personnel safety, the safety of the marine environment, and property vary with the circumstances of each, particularly the geology of the formation and the location of the accident. Any blowout could have serious consequences, and control is difficult to regain once lost. Thus, both industry and government have strong incentives to prevent them.

The basic physics, hydrodynamics, and chemistry of managing subsurface pressures are understood. However, predictive models of the control of a well have not yet been provided with data adequate for accurate predetermination of all well-control parameters before drilling. Improved measurement of the maintenance of the mud column during all phases of well drilling will contribute to the control of kicks and prevention of blowouts. These measurements include, but are not limited, to measurement of mudflow and downhole pressure.

> Development and application of reliable instrumentation, especially for the measurement of mudflow and downhole pressure, should be a focus in the implementation of the best available and safest technologies requirement by the Geological Survey.

The technology available for well control has developed over time, piece by piece, practice by practice, and is still being improved and tested. When properly selected, installed, maintained, and conscientiously applied, the equipment and practices can prevent blowouts except in the most unusual circumstances.

Well-control accidents are chains of events that usually involve failures in (or by) equipment, people, procedures, and adherence to procedures. There is little factual information about the contribution to accidents of individual elements of the system (i.e., equipment, people, procedures, and adherence to procedures). Most if not all blowout causes include personnel failures to implement good well-control practices. The pressure of performance (i.e., hole drilled per unit time or stipulated dates for lease development) produces unfavorable effects on the safety of the whole system by contributing to less than satisfactory material condition, operational planning, including recognition of latent or suspect geological factors and choice of equipment; selection, training, and qualification of personnel; and adherence to good procedures.

To the extent that the contribution of equipment and operating procedures to accidents can be isolated and analyzed, there is little evidence that failure to perform as designed is significant. It is not possible, however, for the committee to conclude whether the equipment and operating procedures are optimum for use by personnel acting under fatigue, stress, boredom, or other adverse environmental factors of the workplace.

For individual blowouts, causes in terms of the chain of events that constitutes the causes may be understood in engineering terms by a limited group of people immediately associated with the operators suffering the accident and also possibly technical personnel of the Geological Survey. The public availability of the information in a verifiable fashion is severely limited. Subject to constitutional constraints against self-incrimination, the conduct of full-scale investigations under the authority of the OCS Lands Act Amendments of 1978 could bring to light useful facts about the interactions of men, machines, and nature in the loss of well control.

Offshore industry personnel emphasize that the capability and quality of rigs vary. In the chains of events associated with blowouts, marginal rig capabilities or equipment maintenance can be contributors to increased accident risk. Sound well-drilling plans should account for the expected or potential effects of the geology and operating environment in the selection of individual rigs and equipment.

Some companies seem to have better records than others in well control.*

Because of increased drilling and development activity, there has been a reduction in the experience (and possibly the skill) level of personnel involved in drilling and other well-control operations.

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*See also the findings in "The Human Element" section in Chapter IV.

Further expansion of leasing activity and development in older fields could exacerbate this problem. Although it is difficult to assess in a quantitative way, the committee is concerned that the risk of blowouts will increase unless the industry can compensate for inexperience.

> Industry should compensate for inexperience in the work force through improved training, tighter procedures, and closer management surveillance.

The regulation of drilling (including well control) depends heavily on the preparation, submission, approval, and execution of specific plans for each well. The adequacy of this regulatory process depends on a high level of technical knowledge on the part of the individuals in the operating organizations who prepare and implement the plans and those in government who review and enforce them.

Of the 55 blowouts that have occurred on the OCS during the last 10 years, 10 have occurred during workover and remedial operations. No specific training requirements or government-sanctioned operating procedures apply to these operations. The American Petroleum Institute is developing operating and training practices for these operations.

> The Geological Survey should expand the coverage of its present regulations to include training requirements and operating procedures for well control during workover and remedial operations. It should utilize industry-developed recommended practices for these operations as a basis for regulatory action.

Pipelines

Pipelines operate as closed systems. A hydrocarbon release from a pipeline may result from structural failure at some point in the pipeline/pump system or occasionally from failure of operating personnel to keep the system closed. One important characteristic of pipelines is that they operate under pressure: pumps force the hydrocarbons through the lines. If a pipeline failure should occur, and careful monitoring detects a drop in pressure, the pumps can be stopped and the flow of oil can be halted.

The Safety Record. From 1970 to 1978, 301 pipeline failures occurred. Of these, 259 resulted in some discharge. Table III-7 shows the pipeline failure data by cause.

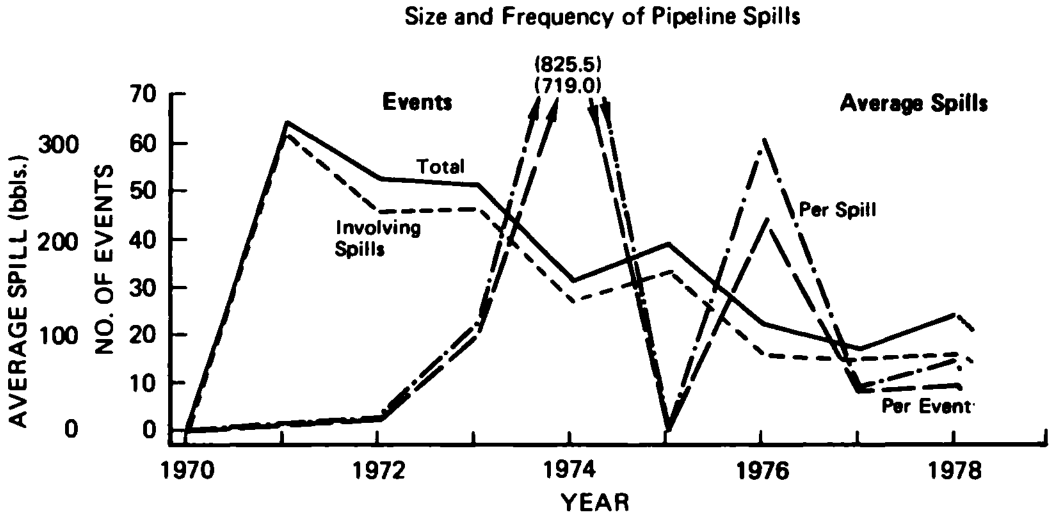
Figure III-3 provides a graphic representation of the size and frequency of pipeline spills. The data reveal a decreasing trend in the number of pipeline incidents leading to oil discharge. As better information has become available, as a result of more stringent reporting requirements, pipeline discharges have been controlled better.

TABLE III-7

Pipeline/Pump Failures
Gulf of Mexico OCS
1970-1978

PROBABLE CAUSE	SPILL	1970	1971	1972	1973	1974	1975	1976	1977	1978	TOTAL
Equipment Problem	No.	-	57	49	46	21	34	18	12	21	258
	%	-	89.0	94.2	90.2	67.7	87.2	81.8	70.6	87.5	86
	BBLS.	-	321	576	185	62	128	798	353	1,129	52
	%	-	73.0	97.3	3.6	0.3	70.3	16.6	51.9	99.5	10
Personnel	No.	-	5	2	3	2	2	1	3	2	20
	%	-	7.8	3.9	5.9	6.5	5.1	4.6	17.6	8.3	6.6
	BBLS.	-	117	13	11	110	10	4,000	75	2	4,338
	%	-	26.6	2.2	0.2	0.5	5.5	83.3	11.0	0.2	12.2
Natural Event	No.	-	1	-	2	4	3	1	2	1	14
	%	-	1.6	-	3.9	12.9	7.7	4.6	11.8	4.2	4.6
	BBLS.	-	2	-	5,002	2,230	44	6	252	3	7,539
	%	-	0.4	-	96.2	10.0	24.2	0.1	37.1	0.3	21.3
Unknown	No.	1	1	1	-	4	-	2	-	-	9
	%	0	1.6	1.9	-	12.9	-	9.0	-	-	2.9
	BBLS.	-	0	3	-	19,877	-	0	-	-	19,890
	%	-	0	0.5	-	09.2	-	0	-	-	56.3
Total All Causes	No.	1	64	52	51	31	39	22	17	24	301
	%	100	100	100	100	100	100	100	100	100	100
	BBLS.	0	440	592	5,198	22,289	182	4,804	680	1,134	35,319
	%	-	100	100	100	100	100	100	100	100	100
Events Involving Spills	No.	0	61	45	46	27	33	16	15	16	259
	%	0	95.3	86.5	90.2	87.1	84.6	72.7	88.2	66.7	85.4

Source: Committee on Assessment of Safety of OCS Activities; data from U.S. Geological Survey



Source: Committee on Assessment of Safety of OCS Activities

Figure III-3

The volume of oil discharged from pipelines is small compared with amount of oil transported.

Analysis of accident records reveals that the leading causes of pipeline discharges are impacts below the water (46 percent) and corrosion (18 percent). Underwater impacts are responsible for the bulk of hydrocarbons spilled from pipelines. These are often anchor-dragging incidents involving small vessels, such as OCS workboats.

Steps to Improve Pipeline Safety. Pipeline failures can be prevented or corrected by eliminating the causes of failure or by improving the reliability of equipment.

The potential causes of discharges are corrosion, impacts, design overload conditions, hot taps, abrasion, and chafing. Corrosion can occur externally and internally on critical elements of the system. External corrosion results from splash-zone problems, stress corrosion occurring at points of minor impacts, and loss of protective coatings during installation and operation. The sources of internal corrosion include increased water content in the oil stream and oxygen-generating bacteria. Impacts can occur above or below the surface of the water. Above-water damage is generally caused by vessel rammings, and that below the water by anchor dragging and trawling, or snagging of anchor cables on the pipelines' manifold protuberances. Design overloads can be caused by pipe movement, excessive unsupported pipe lengths, expansion and contraction, embrittlement, and overpressure. Overpressure can result from malfunctions of a control system or safety device, operator errors on control systems, inadequate design criteria, and design faults. Causes of pipe and riser movement include earthquakes, subsidence, storm winds and waves, tsunamis, and mudslides. Accidents in unsupported pipe lengths can occur from scour, mudslides, subsidence, and inadequate surveys that result in routing over bottom discontinuities. Expansion and contraction of the line, caused by high-temperature products, can impose excessive loads on risers and couplings. Exposure to cold environments, as in the Arctic, can degrade material impact strength. Solid matter, such as sand in the flowline, can cause abrasion, which leads to the internal loss of metal. Chafing of protective coatings and the structure can occur from clamp slippage on risers, improper line crossings, and rubbing by cables and anchor chains.

Preventive or corrective action against pipeline failures can be initiated during one or more phases of the life cycle of a subsea pipeline. These phases are broadly defined as design, construction, and operation and maintenance. Action can take the form of improved design techniques, construction methods, and operational practices--through voluntary actions, regulatory requirements, or both.

Table III-8 matches the potential causes of pipeline failure to discharge sources, the expected volume of discharge in the event of failure, and the time in the life cycle of the pipeline when preventive or corrective action will reduce the likelihood of pipeline

TABLE III-8

Pipeline Discharges: Their Causes, Sources, Anticipated Volumes, and Timetable For Preventive/Corrective Action

Potential Discharge Causes

Discharge Sources	Corrosion	Impact Below Water	Pipe/Riser Movement	Expansion/Contraction	Impact Above Water	Chafing	Excessive Length Between Supports	Abrasion	Modification and Repair	Overpressure	Embrittlement
Platform Fittings	A/3									B/1,3	A/1
Riser	A/1		B/1	A/1	B/1	B/1		B/1		B/1,3	A/1
Carrier Pipe	C/1,2	C/3	C/1			B/1,3	C/1,3			C/1,3	
Corrosion Protection				Unlikely Source							
Weighting-Methods				Unlikely Source							
Unique Couplings				B/1							
Subsea Manifolds		C/3	C/1						A/1	C/1,3	
Control Subsystems				Unlikely Source							

Expected Discharge Volume Code:

A. less than 1,000 bbls
B. 1,000 bbls to 10,000
C. greater than 10,000 bbls

Code: Expected Discharge Volume / Life Cycle Corrective Timing

Timetable for Preventive/ Corrective Action

1. Design
2. Construction
3. Operation and Maintenance

Example: A/3, less than 1,000 bbls expected accidental discharge from a failure; preventive measures to be applied during operation and maintenance.

Source: Committee on Assessment of Safety of OCS Activities

failure. The potential causes of discharges are ranked by their observed or estimated contribution to discharges. Table III-9 sets out observed spill data by potential causes of discharges.

This review of the data shows that the two primary sources of accidental discharges from pipelines, in terms of potential magnitudes and the number of causes, are the riser and the carrier pipe. Discharges of a larger magnitude can be attributed to the carrier pipe. In general, riser-related problems can be addressed in the design phase, whereas carrier pipe problems need to be treated during the design and the operation and maintenance phases. Unique couplings and subsea manifolds also represent sources of potentially large discharges, but there are relatively fewer causes of such discharges.

Each potential source of a pipeline discharge is fed by a number of potential causes of pipeline system failure. The causes in turn are underlain by one or more contributing factors. Preventive or corrective actions to mitigate contributing factors include improved management practices, such as improved maintenance programs and better training, development of new technologies and regulatory changes. These relationships are depicted and defined in Table III-10.

Instrumented control systems capable of detecting leaks have been installed on large offshore pipelines by some operators, particularly where the potential exists of large oil spills in the event of a line break. These systems are being improved by research and development. One particularly important potential use for these systems is in interconnected pipeline systems where, in the event of a failure, it is necessary to shut down the pumps of several operators in order to reduce pressure in a line to control a spill. Instrumented control systems are capable of quickly identifying significant leaks and detecting smaller leaks over a period of time. The smaller the leak, the longer the time necessary to detect it.

Burying pipelines below the seabed is not necessarily a contribution to safety. Trenching operations may damage the pipe or its corrosion protection systems. Moreover, burial of a line hinders its repair if and when that becomes necessary. For these reasons, it is best to consider trenching as just one response to site-specific problems, such as heavy marine transportation or commercial fishing activities.

Engineering Considerations in Frontier Areas. It is reasonable to expect that some frontier areas will be found commercially producible and that pipelines, which are considered the mode of transport presenting the least risk to the environment, will be laid wherever they are technically feasible and economically practicable.

The design, construction, operation, and maintenance of pipelines in frontier areas will involve technological challenges that are influenced by the conditions of the areas where oil is discovered. The engineering considerations for the new areas will include greater water depths and harsher environmental conditions, including ice. Longer transportation routes and conflicts with other

TABLE III-9

Allocation Of Observed Spill Data (Over 50 bbls)
To Potential Discharge Causes

	U.S. OCS[1]		North Sea[2]		Combined	
	Events	Percent	Events	Percent	Events	Percent
Corrosion	4	18.3	5	35.7[3]	9	25.0
Impact Below Water	10	45.5	2	14.3	12	33.3
Pipe Movement	3	13.6	2	14.3	5	13.9
Expansion/ Contraction	0	0	4	28.5	4	11.1
Impact Above Water	0	0	0	0	0	0
Chafing	1	4.5	0	0	1	2.8
Excessive Unsupported Length	0	0	0	0	0	0
Abrasion	0	0	0	0	0	0
Modification and Repair	1	4.5	0	0	1	2.8
Overpressure	0	0	0	0	0	0
Embrittlement	0	0	0	0	0	0
Unknown	3	13.6	1	7.2	4	11.1
Totals	22	100.0	14	100.0	36	100.0

1) DOT Rpt. DOT/MTB/OFSO 77/44, Vol. II Main Text, December 1977, Dravo Van Houten, Inc., updated with U.S. Geological Survey data.

2) Norwegian Council Rpt., "Risk Assessment," Rpt. 26-27/2, pp. 109-110, Table 4.1.10 II - "Apparent Cause of Pipeline Damages During Production (North Sea)."

3) The high incidence of corrosion events evident in North Sea data is probably attributable to high temperature crude oil effects on risers and therefore is somewhat site-specific in nature.

Source: Committee on Assessment of Safety of OCS Activities

TABLE III-10

Characterization of Pipeline Safety Including Means of Improvement

Pipeline Discharge Sources (Potential Cause)	Contributing Factors	New Technology Under Development	Potential Regulatory Considerations
Risers			
1. (Embrittlement)	Arctic environment	Material selection for arctic conditions	Gap in USGS order requiring adequate protection
2. (External Corrosion)	Poor selection of coating system Improper application of coating Inadequate bumper protection Inadequate inspection techniques	Systems and methods of application constantly being improved	
3. (Impact Above Water)	Inadequate bumper protection Poor location selection Poor marine procedures		
4. (Pipe Movement)	Mudslide, etc., induced pipeline failures	Shear safety joint with double acting valves Provide slack in submerged component to accommodate movement	
5. (Internal Erosion)	Sand production	Internal inspection pig Sand probes Piping geometry	
6. (Clamp Slippage-Chafing)	Poor clamp design Inadequate inspection		

TABLE III-10 (cont'd)

Characterization of Pipeline Safety Including Means of Improvement

Pipeline Discharge Sources (Potential Cause)	Contributing Factors	New Technology Under Development	Potential Regulatory Considerations
Carrier Pipe			
1. (Internal Corrosion)	Poor internal coating selection and/or application lack of monitoring and sampling programs	Constantly being improved	
2. (External Corrosion)	Damage to corrosion		
	Coating damage to passive annodes		
3. (External Impact)	Almost exclusively in the course of OCS operations	Use of state of the art survey equipment	Addressed by recent Notice to Lessees and Operators*
	Inadequate coordination of operations	Operator supervision	
4. (Pipe Movement)	Caused by mud slides, etc.	Pipeline route selection, shear joint with double acting valves	Same note as above
		Instrumented survey pig	
		Acoustic survey techniques	
5. (Chafing)	Improper pipeline crossings		
	Spanning of pipelines with chains or cables	Same as impact by external forces No. 3 above	
6. (Unsupported Spans)	Scour and subsidence	Mechanical supports deployed by submersible	

*Operational requirements are needed to mitigate these spills.

Pipeline Discharge Sources (Potential Cause)	Contributing Factors	New Technology Under Development	Potential Regulatory Considerations
7. (Overpressure)	Failure of pipeline related platform safety equipment		
Subsea Manifolds			
1. (Impact External Forces)	Same as for submerged piping. Also, potential for trawl net and anchor cable hangs on appurtances to manifolds	Better design manifold assay Improved cover design	Site specific protection Design requirement needed
2. (Pipe Movement)	Same as for submerged component		
3. (Hot Taps)	Operator error--very limited		
4. (Overpressure)	Same as for submerged component		
Unique Coupling			
1. (Expansion/Contraction)	Inadequate component design	Continued product advancement	
	Improper installation	Better diver training	
		Simpler to install	
2. (Overpressure)	Same as for submerged component		
Platform Piping and Couplings			
1. (Corrosion)	Lack of inspection		
2. (Overpressure)	Same as for submerged component		
3. (Embrittlement)	Same as for riser		

Source: Committee on Assessment of Safety of OCS Activities

resource exploitation activities will be additional considerations in some regions. Some operating experience is applicable to most of the technologies mentioned; quantum leaps in technological innovation are not required.

The Regulation of Pipelines. Several agencies exercise authority over pipelines that transport oil and gas from producing OCS wells to onshore facilities. These authorities are described in Table III-11.

To minimize redundant efforts and to ensure monitoring of all phases of pipeline design, construction, installation, and maintenance, several of the agencies have concluded memoranda of understanding (MOU). One MOU describes the division of responsibilities between the BLM and the Geological Survey. Under the provisions of this MOU, the Geological Survey undertakes the primary responsibility for technically reviewing pipeline design, installation, operation and maintenance in accordance with appropriate safety and environmental protection regulations and standards.

Another MOU states the individual and joint responsibilities of the Department of Transportation (DOT) and the Department of the Interior (DOI) regarding offshore pipelines. Consistent with this MOU and with the OCS Lands Act Amendments, the DOI focuses its pipeline regulations on those pipelines directly associated with production installations, whereas the DOT's program is more concerned with the common carrier lines that move produced oil and gas to shore. However, the implementation of this MOU is incomplete.

Review of regulatory responsibilities makes it apparent that the Geological Survey has the major technical responsibility for regulating OCS pipelines. The Geological Survey performs the following tasks in this role:

o Reviews all applications for pipelines to ensure that they are in accordance with the more stringent DOT or DOI regulations and standards for pipeline design, installation, maintenance, and operation.

o Rejects, modifies, or approves applications for pipelines to be constructed under the authority of a lease instrument or right-of-use and easement and notifies BLM in writing as to the acceptability of the technical aspects of pipelines to be constructed on a BLM-approved right-of-way.

o Inspects the installation of all new pipelines under its jurisdiction for regulatory compliance.

o Reviews the design and proposed repair operations to be conducted on all pipelines under its jurisdiction scheduled for major repairs. Within manpower limitations, actual repair operations are spot-checked and subsequent pressure tests are witnessed by its personnel.

TABLE III-11

PIPELINE REGULATIONS

AGENCY	AUTHORITY	DESCRIPTION
Bureau of Land Management	Pipeline rights-of-way 43 CFR 3340	Procedures for granting and administering rights-of-way to cross public land. Issuing requirements include proper maintenance and use of BAST.
	Lease stipulations	Sometimes the use of pipelines is required if: • rights-of-way can be obtained • they are technically feasible and environmentally preferable • their use would, in the opinion of BLM, constitute a net social benefit Stipulations usually require that pipelines be protected from natural and human hazards.
U.S. Geological Survey	Rights-of-use and easement 30 CFR 250.18	Authorizations to cross leased land issued, subject to conditions such as the use of BAST, and approval of design, fabrication, and plan of installation.
	OCS Order 9 - Oil and Gas Pipelines	Specifies in greater detail the requirements to be met before approval can be obtained. Includes requirements for: • pressure sensors • shut-in valve • check valves • corrosion protection • installation compatible with other ocean uses • hydrostatic testing • monthly inspection
Materials Transportation Bureau (DOT)	Transportation of gas and liquids by pipeline 49 CFR 190, 192, and 195	Extensive and detailed regulations governing the design and construction of all pipelines, both on and offshore. Includes inspection requirements. Since these regulations are not specific to offshore pipelines, they contain some inappropriate requirements and also do not address some OCS-unique problems.
EPA		See Intentional and Accidental Discharges Sections.
Army Corps of Engineers	33 CFR 322.3 and 322.5	Permits covering location of pipelines. Requirements to protect pipelines from underwater impacts. Not specific to the OCS.

Source: Committee on Assessment of Safety of OCS Activities

The existing OCS pipeline regulations have come into effect only in the past 10 years. Many of the regulations became applicable to existing pipelines and are judged to have had a beneficial effect on their operation. The regulations have also triggered industry-wide improvement in performance and therefore a reduction in the number of accidental discharges and in the quantities of hydrocarbons released. In other words, in moving from an unregulated and unmonitored working situation to one that is regulated and monitored, operators have been forced into line with accepted industry practices. Furthermore, certain specific requirements have resulted in the incorporation of such components as drip pans, control valves, and pressure-sensing devices into the regulations. This has tended to reduce the number of small-scale, minor-spillage incidents.

The pipeline regulatory program has led to safety improvements because the regulations address critical considerations in the design, construction, operation, and maintenance of pipelines. Furthermore, they do so in a performance mode without specifying technological details. This has made it possible to develop and introduce technological improvements. The regulations have been further strengthened because they have been based on established industry technology standards.

The Geological Survey requires that it be notified of all failures of pipeline systems. As presently constituted, the information required in this notification describes what happened but not the cause of the failure. For example, a comment that a "riser ruptured" tells what happened, but not how or why.

Findings and Recommendations on the Safety of Pipelines

Reported oil discharges from OCS pipeline failures over the past 10 years have been small in absolute terms and as compared with the volume handled (approximately 12 bbls per million bbls transported).

Impact below water (anchor-dragging) and corrosion are the leading causes of discharges because of pipeline failures.

Pipelines are vulnerable to anchor-dragging accidents, particularly in the course of OCS construction operations. Standard procedures do not exist that address the documentation of pipeline locations, the transfer of information about the location of pipelines to contractors and others who might anchor in their vicinity, and anchoring operations in the vicinity of pipelines.

Pipeline risers are susceptible to impacts and external corrosion. Design standards do not exist that address riser location within the platform, method of riser support, and protection from impacts and external corrosion.

Standard procedures do not exist to ensure that operators will not produce into a pipeline network without being certain of its pressure integrity.

> The DOI should require that procedures be established to ensure that operators will not produce into a pipeline network without being certain of its pressure integrity.

The safety benefit of trenching or burial of pipelines depends on the environmental and operational conditions of the pipeline location. Regulations covering pipeline trenching or burial are occasionally implemented without regard to the safety benefit of such action. Trenching or burial does not always protect pipelines from impacts.

Shear sleeves can be used to minimize pipeline failures that occur as the result of pipeline movement induced by such phenomena as mudslides or earthquakes. Check valves used in conjunction with shear sleeves may be beneficial in some instances for keeping pipeline discharges to a minimum in the event of such failures.

Pipeline regulations comprise both performance requirements, which incorporate accepted industry standards, and specific requirements, which are adopted after review and comment by industry and other interested parties. With the exception of requirements for trenching or burial, regulations are flexible enough to take site-specific considerations into account.

Pipeline regulatory requirements have increased the uniformity of application of accepted industry practices. Some specific requirements, notably those requiring drip pans, shut-in valves, pressure sensors, and check valves, have reduced the number of spill incidents. These requirements can be expected to benefit the safety record of operations in frontier areas to a greater extent than in developed areas due to early and total application to every line laid.

The lack of implementation of a MOU on pipelines between the DOI and DOT has left operators confused with respect to the allocation of regulatory authority.

> Industry should take steps to improve the safety of pipeline technologies. These should include the development of the following:
>
> o Recommended practices for riser design that address riser location within the platform, the method of riser support on the platform, and protection of the riser from impacts and external corrosion.
>
> o Operating practices that address the documentation of pipeline locations, the transfer of information about the location of pipelines to contractors and others who might anchor in their vicinity, and anchoring operations in the vicinity of pipelines.
>
> The government should expand the coverage of its regulations to include regulations on riser design and the documentation of pipeline locations and anchoring operations in their vicinity. It should utilize industry-developed practices as a basis for regulatory action.

Accidental Spills From Other Sources

This chapter has analyzed the safety of OCS activities regarding all intentional discharges of pollutants, as well as accidental discharges as a result of loss of well control and from pipelines. Without more comprehensive data on the sources and causes of accidental discharges, it is difficult to tell whether there are other aspects of OCS operations in which there is risk of accidental discharges. For example, it is possible that fuel transfer hoses (by which diesel fuel is conveyed from a supply boat to a platform) may be the source of a number of small accidental discharges. Those portions of vessel-to-installation fuel transfer systems that are based on fixed installations are unregulated at the present time. Tankering in frontier areas will also be a clear source of risk, as will product-transfer operations in severe weather conditions.

The regulations governing accidental discharges include appropriate sections of the regulations analyzed in the intentional discharges, well-control, and pipeline sections. A number of requirements of the agencies are redundant. Two agencies require the reporting of pipeline failures (Geological Survey: 30 CFR 250.45; Coast Guard: 46 CFR 109.411). Three agencies require the reporting of oil spills (Geological Survey: 30 CFR 250.43; Coast Guard: 33 CFR 153.203; EPA: 40 CFR 110.9). Two agencies administer requirements for deck drainage, gutters, and sumps (Geological Survey: OCS Order No. 7-1; EPA: 40 CFR 112.7(c) and (e)).

Offshore Loading Facilities. In several producing areas in the world, oil is transported from fixed production platforms through a short seabed pipeline to an offshore tanker loading facility, such as a single point mooring (SPM) or single anchor leg mooring (SALM). Offshore loading facilities are used when a pipeline is not economically justified, as when there is too little oil reserve, or there is a no suitable pipeline landfall. Any substantial oil spills resulting from the damage of offshore loading facilities should be limited to the quantity of oil in the system at any one time.

Offshore loading operations in the U.S. have been limited so far. However, these operations may become more common as development occurs in some frontier areas where pipeline transport to shore may not be economically feasible.

Very small discharges of petroleum may occur almost routinely in the course of operating offshore loading systems. The components of offshore loading systems most vulnerable to damage are the flexible hose connections between the pipeline and floating facility (SPM type), the flexible joints built into the facility (SALM type), and the flexible hose connection from the facility to the tanker. Control systems are necessary to shut down the loading operation quickly in the event of a spill. Such offshore transfer operations are not covered by detailed, comprehensive regulations at the present time.

Findings and Recommendations on Accidental Spills from Other Sources

Precise identification of the causes of accidental discharges generally does not exist. If such information were available, it might be possible to identify and eliminate spurious regulations while improving the effectiveness of others. Present information identifies fuel transfer as a possible source of accidental discharges not presently covered by regulations.

> The Geological Survey and the Coast Guard should coordinate and revise their regulations regarding fuel transfer hoses to ensure full coverage of all contingencies. In particular, regulations should be developed for fuel transfer in situations where all the transfer gear is based on a fixed OCS installation.

There is overlap in the regulations of the Geological Survey, the Coast Guard and the EPA in the reporting of pipeline breaks and oil spills and also in deck drainage requirements. The usefulness of reported information is limited because it does not include adequate causal information.

> The EPA, USCG, and the USGS should standardize their reporting requirements regarding accidental discharges. The Geological Survey reporting requirements should be revised to meet the needs of other agencies. These requirements should be expanded to include the reporting of specific information on the causes of accidental discharges.

Offshore loading operations, which have been limited to date may be expected to increase as frontier areas are developed. Such operations are inadequately regulated.

> The Coast Guard should develop regulations for offshore loading operations prior to the expansion of such opertions.

Oil Spill Containment and Cleanup

The first line of defense against oil spills is prevention. In the event of an oil spill, mechanical containment and recovery or chemical dispersal (or some combination thereof) can be used to minimize pollution in some instances. The success of these countermeasures depends on adequate planning and execution. The physical circumstances surrounding a spill--the rate and volume of oil spilled, sea state, currents, and weather conditions--may severely limit their effectiveness.[18]

Containment and Cleanup Technology.

- o Containment. Should oil spills be threatened or occur, booms or barriers correctly placed and moored (or manuevered) can corral the slick for further action or deflect its movement away from people, property, or environmentally sensitive areas. Booms have been designed for offshore, outer harbor, and inner harbor applications. An oil-containment boom extends above and below the water and is moored or towed to form a stationary or fixed fence ("fixed" but not rigid--an oil-containment boom must rise and fall with the waves). The boom's extent above and below the water prevents entrained oil from passing under the barrier or floating oil from passing over the top. The loss of oil droplets by entrainment is small at speeds below 1 knot, and large at higher speeds: for the available open-ocean systems, 1 knot is a practical upper limit of the relative velocity between a collection or containment device and the fluid.

- o Mechanical Recovery. Spilled oil must be contained and the slick must be concentrated for efficient mechanical skimming. The containment and concentration is usually effected by booms, and the oil is recovered from the water by mechanical skimming systems. The booms are deployed in a "V" or "U" shape, and on the open ocean, towed slowly to concentrate the oil at the apex of the boom. Skimmers are used to remove the pooled oil. The Navy's skimmer-belt recovery systems, for example, depend on the V-booms used with them to concentrate the oil to a thickness of at least 0.99 inches for recovery. The Coast Guard's Open Water Oil Containment System, a combination boom and skimmer, is designed to pick up oil from a pool about 4 to 6 inches thick that forms in the apex of the boom.

  The use of boom/skimmer recovery systems is practical if the slick is 1 to 5 millimeters thick and covers an area at environmental risk from dispersed oil and if the sea and weather conditions are expected to be within the operational limits of the equipment. The principal varieties of skimming systems available for use at sea are described in Table III-12.

  The most difficult operating conditions for any of these skimmers are high seas, storms, rapid water currents, and ice. The systems that have been used with some effect on the open ocean are those of the Coast Guard (combination boom and weir-type skimmers), the Navy (belt-type, self-propelled skimmers used with booms), and variations of these two systems.

  A combination of boom/skimmer systems is often more effective than one system used alone. For example, the Navy's system is designed to be transported in modules anywhere a Navy spill might occur and is therefore flexible and adaptable (within limits). The Coast Guard's principal open-seas system

TABLE III-12

Skimming Systems

Skimmers Used With Booms (Or Barriers): Variations

Independent skimmer, operating inside boom at apex	Skimmer-boom systems	Direct-action skimmers (no long booms required)
Skimmer tethered in apex, connected to vessel by umbilical line	Skimming mechanism built into boom	Dedicated, independent skimmers
Skimmer supported by boom mounted on adjacent vessel	Skimmer with herding barriers attached to hull	Vessel-of-opportunity skimming systems (VOSS)
Self-propelled skimmer, operated by remote control from vessel in area		

Types of Skimmers	Description and Considerations for Use
Weir Skimmers	Weir separates oil layer from underlying layer. Wave conformance of weir lip is critical. Most appropriately employed in skimmer-boom systems, particularly with booms that conform well to surface in higher sea states.
Oleophilic Disks	Rotating disks lift oil from surface; oil is scraped off, and recovered. Hull-shaped or other floating devices support disk arrays and other machinery. Must be used with booms. A calm-water skimmer.
Surface-Piercing Oleophilic Belt	Endless rotating porous belt dips into thickened pool of oil; removes oil by sorbent action, water drains back to surface. Requires heavy supporting structure; usually employed in vessel system.
Dynamic Inclined Plane	Non-porous rotating conveyer belt directs oil beneath skimmer to collecting chamber. A calm-water skimmer.
Cyclonic Separator	Momentum of water flowing past ship used to create centrifugal force inside device's helical chamber; oil separates and exits at top for recovery, water at bottom.
SOCK Skimmer	Covered oil booms on either side of vessel, and wide opening scoop oil to rear of device, to be collected by oil suction ports. (Under development)
Zero-Relative-Velocity Sorbent Mechanisms	Various sorbent materials in these mechanisms are made to lie momentarily stationary (e.g., by rotation in the opposite direction from that of vessel) on the surface of the water. As sorbent is brought out of slick, oil and water are squeezed out, and oil recovered. Can move at higher speeds than towed systems; prototypes offer various degrees of wave conformance.

Source: U.S. Coast Guard, Oil Pollution Response Planning Guide for Extreme Weather, (Washington, D.C.: Government Printing Office, 1980), p. 60, pp. B-1-B-2.

is designed for high sea states and large volumes of oil, but is less maneuverable than the Navy's system. In the case of the BURMAH AGATE spill in 1979, each system provided a backstop for the other. Both were operating in conditions that frustrated the recovery effort. The ship caught fire, preventing close operations and eventually burning the closest boom. Support vessels capable of towing the booms at the optimal low speeds were not available which, together with shifting currents and the thinness of the oil, reduced the effectiveness of the combined boom/skimmer system. Nevertheless, the self-propelled skimmers were able to pick up oil that escaped the combined system, and the two systems were generally complementary.

The zero-relative-velocity skimmer was designed to overcome the 1-knot limitation mentioned previously, and, if successful, could be used in rapid currents. It has been tested in the EPA's Oil and Hazardous Materials Simulated Test Tank in Leonardo, New Jersey, but has not yet been used on an oil spill at sea. The skimmer's design goal is recovery oil in currents of up to 8 knots. It performed well in the test tank, but collected as much water as oil.[19]

Many mechanical procedures, improvements, and equipment are new and only partly tested. For oil recovery on the open seas, any system or set of systems deployed demands heavy support. For example, the Navy and Coast Guard skimming systems both require three vessels to tow the barriers and hold the collected oil. These vessels must be well equipped with communications equipment and capable of operating at speeds below 1 knot. Towed dracones (oil-holding bladders) have limited capacity. Barges or tankers would probably be needed to hold oil recovered after large spills. Other logistical requirements in oil spill recovery include vessels to act as lighters and as at-sea supply, storage, command, and communications headquarters. Helicopters and fixed-wing aircraft are needed to monitor and report the oil's movement and to help direct the movements of recovery equipment.

o Dispersants.[20] Chemical dispersants alter the surface tension of the water, or the interfacial tension between oil and seawater, allowing ocean forces to break the oil into small particles for readier assimilation into the water column and degradation. They can be used in a variety of sea and other states that seriously reduce the performance of mechanical recovery systems or that preclude their use, but have rarely been employed to maximum effect.[21] First-generation chemical dispersants had to be premixed, and their use on oil spills constituted a trial-and-error process. Evaluations conducted after the use of these chemical dispersants indicated that they were more toxic to marine life than the oil itself. Nevertheless, the attractive features of chemical dispersants, particularly the extension they seemed to offer of response to oil spills on the open seas, exerted a pull on research and development efforts. Biodegradable dispersants that require no premixing have been developed. They can be distributed by a number of different systems on vessels and aircraft. These new dispersants seem to be far less toxic than earlier formulas, but much more information and research is needed for their evaluation.[22]

The use of dispersants might be particularly appropriate if colonies of pelagic seabirds are at risk from an oil spill or if significant numbers of a valuable species are in the path of a spill. In these cases, the decision may have to be taken at once. In other cases, opinion divides about whether the light toxic fractions should be allowed to evaporate before the dispersant is applied (to prevent their mixing into the water column). As the slick weathers, it increasingly resists chemical dispersion. The decision about timing the application of chemical dispersants is made more difficult by the gaps in our knowledge of the fate and effects of oil in the oceans and our scanter knowledge of the fate and effects of chemically dispersed oil.

o Ultimate Disposal of Oily Debris. Recovered oil and oily debris must still be disposed of. Oil decomposes very slowly in the aerobic atmosphere of a sanitary landfill. Landfill technology cannot guarantee that groundwater will not eventually be contaminated. Alternatives such as incineration and land cultivation offer other problems, e.g., compliance with air pollution regulations, and swamping of the site to be cultivated if the oily volumes are large.

Some oil recovered at sea may lend itself to processing in refineries, either as crude or waste. The soundness of any method of disposal, singly or in combination, depends on intelligent planning and conscientious execution.

o Oil and Ice. Generally, the conditions that impede people responding to an oil spill--ice, snow, very low temperatures--also impede the evaporation, spread, and movement of spilled oil. The area affected is smaller (in comparison to the area that would be affected in temperate conditions), and time is gained to respond and conduct operations. Nevertheless, any one of the conditions that must be dealt with is formidable by itself.

The Coast Guard's Arctic Pollution Response Research and Development Program recently reported the results of scenario exercises for spills in coastal or offshore Alaskan waters. If the oil is exposed (mechanically or during thawing) or pooled on the ice, it can be burned *in situ*. The Coast Guard and the Canadian Environmental Protection Service have been working on incendiary devices that can be dropped from

> helicopters for offshore spills. If the oil forms a mulch with melting ice or snow (or both), it must be removed physically. Some techniques and equipment necessary to respond to these spills have been developed, but tests and evaluation are necessary, as is the acquisition of operating experience. Some of the equipment required is unique, some needs further development, and some must be applied in novel ways. All of the equipment and logistical support for oil spill cleanup in dynamic ice "must be specially designed to operate in a low-temperature oil/ice/water environment. Special materials, lubricating fluid and operating procedures are required. All response equipment for Alaskan applications must be configured for delivery by C-130 aircraft. Heavy lift helicopters may frequently be required for equipment deployment. Support vessels used in the response operation must have some icebreaking or transiting capability. Helicopter support is needed for surveillance, cleanup, monitoring, and emergency evacuation."[23]

Industry Capability. Companies operating on the OCS are required to submit oil spill contingency plans to the Geological Survey for approval. Many companies have elected to form cooperatives to satisfy all or part of their need for oil spill response. The burden of purchasing and maintaining equipment stockpiles is shared by the cooperative members. Existing cooperatives serve specific operating areas, and their equipment stockpiles and arrangements for support services are intended to reflect the needs of a particular region, including the level of OCS activity and prevailing environmental conditions. The cooperatives maintain the equipment and train the personnel of member companies and third-party contractors in its use.[24]

The Regulation of Spill Containment and Cleanup. The authority to regulate containment and cleanup of oil spills on the OCS is stated in the Clean Water Act (33 USC 1251), as amended, and in the OCS Lands Act (43 USC 1331), as amended. The key provisions of the Clean Water Act are in Section 311:

- The discharge of oil "in such quantities as may be harmful" into or on the navigable waters, shorelines, or contiguous zone, in connection with activities under the OCS Lands Act, the Deepwater Port Act, or Fisheries Conservation and Management Act, or that threatens natural resources under the management of the U.S. government is prohibited;

- Should a spill occur, or threat of a spill, in the areas or in connection with the activities named, the President can arrange to remove the threat or oil, unless he determines the spiller will do an adequate job. (The President has delegated this authority to the Coast Guard for the OCS.)

- The President will prepare a National Contingency Plan (delegated to the Council on Environmental Quality).
- Spills or discharges on the OCS or in coastal waters must be reported to the appropriate federal agencies.
- The Coast Guard shall assess civil penalties up to $5,000 for each discharge that violates the act.
- The spiller (owner or operator) is liable for the actual costs of cleanup. Liability is limited to $50 million for offshore facilities $125/gross ton or $125,000 for oil barges and $150/ gross ton or $250,000 for vessels carrying oil or hazardous substances as cargoes.
- A revolving fund of up to $35 million is authorized to pay the government's cost of dealing with threatened or actual spills, when it must undertake the containment and cleanup operations. The fund is administered by the Coast Guard.

The EPA defines such quantities of oil "as may be harmful" as those that violate applicable water quality standards or cause a sheen or discoloration on the surface of the ocean or shorelines (40 CFR 110), although the sheen test produces varying results based on sea conditions, weather, time of day, the position of the observer, and other variables. Any such spill on the OCS must be reported to the Coast Guard.

The articulation of the Clean Water Act and other applicable statutes into a set of regulations and agency responsibilities is briefly summed up in Table III-13.

- The National Contingency Plan. By Executive Order, the President designated the Council on Environmental Quality as the organization responsible for issuing a national plan of response to spills of oil or hazardous substances. The National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 1510) now in effect spells out the organizational structure and response to actual or threatened spills of oil or hazardous substances. A single 24-hour communications center is established at Coast Guard headquarters, and an on-scene coordinator is designated by the Coast Guard for offshore oil spills. The federal on-scene coordinator:
    - promptly determines if the person responsible for the discharge is taking proper action to remove the discharge or threat of discharge;
    - if practicable, makes the person aware of his financial responsibility; and

TABLE III-13

Regulations Governing Oil Spill Containment and Cleanup of Oil and Gas Operations on the Outer Continental Shelf

	U.S. Geological Survey	U.S. Coast Guard	Council on Environmental Quality
Plans	Lessee shall submit oil-spill contingency plan detailing equipment, personnel, time to respond, etc. designating person to coordinate activities, response team and central location, actions to be followed, with or before exploration plan or development and production plan, OCS Order 7.3	Participation in national regional planning; review of regional contingency plans, in accordance with National Contingency Plan.	Responsibility for National Contingency Plan: spells out policy and responsibilities, requires regional and local contingency plans, provides for National Response Center, National Response Team, Regional Response Team, special forces, etc., 40 CFR 1510.
Spill Reporting	All spills of oil or liquid pollutants to be reported to National Response Center (Coast Guard); and the District Supervisor, OCS Order 7.2.3.	All oil spills that cause a sheen on the water to be reported to National Response Center, 33 CFR 153, Subpart B.	All reports to be channeled to National Response Center, relayed as provided in Plan 40 CFR 1510.51(a)-(c).
Action	Immediate corrective action by lessee; primary jurisdiction to require abatement of source with District Supervisor (MOU, USGS, USCG), OCS Order 7.5.	Primary responsibility with spiller; use mechanical methods to max. extent feasible, control source, remove oil from water and shorelines mechanically, chemicals only as provided in Plan, dispose of recovered oil, etc., in accordance with state and local procedures, 33 CFR 153, Subpart C.	On-scene coordinator to find spiller, if possible, monitor cleanup. If spiller can't be found, does inadequate job, etc., can designate federal spill and take action. Defensive actions as soon as possible; containment with booms and barriers, mechanically recovery; OCS can use chemicals only if hazard to human life, otherwise, permission of EPA designate required (Annex X, Plan), disposal in accordance with state and local procedures 40 CFR 1510.
Drills, Training	Once every 12 mos. with participation of response team named in plan, retain records of training of personnel who would carry out contingency plan, keep records of drills, OCS Order 7.4.		

TABLE III-13 (cont'd)

Regulations Governing Oil Spill Containment and Cleanup of Oil and Gas Operations on the Outer Continental Shelf

	U.S. Geological Survey	U.S. Coast Guard	Council on Environmental Quality
Funding		Administration of revolving Pollution Fund for reimbursement of federal, state and local government spill control and cleanup activities, 33 CFR, 153 Subpart D.	

Authorities:

	Section	Provision
Clean Water Act 33 USC 466 +	311	Discharge of oil in quantities that may be harmful prohibited; immediate notification of appropriate agency and cleanup of site required. Provision for imposition of civil penalties, spiller responsibilities for reimbursement or payment of cost of cleanup, federal revolving fund (administered by Coast Guard) for payment of federal activities in containment or cleanup.
Outer Continental Shelf Lands Act Amendment 43 USC 1801	Title III Offshore Oil Spill Pollution Fund	Not more than $200 million, established by 3¢ per bbl levy on OCS oil, provides for payment of damage claims, limits liability.
	Title IV Fishermen's Contingency Plan	Fund set aside (may be replenished by assessments on leaseholders) to pay damages, loss of profits, etc., suffered by commercial fishermen owing to OCS activities.
Executive Order 11735		Designates the Council on Environmental Quality as responsible for the National Oil and Hazardous Substances Pollution Contingency Plan.

Source: Committee on Assessment of Safety of OCS Activities

- if the person responsible does not act promptly, or fails to take proper removal actions, or if the person responsible is unknown, or if a potential discharge is considered to exist, the on-scene coordinater decides the further federal response actions to be taken in accordance with the plan.

The plan provides for a National Response Team and Regional Response Teams that can be activated to assist the on-scene coordinator and that serve as standing committees for evaluation and review of national or regional and local contingency plans. The on-scene coordinator can also call on the National Strike Force of the Coast Guard, a 60-man contingent of pollution-fighting specialists stationed in 20-man groups on the East (Elizabeth City, North Carolina), West (San Francisco, California), and Gulf (Bay St. Louis, Mississippi) coasts. The Coast Guard plans to station Emergency Task Forces at major ports. The equipment and personnel of the Navy's Supervisor of Salvage can be called upon to respond to an offshore spill. The plan provides for a scientific support coordinator and an environmental response team.

o Presidential Directive. In 1977, the President directed "the appropriate federal agencies, particularly the Coast Guard and the EPA, in cooperation with the state and local governments to improve our ability to contain and minimize the damaging effects of oil spills. The goal is an ability to respond within six hours to a spill of 100,000 tons."[25] While this directive is not a regulation it has acquired force with the agencies' planning to meet it. The Coast Guard reported a plan that would enable response to most serious spills within six hours in 1978.[26]

o Oil Debris Removal and Disposal. Regulations specify that those who remove oil discharges shall minimize secondary pollution and dispose of recovered oil and oil-contaminated materials in accordance with applicable state and local government procedures (33 CFR 153.30).

o Industry Responsibilities. The laws and regulations dealing with oil pollution of the oceans emphasize the first-line responsibility of potential and actual spillers for prevention, containment, and cleanup. As indicated previously, many oil and gas operators have joined in the support of oil spill cooperatives and have acquired equipment, or hired private contractors specializing in these services, or both.

The operators on the OCS are required to file an inventory of the equipment that would be used in case of an oil spill, the response team that would direct the efforts, and their contingency plans with the Geological Survey (OCS Order No. 7). The operator takes responsibility for seeing that personnel are trained in the use of the equipment and for holding a full-scale drill at least once a year. (These requirements are often met through participation in a cooperative.) The Geological Survey approves or disapproves proposed plans. As previously noted, the Coast Guard assists in the technical evaluation of proposed plans. The Coast Guard indicates that state-of-the-art technology will be required of operators on the OCS, in accordance with the goals of the Presidential Directive for more effective response to oil pollution incidents affecting the oceans.

Adequacy of Technologies and Regulations. The effectiveness of the technology developed for removing or dispersing oil spilled on the open oceans is limited.

The equipment and practices that have been developed to contain and recover oil from the open oceans must contend with a dynamic, changing situation influenced by a number of as yet imperfectly understood mechanical, chemical, and biological factors. While the technology for mitigating oil spills at sea has advanced in the 13 years since the TORREY CANYON incident, it is still limited by such physical/environmental conditions as high sea states and ice. Each of the available technologies has been differentially effective or ineffective in various sets of circumstances. The success of the response to a major spill on the OCS is more likely to be determined by the effectiveness of its planning and organization and by the experience and judgment of the people taking part, than by the deployment of any particular technology. These aspects, as well as readiness, are emphasized by applicable regulations.

The planning and practice now being carried out under the guidelines of the National Contingency Plan for possible oil spills on the OCS offer appropriate opportunities to resolve many issues in advance and to maintain an agreed-upon level of readiness. The Geological Survey has developed site-specific criteria for the oil spill contingency plans of leases, and these plans are reviewed by the Coast Guard. The oil and gas operators on the OCS, principally through oil spill cooperatives, now stockpile state-of-the-art mechanical recovery equipment and chemical dispersants or are planning to acquire them. Supplementary to the planning and preparation to respond to large spills that are required and undertaken, it is also necessary for OCS operators to have on hand at the site of operations equipment and personnel capable of responding promptly to any small spills that may occur incident to operations.

Several comments about the National Contingency Plan frequently raised in the review of proposed amendments, and in published reports, turn on the general question, "Who's in charge?"[27] Do the new provisions reflecting requirements of the Endangered Species Act, for example, imply that officials of the Fish and Wildlife Service or the National Marine Fisheries Service make the decisions on containment and cleanup affecting endangered species or does the on-scene coordinator have the authority to override them?

There is obviously a major organizational job in the response to any large oil spill on the open oceans. Arranging for a sufficient number of private and public vessels to transport pollution-combatting equipment and people, scientific personnel, and sampling equipment, to provide support (fuel, meals, oil and debris removal), and to document position, weather, sea states, and details of the size and movement (or potential) of oil spills is a massive undertaking. At this stage in the development and application of technology for containing and cleaning up medium- or large-scale spills on the open ocean, only the Coast Guard and the Navy have experience organizing a response. The explicit assumption of the laws and regulations governing containment and cleanup activities is that, if the operator takes responsibility, the on-scene coordinator monitors and supports the activities. How well this actually works can be helped by the regional planning and practice sessions now under way, but is not helped by the lack of clear authority to make many of the decisions that must be made quickly on the spot. Quick action is often decisive in the success of containment and cleanup. There are few (and not yet entirely adequate) models to guide decision-making in many circumstances likely to be encountered in large spills in unprotected waters.

A related comment often heard as a specific complaint is that the on-scene coordinator cannot make an executive decision to apply chemical dispersants unless life and limb are threatened. In any other case, EPA approval is required.

With some notable exceptions, states and localities have not planned for receipt and disposal of the oily wastes collected in cleanup operations. (Some cooperatives and operators have made their own arrangements.) Neither the federal government nor most states have developed a consistently applied set of minimum standards for licensing disposal sites and procedures. The federal government is considering new regulations to comply with the Resource Conservation and Recovery Act of 1976; if oily wastes are declared hazardous substances, state or federal permits will be required for their disposal. The EPA has developed a set of guidelines and recommended procedures for management of these wastes.[28]

Findings and Recommendations on Oil Spill Containment and Clean-up

Current technology to recover spilled oil is severely limited above sea state 3, in rapidly moving ice-bearing waters, and at night. The ability to clean up spills could be negligible during major periods of the year in frontier areas such as the North Atlantic and Alaska. Some of the above conditions may lead to the suspension of oil in the water column; the containment and cleanup of oil spills when the oil becomes suspended is not technologically feasible at this time. Continuing research and development, with incentives for industry, is necessary to advance the state of the art.

> The Coast Guard should continue to support a research and development program and should establish appropriate incentives for industrial research and development, to advance oil spill containment and cleanup equipment and practices, particularly for the North Atlantic and the Arctic.

The Geological Survey approves the adequacy of contingency plans proposed for areas on the OCS. For those areas where the Geological Survey has set site-specific criteria (i.e., source, type and rate of spill, sea states, and response times), the industry has demonstrated technology and equipment to satisfy the criteria. The industry's existing capability generally represents the best available.

The criteria of adequacy for contingency plans will vary, and possibly become more stringent, as new areas of the OCS introduce additional source types (i.e., tanker loading operations) and environmental conditions, such as ice. Wherever these eventualities may occur, criteria are needed in advance of lease sale commitments, and the industry, in turn, needs to demonstrate adequate capability and plans.

The Coast Guard, the Navy, and industry have developed and maintained (for different purposes) complementary oil spill containment and cleanup technology and support equipment. The requirement that industry demonstrate its readiness to contain and clean up oil spills prior to undertaking offshore petroleum development operations should lead to improved ability to respond to oil spills on the open ocean.

The National Contingency Plan and the regulatory practices of the Geological Survey provide some assurance of response within the limitations of existing technology to oil spills on the OCS. The plan's requirements for regional contingency plans, provisions for special forces, and so on have brought together officials of the pertinent agencies and local and state governments and those whose coordinated decisions and actions are necessary to oil spill response. The plan is periodically revised, and the process of planning and practicing for oil spill response is just being established on firm ground. An important limitation of the National Contingency Plan is that its effectiveness depends on timely decisions from external sources to support the on-scene coordinator.

Dispersants, as a means of lessening the environmental effects of spills, have been a controversial issue since the TORREY CANYON incident. They may be used today on the OCS at the discretion of the on-scene coordinator only if danger to human life or limb, or fire, is imminent. There are, however, circumstances in which their use may be warranted for the protection of certain populations of birds or other important biological resources. Although many new dispersants have been developed since the TORREY CANYON incident, the EPA has not completed a review of dispersants and oil/dispersant mixtures for toxicity nor has it established which, if any, are acceptable for use in special circumstances. The National Contingency Plan could provide for the rapid acquisition of permission to use those dispersants found acceptable by the EPA in certain circumstances.

The EPA should review dispersants and oil/dispersants mixtures for toxicity and establish which, if any, are acceptable for use and under what circumstances.

Human Safety and the Safety of Installations

Workplace Safety

"Workplace safety" is defined as the freedom of a given workplace from hazards that could harm trained workers carrying out the proper functions of their jobs. The evaluation of a workplace against this broad criterion can be approached by analysis of accident frequencies and prevalent facts about the accidents of particular workplaces. In any workplace accident, a susceptible individual, a hazardous environment or piece of equipment, and an injury-producing agent interact. Unexpected, avoidable, or unintended aspects of the physical environment, in combination with various aspects of the individual's behavior, result in injury to the individual (or others), damage to equipment, or both.

As of the end of 1979, about 61,500 U.S. workers were regularly employed in OCS oil and gas exploration, development and production.* On any given day about one-half of this number, or 30,750 workers were on duty. Over the ten-year period 1970-1979, the OCS workforce grew by approximately 34,000 "full-time equivalents."** This represents an elapsed growth of 71 percent over ten years. From 1970-1977, the average annual growth rate was 3 percent. From 1977-1979, however, average annual growth in the offshore workforce was 20 percent.

The Safety Record. No comprehensive source of data on accidents in OCS operations exists. The committee collected and analyzed data from a number of sources and made estimates as needed, e.g., the size of the OCS work force.

In the nine-year period from 1970 to 1978, the Geological Survey reported that 187 workers were killed in 116 incidents on the OCS. As can be seen in Table III-14, the number of fatalities and their rate of occurrence appear to be declining slightly.

While the incidence of fatalities shows little variation from year to year, that of injuries appears to be declining, at least in drilling operations. Although the total number of drilling man-hours reported for the OCS increased from 26 million to 105 million between 1962 and 1977, the accident frequency for the same period declined from 14.9 to 9.3 accidents per 100 man-years.[29] In other words, there was a fourfold increase in exposure-hours, but a 38 percent decrease in accident frequency.

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*This estimate is very tentative. No census of the OCS workforce has ever been undertaken.

**"A full-time equivalent" (FTE) is 2,000 man-hours per year. OCS shifts and work schedules are such that the number of workers on duty at any given time is about 50 percent of the number of FTE's while the total number of offshore workers is about 90 percent of the number of FTE's.

TABLE III-14

OCS FATALITIES(1)

	1976	1977	1978	1979	Total
U.S. OCS Fatalities	49	42	44	39(2)	174
Rate (per 100,000 workers per year)	112.7	95.8	85.4	61.6	

(1)This Table takes into account total exposure of workers to risk, both on and off duty.
(2)Data for 1979 may be low because of reporting delays.

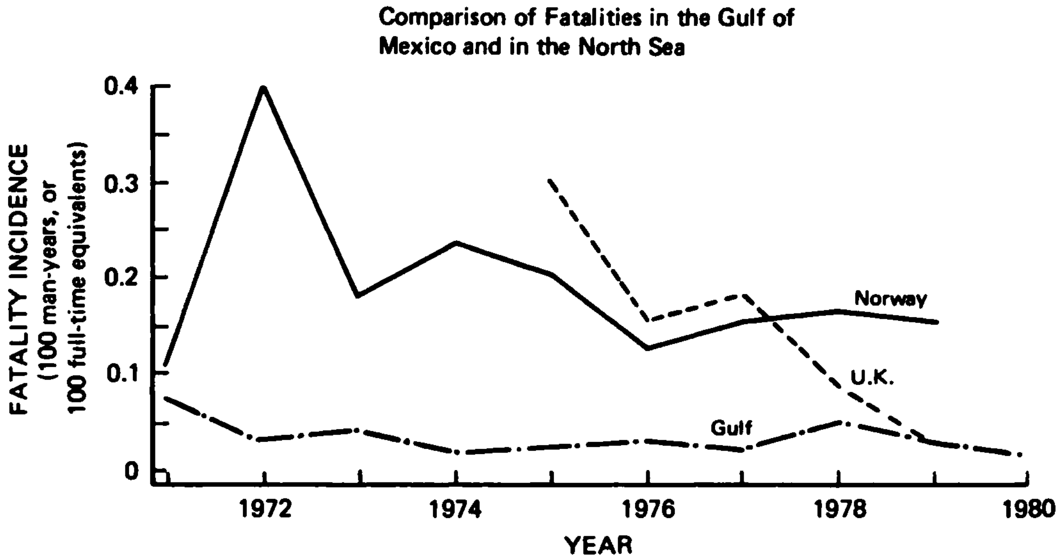
Source: U.S Coast Guard, based on data from the Coast Guard, Geological Survey and Office of Workmen's Compensation.

The frequency of injuries on oil and gas operations on the OCS is comparable to that of other industries, such as mining, maritime transportation, and heavy construction, and also offshore operations in other countries. For example, the injury rate in the deep-sea maritime transportation industry in 1979 was 38.4 percent, while the incidence of personal injuries in OCS operations was 23.4 percent.[30] The injury and illness rates per 100 full-time workers in all oil and gas extraction activities totaled 13.9 in 1978, about the same as general manufacturing (13.2).[31] Figure III-4 compares the incidence of fatalities on the Gulf of Mexico OCS with that for the North Sea. The incidence of fatalities is lower in the Gulf of Mexico; however, the incidence of fatalities is declining in the North Sea and holding steady in the Gulf. Table III-15 characterizes Gulf of Mexico OCS accidents involving fatalities by type of operation, type of accident, and (to the extent possible with limited data) cause. The majority of fatalities have occurred in drilling and completing wells. The attributed causes of fatalities appear to be about equally distributed between mechanical failure and human actions. The causal data in the table are not adequate to support exhaustive analysis, but the committee's review of the Geological Survey's Events File indicates that most mechanical failures can be traced to an error in operations or maintenance.

By using workmen's compensation lost-time injury reports, it is possible to compare injury data among various types of OCS activities (Table III-16). Most injuries occur in the "service" category. This group includes such varied and common services as material handling and housekeeping. The drilling category is the other major source of injuries.

Since drilling operations are one of the two major categories of OCS accidents, and since the committee had more reliable data on drilling accidents than on accidents in other types of OCS operations, the committee based its technical analysis of workplace safety on the available data for accidents during drilling operations. The examination of workplace accidents during drilling approaches a worst-case analysis of workplace safety on the OCS.

Comparison of company lost-time accident records reveals substantial differences in levels of workplace safety achieved.[32] In 1978, an average rate of 49 deaths and disabling injuries per million man-hours of drilling operation was reported by the OCS drilling industry. The variability in injury rate among companies was very high, ranging from a low of zero per million man-hours to a high of 200. Year-to-year variability in accident rate is greatest for the small companies operating relatively few drilling rigs. With these companies, the base of man-hours worked is so small that a single unfortunate incident involving several workers can swing the safety record from one end of the scale to the other. Although some companies appear to have policies that directly affect the level of workplace safety achieved, the variability in the data may require observations over several years before the accident-minimizing value



Comparison of Fatalities in the Gulf of Mexico and in the North Sea

Source: Committee on Assessment of Safety of OCS Activities

Figure III-4

TABLE III-15

Gulf of Mexico Accidents Involving Fatalities 1970-1979(1)

By Operation	Events	Percent	Fatalities	Percent
Drilling	55	47	79	42
Completion	15	13	25	13
Construction	2	2	2	2
Production	42	36	77	41
Abandonment	2	2	4	2
By Type of Accident				
Fire/Explosion	14	12	36	19
Machine or Equipment Failure	39	34	51	27
Personal	44	38	44	24
Vessel Mishap	5	4	14	7
Helicopter Crash	4	3	31	17
Blowout	1	1	1	1
Wave	3	3	4	2
Unknown	6	5	6	3
By Primary Cause				
Mechanical	50	43	76	41
Human	47	41	81	43
Natural Event	4	3	5	3
Unknown	15	13	25	13
TOTAL				
	116		187	

(1)The data in this table are not directly comparable to the data in Table III-14.

Source: Committee on Assessment of Safety of OCS Activities, adapted from data in the U.S. Geological Survey Events File.

TABLE III-16

Percent of Injuries by OCS Activity

(1976-1977)

Activity	Percent of Injuries
Service	31%
Drilling	27%
Well Service	14%
Production	11%
Construction	10%
Workover	5%
Other (geophysical, helos, etc.)	2%

Source: U.S. Coast Guard, OCS Safety Project; based on Workmen's Compensation injury data reported on form LS-202.

of those policies can be measured. A small number of companies, approximately 12 percent, have safety records so poor (greater than 140 disabling injuries per million man-hours), that it is probable that their safety standards differ from those of the remainder of the industry.

Elements of Workplace Accidents. The factors that interact to produce a workplace accident, or to mitigate or aggravate its consequences, include the physical environment, the nature of the work activity and equipment, and worker characteristics.

- The Physical Environment. Workplace hazards resulting from the physical environment must be divided into those attending the man-made structure (the drilling or production platform) and the natural environment. The typical offshore platform, semisubmersible, or jack-up rig is a multilevel structure of relatively small area. Operations are carried out on several levels, and members of the crew are required to move from level to level as their jobs require. Decks frequently have access holes to service equipment below deck level. To conserve limited deck space, stairs often have a higher pitch than would be optimum for safety. The hazards are patent. As a consequence, falls represent a major source of injury and the greatest source of fatalities on the OCS.

  The natural environment poses hazards attending extremes of temperature, strong winds, and the like. The marine environment does not seem to make working offshore more dangerous than similar work on land. The statistics compiled by the International Association of Drilling Contractors for 1978 show that the drilling accident rate is nearly 15 percent lower for marine oil and gas operations than for those on land.[33]

  Whereas weather has a small influence on day-to-day workplace safety, it exerts a major influence on the safe landing or loading of personnel and equipment from boats or helicopters. Because of the work cycle on the OCS, almost everyone in the work force makes a round trip to shore every month. Most transportation-related OCS accidents occur in the transfer of personnel or equipment to and from boats in adverse weather or sea conditions (see Figure III-5). Few occur in transit. The heave and pitch of workboats and supply boats also make loading or unloading equipment in bad weather risky. Several fatalities have occurred during unloading operations in bad weather.

- Work Activities and Equipment. Work on the OCS is divided into three major phases: construction, exploration and development drilling, and production. Each phase is characterized by distinct work activities and workplace hazards. The pattern of injuries is different for each phase. These phases, activities, and hazards are set out in Table III-17.

Most Transportation-Related Accidents Occur
in the Transfer of Personnel or Equipment

Source: Shell Oil Company

Figure III-5

TABLE III-17

Hazards Inherent in OCS Work Activities

Phase	Nature of Activity	Human Functions In Workplace	Analogous Shoreside Activities	Probable Safety Hazards	Nature of Injuries	Preventive Actions
Construction	Fabrication and/or assembly of structures on site Installation of drill rigs Removal of structures	Activities related to steel erection; welding, cutting; assembly Heavy lift crane operations Diving	Commercial construction Bridge and tunnel work Shipbuilding.	Falls-most frequent cause of injury Falling objects, bad weather exposure, welding, cutting hazards. Poorly secured scaffolds and temporary structures, crane and cable failure, high population density	Fractures, death from high-level falls Drowning Burns from welding Contusions, and abrasions Sprains, strains Crushing from crane accidents	Early installation of guard rails, nets and safety harnesses Protective head gear and clothing Man-overboard recovery system Crane inspection and cable renewal Safety training of contract personnel
Drilling and Workover	Drilling, logging, fishing, setting casing, cementing, completion, workover operations	Manhandling drill string during tripping Moving casing, setting. Placing, and withdrawing instruments and equipment in well Cementing (contract personnel) Control of well pressure during drilling Blowout diagnosis and prevention Hoist and crane operations	Land based drilling Heavy equipment assembly Foundry work	Struck by objects Caught between objects 80% Falls between levels Slippery drill floors Rotating equipment Exposure, fatigue, long shifts Infrequent, but catastrophic, blowouts Frequent crane load shifts	Injury to extremities Contusions, crushing, abrasions Sprains, strains from moving heavy equipment Fractures from falls	Drill floor housekeeping Proper training of drilling team "Iron Roughneck" guard rails Deck opening barriers Training in blowout prevention Personnel selection, safety training

Phase	Nature of Activity	Human Functions In Workplace	Analogous Shoreside Activities	Probable Safety Hazards	Nature of Injuries	Preventive Actions
Production	Control of product flow from well Degassing Equipment maintenance Production recordkeeping Well maintenance	Monitoring well status Control of well output Recordkeeping Maintenance activities	Process control industries; Chemical plant, refinery	Falls between levels Fire High pressure systems Crane operations by unqualified personnel	Fractures Burns Struck by falling objects	Proper training to maintenance procedures Training in safety consciousness Fire control equipment Fire control training
Transportation/ Facilities Interaction	Transport of workers and equipment to and from site Loading and unloading boats	Moving personnel and equipment from boat to platform Crane operation		Falling from moving surfaces Crushing between boat and landing platform Crane lifts from heaving surfaces Cable and rope failure	Fall- and crush-related injuries Drowning Exposure	Improved facilities for transferring personnel Cable and rope renewal Heave compensation on cranes Safety training of personnel

Source: Committee on Assessment of Safety of OCS Activities

Construction involves the fabrication and assembly of platforms and other structures on the drilling site. It closely resembles shoreside commercial construction and steel erection in the skills used and in the hazards faced by workers. Fatalities in this phase of operations represent 1.1 percent of total fatalities in OCS operations in the Gulf of Mexico. Falls are the single most common cause of injury, followed closely by burns from welding equipment, and injuries from falling objects.

Drilling involves all activities necessary to drill a hole and install casing. Drilling operations are conducted in the exploration, appraisal, and development phases of OCS activities. Drilling is labor-intensive and requires the manhandling of bits, drill pipe, casing, and other heavy pieces of equipment. On occasion, the drill floor exhibits unusual hazards. Some work takes place in the open, unprotected from temperature and weather extremes. Drilling is a 24-hour activity and shifts are 12 hours long. The most common cause of injury during drilling results from being struck by an object, being caught between objects, or being crushed between an object and the rig structure. Observation of a drilling crew at work shows why this is so. When pipe is being tripped in or out of a hole, the crew moves with choreographic precision (see Figure III-6). A crew member can be injured by a moment's misstep or slip. Tongs are the single piece of equipment most likely to cause injury on the drilling floor, accounting for nearly a third of all casualties. Falls are the next major source of injury.

Production involves controlling the flow from wells and processing the oil, gas, and water. It differs from construction and drilling in that the problems of the workplace are common to many industrial activities. Aside from the ever-present danger of falls, the flammable or explosive nature of oil and gas under pressure presents the greatest hazard in the workplace. Of the 187 fatalities in the Gulf of Mexico in the last 10 years, 77 occurred in the production phases.* Review of Geological Survey's accident reports shows a number of injuries related to pressurized parts of the system. Workers are either injured by the failed component or burned by the flash fire consequent to leaking gas. The committee's review of accident data and reports indicates that failure to observe safety precautions when working around pressurized systems (e.g., while welding) is a major precipitating cause of these incidents.

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*Data from Geological Survey events file. These data are not directly comparable to the data in Table III-14.

Drilling Crews Move With Choreographic Precision

Source: Transco Companies, Incorporated

Figure III-6

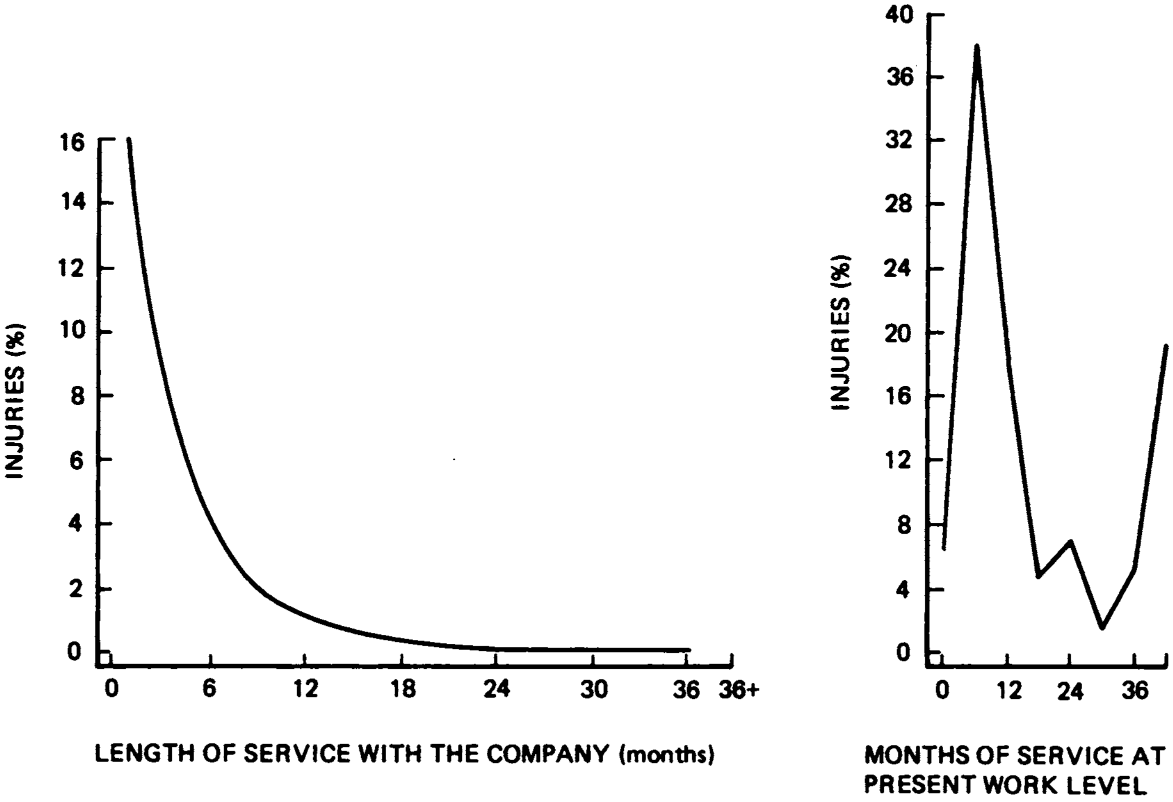
- Worker Characteristics. The problem of workplace accidents is, to a considerable extent, a problem of human characteristics, limitations, and attitudes. There are few working environments so benign that a poorly trained, incompetent, or careless person cannot come to harm himself or those around him. Most analyses reveal that the individual worker plays a significant role in workplace accidents through unsafe acts, tolerance of unsafe conditions, or failure to follow proper operating procedures. The following information emerged from analysis of drilling accident data:[34]

    - 76.5 percent of injuries occurred to employees with less than a year on the job;
    - 54.8 percent of injuries occurred within the first six months of employment;
    - of all job categories, four suffer the most injuries: roustabout, roughneck, derrickman, and driller.

  The entry-level position on most drilling rigs is the roustabout position. As with entry-level positions in many industries, the individual is not required to have experience. Roughnecks (rotary helpers) are normally drawn from the roustabout crews and have experience working on the rig but not on the drill floor. Certain individuals advance the position of derrickman and subsequently to the position of driller.

  Coordination of teams of two to four people is often required. Teamwork is essential to the safety of people, equipment, and materials; yet, teamwork is a learned skill. The rhythm and coordination of the drill floor's work is significant. Many accidents can be attributed to the unfortunate acts of others.

Motivation and Training. Many entry-level workers find the hard rk and long hours on the OCS unacceptable. Consequently, turnover high. Figure III-7 shows that accidents are more likely to happen inexperienced workers than to experienced ones. The essential fference between the inexperienced and the experienced worker is e knowledge of safe practices, which more experienced workers are kely to exhibit.



Relationship Between Injuries and on the Job Experience in OCS Drilling

Source: U.S. Coast Guard

Figure III-7

The most important human factor in workplace accidents is the worker's attitude toward safety: his appraisal of hazardous situations, level of watchfulness, the margin for error he allows in his work, and the level of risk he regards as acceptable. Clearly, the screening and selection of workers is an important aspect of workplace safety. Nevertheless, individual attitudes are difficult to measure and even more difficult to maintain. The operator who has an interest in this attitude can seek to create and maintain safety-consciousness through motivation. Because the worker's attitude is personal, the operator's safety program will only be as successful as the degree to which safety-consciousness is personally motivated.

Safe performance is not an end in itself, but a way to ensure the most efficient and productive work. Training and motivation are integral to each other. Training can be mandated, but its effectiveness cannot be assumed. In contrast, motivation is very difficult to mandate except in the form of compliance to avoid reprisal. In this form, the result is likely to be barely acceptable safety performance, or worse. More impelling and positive motivation is necessary to raise the level of safety above this minimum.

One step toward motivating the use of safe operating practices is to promote thorough understanding of them. This can be handled at the performance (worker) level by training and at the procedural (middle management) level by training and education. At the senior management level, this is almost entirely a matter of education. At all levels, training and or education is necessary for sustained safe performance.

In emphasizing the importance of training, it is important to underscore the fact that training alone cannot serve both as an end and means. The application of training to the task is the desired end and the degree to which training is applied in the workplace is influenced by the manifest philosophy and direction of the organization.

The most important aspect of motivating employees to work safely is demonstrated management interest at all levels. This interest must be credible and constant. Safe performance must be an integral part of the efficient completion of tasks.

Workers respond to three kinds of approval: that of their peer group, their immediate supervisors, and personal satisfaction from attaining personal objectives. The relationship of these types of approval to personal motivation has several implications. The influence of the peer group is often as strong as the boss's word. Safe performance needs the approval of the peer group. Supervisors must insist on safe performance in a positive manner. This can be achieved if company objectives of safe and efficient job performance can be aligned with personal and peer-group objectives of individual recognition, promotion, and good pay.

Adequacy of the Technology. Improvements in the safety of OCS oil and gas operations have historically been achieved through technological advances, the incorporation of those advances into industry-wide standards, and the uniform application of the standards through incorporation into government regulations. Technological areas that have followed this pattern include the design and layout of equipment. Some improvements are being pursued through the advancement of technology; for example, automating particularly hazardous jobs.

An area of operations on the OCS that would benefit from technological improvements, especially safety engineering, is the design and operation of cranes specifically to cope with frequent dynamic, rather than stationary, lifts. Conditions that can be rectified through engineering are the variation in cab design, layout and controls, poor visibility, and cable breakage. The cabs can be redesigned, the controls and layout standardized to best human factors practice, and a schedule can be set for maintenance and inspection. The training of crane operators to a recognized standard of proficiency can also be required and enforced.

Adequacy of Regulations. No single, consistent set of regulations governs workplace safety on the OCS. However, the Coast Guard is currently preparing a set of regulations under the authority of the OCS Lands Act Amendments to address identified workplace safety problems.

Regulations of the Coast Guard generally apply to MODUs, and those of the Geological Survey to fixed platforms. The Coast Guard's regulatory authority over maritime safety, and specifically (under the OCS Lands Act, P.L. 83-212; 67 Stat. 462) for the safety of life and property on offshore structures, finds expression in regulations for fixed platforms governing fire extinguishers, guard rails, and illumination of helicopter landing areas. A summary of the pertinent regulations is given in Table III-18.

The regulations make frequent reference to industry standards and recommended practices. The history of offshore oil and gas operations and the regulations that govern them evinces the following pattern. Technology and safety improvements have been initiated by the commercial sector. The use of the improvements provides a basis and impetus for the development of a relevant standard. Industry-recommended practices and standards have been incorporated into regulations. The general provisions of Geological Survey and the Coast Guard regulations requiring "maintenance of safe and workmanlike conditions," and "operations...conducted in compliance with occupational safety and health regulations, and free from recognized hazards," act in concert with industry-wide standards to mandate a basic level of compliance. Even though responsible operators may exceed this levels of compliance, the existing influences on offshore safety are inadequate to raise the level of the companies exhibiting the lowest safety performance, as evidenced in the analysis of accident data presented earlier in this section.

Table III-18 indicates that the regulations do not comprehensively address the subject of worker training and qualification with regard to workplace safety. The regulations have been much more

TABLE III-18

Workplace Safety Regulations Governing Oil and Gas Operations on the Outer Continental Shelf

	Fixed Platforms		Mobile Drilling Units (MODUs)
Workplace Safety Condition	U.S. Coast Guard	U.S. Geological Survey	U.S. Coast Guard
Drill Floor	No	No	No
Material Handling	No	No	46 CFR 58.60-1(f)--Part of plans and specifications submitted for approval
Supply Boat	No	No	No
Pipe Rack	No	No	No
Forklift	No	No	46 CFR 109.529--Designates types for use in certain areas
Helicopter Decks	No	No	46 CFR 108.231, 108.421 --Specifies size, clearance, loadings, surface, drainage, etc.
Fueling	No	No	46 CFR 109.577--Only by designated person familiar with fueling and safety procedures
Machinery Spaces	33 CFR 145--Number, types, and locations of fire extinguishers	OCS Order 5-5.1.5 --Engine exhaust insulation and personnel protection to comply with API standard; exhaust piping from diesel engines equipped with spark arresters	46 CFR 108.187--Ventilation for brush-type electrical motors, NFPA standard
Mud Room	No	No	No
Subdeck Under Drill Floor	No	No	No
Personnel Transfer	33 CFR 143--landings to be illuminated	No	No
Chemical Exposure	No	No	No
Tools	No	No	No
Electrical Shock	No	No	46 CFR 111.92-3--Only intrinsically safe, approved electrical equipment installed in designated semi-enclosed spaces
Machinery	No	No	46 CFR 58.10-10-15--Neither air inlet nor exhaust in enclosed spaces, semi-enclosed spaces, nor near possible sources of discharging gases (drill floor), as specified

TABLE III-18 (cont'd)

Workplace Safety Regulations Governing Oil and Gas Operations on the Outer Continental Shelf

	Fixed Platforms		Mobile Drilling Units (MODUs)
Workplace Safety Condition	U.S. Coast Guard	U.S. Geological Survey	U.S. Coast Guard
High-Pressure Piping	No	OCS Order 5-5.1.2 --All flowlines from wells to be equipped with high- and low-pressure shut-in sensors, API standards	46 CFR 58.60-1(g), 58.60-7 --Must meet ANSI standards
Pressure Vessels	No	OCS Order 5-5.1.1--In accordance with ASME Code	46 CFR 60-3--Must meet standards of Coast Guard, including ASME Code
Hazardous Materials	No	No	46 CFR 109.557, 109.559 --Flammable liquids, explosives, radio-active materials may not be carried in bulk, unless allowed by Certificate of Inspection, then only in accordance with specifications; used only as authorized by person in charge
Production Systems	No	OCS Order 5-4--Design, installation, and operation of surface production systems, existing and new platforms in accordance with API standards and National Electrical Code; OCS Order 5-5.7--Training in use of safety devices meeting API standard, documentation of training	No
Cranes	No	OCS Order 5-7	46 CFR 107.258, 108.601, 109.527*
Derrick	No	No	46 CFR 58.60-9--Designed and analyzed by reference to API standard
Personal Protective Equipment	No	No	46 CFR 109.334--Must wear life-preservers or buoyant work vests when working over water; 46 CFR 108.703 --Each unit must have self-contained breath apparatus in case of gas leaking from refrigeration unit

TABLE III-18 (cont'd)

Workplace Safety Regulations Governing Oil and Gas Operations on the Outer Continental Shelf

	Fixed Platforms		Mobile Drilling Units (MODUs)
Workplace Safety Condition	U.S. Coast Guard	U.S. Geological Survey	U.S. Coast Guard
Gases and Vapors	No	OCS Order 2-8 --Drilling operations that will penetrate known reservoirs of hydrogen sulfide will employ procedures and practices specified in USGS standards	46 CFR 108.703 (see above, refrigeration gases)
Rails, Ladders, Access	33 CFR 143.15--Guards or fences around all floor and deck perimeters and openings; rails on all stairs and catwalks	No	46 CFR 108.217, 108.223 --Specify location of bulwarks, rails, ladders
Training	No	OCS Order 5-8 --Orientation and motivation programs for employees going offshore recommended by referenced API standards	No
General	33 CFR 142.1--Persons responsible shall ensure that operations are conducted in compliance with occupational safety and health regulations, and are free from recognized hazards (proposed)	30 CFR 250.56--Lessee will perform all operations in a safe and workmanlike manner	33 CFR 142.1--Persons responsible shall ensure that operations are conducted in compliance with occupational safety and health regulations, and are free from recognized hazards (proposed)

Abbreviations:
ANSI--American National Standards Institute
API --American Petroleum Institute
ASME--American Society of Mechanical Engineers
NFPA--National Fire Protection Association

Source: Committee on Assessment of Safety of OCS Activities

successful in ensuring the use of adequate technologies than in ensuring that workers, particularly entry-level workers, are properly trained in safe practices.

Diving.*[35]. Despite the domination of oil field work in the diving industry, the diving population on the OCS is small--probably fewer than a thousand. During the winter months, the number of working divers may fall as low as 25.

When petroleum operations were concentrated in shallow water (the majority still are), divers could maneuver freely and manipulate equipment adapted from land operations to perform tasks underwater that a roughneck would perform on land. Because of the relative ease of diving operations in shallow water, underwater equipment and systems were designed to take advantage of divers' abilities to maneuver and to manipulate equipment.

Deep water, with attendant higher pressures, is a far more complex diving environment. While techniques have been developed to enable divers to perform tasks in deeper water, the safer course (and it has largely been followed) is the development of equipment that does not rely on divers for installation and operation. There are no tasks in exploration or production that are necessarily dependent on diving, provided that the systems are designed around diverless technologies.

Diving in support of petroleum operations employs techniques and procedures common to other diving operations. The sole diving practice that is peculiar to the offshore oil fields is "live-boating"--diving from a boat that is underway for pipeline inspections or other purposes where the diver must move well beyond his umbilical reach from a fixed station. Regulations on "live-boating" have been issued by the Department of Labor and the Department of Transportation. An activity related to "live-boating" is diving from dynamically positioned vessels. This has not yet been done on the OCS, although it is common in the North Sea.

Safety in diving is sound business practice. Diving companies with high accident rates are unlikely to maintain their customers when diving accidents frequently shut down offshore operations.

Most diving accidents involve some degree of human error. However, it is difficult to discern specific causes of accidents and to learn lessons from them because there is no center for the collection, analysis and utilization of diving safety information, including the systematic investigation of accidents.

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*The OCS Safety Study of which this report is a part was mandated by Section 21(a) of the OCS Lands Act Amendments of 1978. Section 21(e) of the Act called for a separate investigation of the safety of diving. The diving study is being carried out under entirely separate auspices. This discussion treats only aspects of diving that are unique to OCS operations.

Workplace Safety Considerations in Frontier Areas. Exploration, drilling, and production operations in the frontier areas of the OCS will face more hostile environments than those of the Gulf of Mexico and the Pacific. Many companies now operating in the U.S. have North Sea experience that can be applied to these new operations. The regulatory agencies, however, have had little operating experience with oil and gas operations in these areas. Some of the activities of the Coast Guard and the Geological Survey in the North Atlantic and Alaska will be pertinent. Design and human-factors criteria for hostile environments have been acquired in the military services and other agencies of the government. This expertise and experience can be drawn on in regulating the safety of oil and gas operations in frontier areas.

Operations initiated in frontier areas of the OCS will, of necessity, be high-cost, high-technology ventures. Opportunities and incentives to enhance their safety will be manifest in every stage of design, testing, and installation. The principal challenge for the operators will continue to be development of the administrative practices adequate to safe and effective management.

Improving Workplace Safety. There are three approaches to improving workplace safety: engineering, personnel selection and training, and motivation. In each of these, a solid base of data can facilitate improvement. Furthermore, regulations can encourage safety improvements by setting objectives of performance and initiating enforcement practices directed toward their achievement. Finally, companies can initiate new safety programs specifically designed to achieve certain objectives to improve their safety performance.

- Better Data and Analysis. The incompleteness, inadequacy, and tentative state of workplace safety data hobbles efforts to pinpoint hazards and the underlying causes of workplace accidents. One reason for the present state of the data is the number of agencies and organizations that collect data for different reasons (and thus by different conventions and categories) and that array and publish them in non-comparable units.

- Encouraging Safety Through Regulations. The regulatory agencies currently have little capability to identify companies whose level of safety falls far behind that of most other offshore operators. Nor have they devised approaches to improve the safety performance of those companies and to ensure that workers are trained and safety-conscious. While the historical pattern of industrial development and regulatory application of standards and specifications has been effective in improving (and maintaining) the over all record of safety in operations on the OCS, this pattern has been more successful in ensuring the use of adequate technology than in ensuring the use of best practices. Action toward these two ends is most appropriately initiated by the companies themselves. Regulatory agencies can encourage these actions by setting acceptable levels of safety performance and by aligning enforcement activities to constitute a clear system of rewards for meeting or exceeding these levels and punishments for falling short.[36]

Company Safety Programs. Of the three approaches to improving workplace safety mentioned previously, the first is safety engineering: modifying the equipment or the workplace to eliminate hazardous conditions or injury-producing agents, as described briefly in the analysis of crane operations. Thus, if falls represent a major source of injury, their frequency can be reduced by providing guardrails or their effects can be attenuated by the use of nets or safety harnesses. Experience shows that a safety engineering program can reduce workplace-related injuries to about 50 percent of their unengineered level.[37] However, safety devices begin to lose their efficiency when they get in the way of work, and employees find ways to circumvent them to get their work done. Considering the advanced state of safety engineering on the OCS, there is no guarantee that extensive additional safety engineering in OCS operations would produce significant safety improvements.

The second avenue to reduction of workplace accidents is appropriate screening and selection of personnel. Although the concept of "accident proneness" has lost favor in recent years, it is a fact that some workers simply have more accidents than others. In the merchant marine, some men may have more than 10 times the accidents others have for exposure to the same risks.[38] While bad luck may be the major factor for some of these men, it may be that many of the others suffer more accidents by virtue of some combination of physical characteristics, personality, and attitude. Identification of these individuals can help reduce workplace accidents by excluding them from potentially hazardous job situations or targeting them for retraining.

The third method of improving workplace safety has been termed the motivational approach. The assumption of this approach is that workers must be motivated to behave safely and they must perceive the reasons for prudent behavior in the workplace. Common sense would suggest that protection of life and limb would be sufficient reason for workers to behave safely, but this is not the case. The survival motive loses force as workers take chances and accidents do not result.

It may be that the work commonly required in oil and gas operations on the OCS offers satisfying physical effort and coordinated teamwork very much like competitive sports. Safety goggles, ear protectors, and special safety equipment are cumbersome and inhibitive. The motivational approach to safety attempts to change workers' preferences and satisfactions by encouraging them to identify unsafe practices and behavior and suggest their own safer solutions. Safety is put on a competitive basis, and rewards--immediate and direct--are offered for accident-free periods. Feedback and reinforcement are offered whenever possible to encourage safety. This technique is effective and positive, but very fragile. It requires firm and continuing commitment from the highest levels of management and a well-worked-out plan that reaches the entry-level worker.

There is no single ideal way to enhance workplace safety on the OCS. Engineering is effective, but eventually self-limiting. The personnel approach entails the institution of a separate record-keeping agency and considerable research. The motivational approach requires high-level commitment and constant attention by management and supervisory personnel. These three approaches are neither exclusive nor exhaustive, some combination may prove efficacious.

Findings and Recommendations on Workplace Safety

Workplace safety on the OCS is an area of concern, but not one easily improved by legislation or detailed regulation. Work on the OCS appears no more hazardous than in similar industries ashore. This does not mean that improvements in workplace safety cannot be achieved nor that regulatory agencies should not be concerned.

Both the Geological Survey and the Coast Guard require the reporting of lost-time injuries and fatalities that occur in OCS operations. Industry keeps workplace safety statistics as well. These data are collected for different purposes, and the methods of collection and format of presentation vary. This results in workplace safety data that are neither consistent nor comparable between data banks. Also, the data are not necessarily comparable to that of other industries, such as mining and shipyard construction, with which safety comparisons could be useful.

> The Coast Guard and the Geological Survey should coordinate and strengthen the collection of workplace data. A single accident-reporting form collected by a single agency could provide the kind of information needed to gain better understanding of the causal factors and characteristics of workers that could lead to improved safety.

Current technology and engineering systems now in use on the OCS appear to provide adequate workplace safety. Most of the improvement in safety that can be achieved by engineering has already been accomplished. The principal item in improving workplace safety is not technology, but improvement in personnel performance.

In drilling operations, entry-level workers account for more than 70 percent of lost-time accidents, and these typically occur within the first six months of employment. In the experience of the committee, this pattern is similar to that of other industries and typical of other operations on the OCS.

The application of effective workplace safety practices by responsible companies has provided a favorable overall safety record, even though there is no single, comprehensive set of federal regulations being applied specifically to workplace safety on the OCS.

Although some companies exhibit a level of safety performance substantially below the industry average, existing regulations and enforcement practices do not provide a means readily to identify the companies exhibiting the lowest safety records and target the companies for closer scrutiny to improve their safety performance.

The available data show few qualitative or quantitative differences between North Sea and Gulf of Mexico experience. The committee has found no evidence that more hostile physical environments or more difficult operations, by themselves, lead to more accidents. However, they may indicate a need for special measures —protective gear, general procedures, training, supervision, and personnel selection. The knowledge required to ensure workplace safety in extreme environments is already in hand in the cumulative experience of the oil industry and the military services. There is no evidence that additional regulations regarding workplace safety are needed for frontier areas nor that major developments in workplace safety technology are indicated.

Fires and Explosions

The nature of the enterprise on the OCS makes fires and explosions an ever-present threat. These accidents can be divided into two categories by cause:

- Fires and explosions incident to blowouts.* A blowout is the uncontrolled release of fluids or gas from the well. Blowouts are integrally related to the loss of well control. The attendant releases of pressure, leaking gases, and large volumes of complex hydrocarbons that might ignite pose the hazard of potentially catastrophic explosions and fires.

- Operational fires and explosions. The association of fuel and combustibles (from any source other than an uncontrolled well) with a source of ignition in the presence of oxygen causes fires and explosions that are for convenience are called "operational" to distinguish them from those attending blowouts and to indicate their origin in human error, equipment failure, or design. These may be so minor that neither equipment nor the workforce is affected or as catastrophic as those incident to blowouts.

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*The division of subjects into separate areas of concern limits this section to analysis of fire and explosion aspects of blowouts. The need to maintain well control, and other aspects of blowouts, are analyzed elsewhere.

Fires and Explosions on the OCS. The principal source of data on fires and explosions in oil and gas operations on the OCS is the events file maintained by the Geological Survey. Regulations require that the Geological Survey be notified immediately of all fires. A full written report must be filed within 10 days. Compliance with this requirement has established a solid data base for the total number of fires and explosions in these operations and for general trends in their incidence. Fires and explosions on MODUs must also be reported to the Coast Guard if they cause more than $5,000 damage, affect the seaworthiness or operating efficiency of the vessel, result in loss of life, or result in injuries requiring 24 hours or more of hospitalization or 72 hours or more of recuperation. The reports are entered in the Coast Guard's casualty file. The Geological Survey and the Coast Guard investigate and file reports on major casualties. These provide additional detail on the causes and effects of fires and explosions.

From 1970 to 1979, 278 fires and explosions occurred in oil and gas operations on the OCS. The record of fires and explosions in the Gulf of Mexico for the period 1970-1978 is illustrated and described in Figure III-8 (270 of the 278 incidents on the OCS occurred in this area). The 270 fires and explosions reported in the Gulf of Mexico over this period resulted in a total of 42 fatalities (about 22 percent of the total fatalities in this region) and 188 injuries.

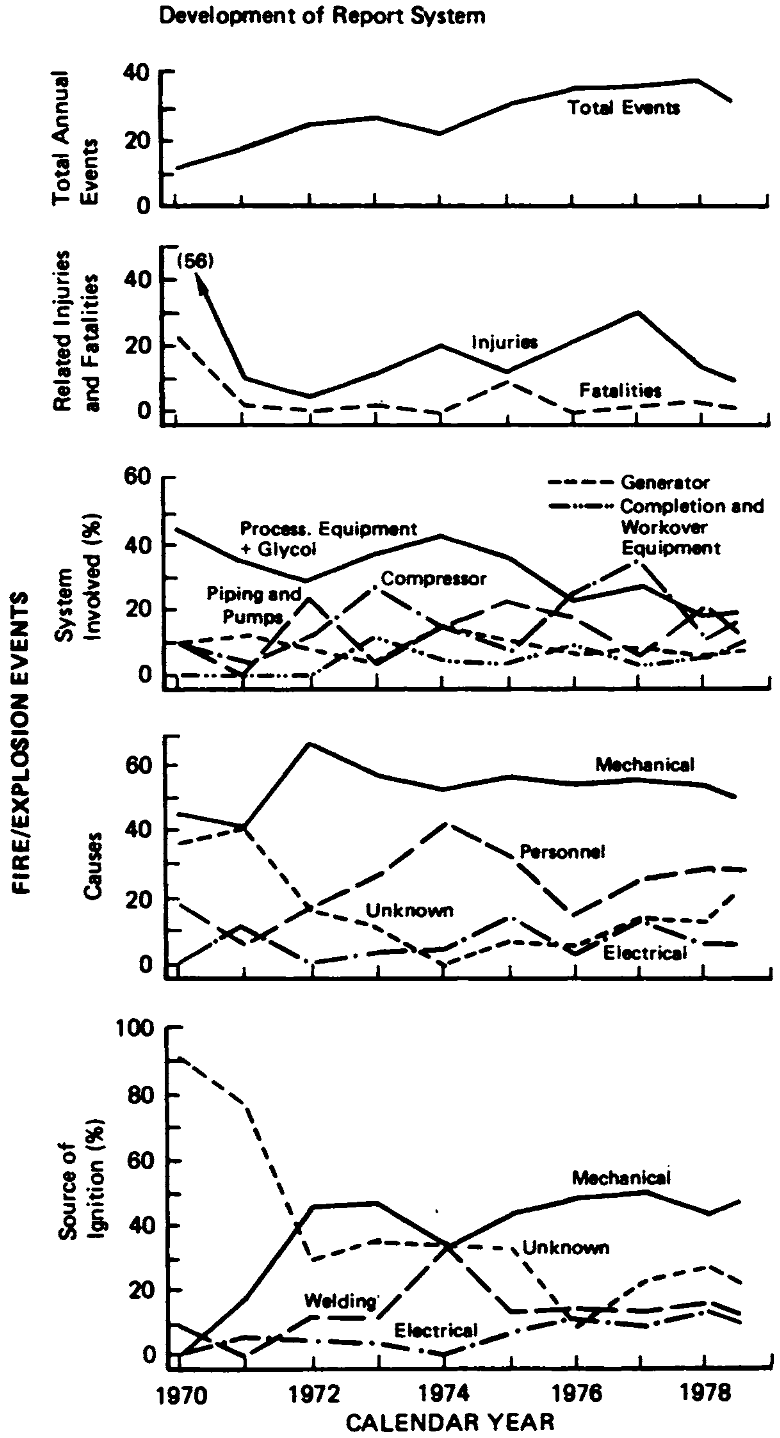
Over the period 1976-1979 (for which numbers of facilities are available), the number of fires and explosions increased about 3 percent a year. During the same period, the number of working drilling rigs increased at a rate of about 15 percent a year, that of complexes by 4.4 percent a year, and total structures by 4.9 percent a year. From 1970 to 1979, the number of wells completed rose from 5,584 to 9,140. Thus the rate of fires and explosions shows a level or slightly declining trend.

The majority--261 fires and explosions--occurred on fixed platforms, and 231 occurred during production. Although fixed platforms are used for both drilling and production, their principal use is in production, where large volumes of hydrocarbons are always present. Nearly a third of the fires and explosions that occurred during production were associated with processing equipment and glycol systems.

The second most frequent cause of operational fires and explosions is the entrapment of natural gas in enclosed spaces, especially while drilling.

One half to two thirds of all fires and explosions are attributed to equipment or mechanical failure, and the remainder are attributed to human factors, principally errors of judgment. The interaction of the causal factors that contribute to any fire or explosion and the severity of the resulting consequences is unclear.

The rate of occurrence of fires and explosions in the U.S. is very low compared with that of the North Sea: Norway (1976 to 1978) 1 event per .76 complex-years; U.S. (1977 to 1979) 1 event per 49 complex-years.[39] One reason for the disparity in incidence of



Fires and Explosions in the Gulf of Mexico (1969-1978)

Source: Committee on Assessment of Safety of OCS Activities

Figure III-8

occurrence is that North Sea complexes often have enclosed workspaces for protection against frequently inclement weather, whereas in the Gulf of Mexico open workspaces prevail. The enclosed workspaces apparently provide traps for the accumulation of combustible gases.

The data on fires and explosions are specific enough to draw conclusions about the items of equipment or mechanical failure that repeatedly contribute to fires and explosions, but not specific enough to reveal the human element that might have been involved.

Fire and Explosion Hazards in OCS Operations. In simple terms, the completion of the fire triangle--fuel, a source of ignition, and oxygen--is necessary and sufficient for a fire or explosion. The elimination or separation of one (or more) items of the triangle is essential to preventing fires and explosions. This is particularly difficult on the platforms and mobile drilling units of the OCS, where space is at a premium and oil and gas are often present. Lightning (the agent of seven fires and explosions in the Gulf of Mexico over the past ten years), the equipment (internal combustion engines, arcing electrical devices), the systems (hot exhaust pipes), and the workers (careless welding or smoking) all represent sources of ignition. The sometimes unavoidable but often inadvertent proximity of fuel and ignition sources on offshore drilling and production units makes some areas hazardous. Areas of fire and explosion hazard, with the sources of fuel and ignition particular to each, are cataloged in Table III-19.

The most common fire hazard in drilling is entrained gas. Throughout the entire path of up hole flow, any entrained gas is released to the atmosphere. Whenever gas is anticipated, a degasser is put on line to remove most of the gas. Degassers are most frequently used before the drilling fluid and cuttings enter the shale shaker and desander in the mud room. Control of the entrained gas consists of safe venting of the degasser and liberal ventilation of the mud room. However, meteorological changes can cause vented gas to collect in areas that are ordinarily gas-free. To guard against unanticipated gas concentrations, both the Coast Guard and the Geological Survey designate certain areas as hazardous. These include mud rooms, the drill floor to a height of three meters, areas below the drill floor within three meters of a possible gas release, and any area connected with the above that may accumulate gas. Within these areas, ignition sources must be minimized by various means, including no smoking in the area; low-tension ignition systems for internal combustion engines; intrinsically safe electrical controls (i.e., non sparking); no welding, cutting, or grinding; shipboard-type marine electrical cables; and positive-pressure ventilation when sparking cannot be prevented.

The same hazards present in drilling operations are present in production. One increased hazard is that oil and gas, though contained, are continually flowing in production operations. Another hazard unique to production is that of fire in glycol-dehydration systems. Natural gas flowing from the well is passed through liquid

TABLE III-19

Areas of Fire and Explosion Hazards on OCS Installations: Fuel Sources and Sources of Ignition

Areas of Hazard	Fuel Source	Ignition Source
Quarter Buildings	Gas Utilities Random Gas Combustible Materials	Hot Burners Gas Range Flames Smoking Arcing Devices
Welding Areas	Random Gas Oil in Drip Pans Leaking Gas or Oil	Welding Cutting
Gas Vents (Unlit)	Vented Gas	Lightning Static Electricity Helicopters
Wellhead Areas	Bleeding Gas Blowdown of Wells	Sparks Internal Combustion Engines
Enclosed Areas	Gas Instruments Gas Leakage Gas Utilities	Arcing Devices Internal Combustion Engines
Construction	Oil and Gas in Lines Oil and Gas in Vessels Random Gas	Welding Cutting Portable Generators Welding Machines Smoking (Untrained Crews)
Compressors	Random Gas Lube Oil Leaks High-Pressure Gas Leaks	Hot Pipes Internal Combustion Engines Sparking
Motor Control Testers	Random Gas	Arcing Devices
Microwave Building	Random Gas	Arcing Devices
Generator Buildings	Fuel Gas Lube Oil Leaks Random Gas	Internal Combustion Engines Hot Pipes Arcing Equipment
Pumps	High-Pressure Oil Leaks	Internal Combustion Engines Hot Pipes
Tanks	Tank Vapors	Helicopters Lightning Static Electricity
Drip Pans	Pooled Oil	Sparks Welding
Unkept Storage Areas	Rags	Spontaneous Combustion
Trash Bins	Trash	Sparks
Electrical Tools	Random Gas	Arcing Devices
Helicopters	Random Gas Tank Vapors	Engine
Shop Areas, if any	Combustible Materials	Power Tools, Grinding, Welding

Source: Committee on Assessment of Safety of OCS Activities

glycol to remove entrained moisture. The wet glycol is heated to evaporate water and recycled. Any failure of the relief valve in the glycol system can result in overpressure. When this occurs, hot glycol can ignite. Glycol fires can usually be extinguished early, but they also serve as an extra ignition source for leaking natural gas.

Preventing Fires and Explosions. The prevention of fires and explosions is a prime consideration in the design, construction, and operation of offshore installations and units. The following steps are fundamental: complete engineering design and specification, including classification of hazardous areas; reliable equipment components; correct fabrication and installation; complete testing; rigorous inspection; adequate operating procedures; preventive maintenance; and proper repair and replacement. The elements of fire and explosion are brought together in the improper execution of these fundamentals.

Specific measures directed against all elements of the fire triangle are incorporated in platforms and mobile drilling units. Table III-20 describes typical fire prevention measures for sources of ignition. Table III-21 describes prevention measures for areas of hazards. These tables reflect existing practice in the offshore industry. Some of this practice has been developed to comply with regulations; other aspects reflect good engineering practice or common sense. Mobile drilling units incorporate additional protective requirements promulgated by the Coast Guard for seagoing vessels. In reviewing these ignition sources and the preventive measures attendant to them, it is important to recognize that some ignition sources, such as helicopters, boats, and lightning, can neither be modified nor eliminated. Preventive measures cannot completely eliminate hazards of fire and explosion; rather, they minimize risk, reduce exposure to hazards, or both.

Regulatory Analysis. The regulation of protective measures against fires and explosions at sea follows a pattern of research and standard-setting by professional organizations and federal agencies, testing by equipment suppliers and operators, and incorporation of the results of these activities into government regulation.[40] An additional element in the regulation of fires and explosions in operations on the OCS has been the continuing efforts of industry to improve the technology of well control (described separately), that of drilling and production systems, to minimize the potential and consequences of operational fires and explosions.

The Coast Guard is responsible for the regulation of structural fire protection, fire prevention, fire fighting, and training on MODUs and for the safety of life at sea on both fixed and mobile units (described below). The Geological Survey is responsible for fire prevention, fire fighting, and training for well control at the wellhead and on fixed platforms. The regulations developed by both

TABLE III-20 Fire and Explosion Prevention Measures Directed to Ignition Sources

Ignition Sources	Preventive Measures
Equipment	
Internal Combustion Engines	Spark-arresting mufflers Low-tension ignition systems Air starters
Direct-Fired Equipment	Fire wall separation Optimum location away from gas sources Forced-draft air feed Waste heat recovery alternate Explosion-proof housing
Arcing Devices	Hermetic seals (and low voltage) Pneumatic versus electric Pressurized enclosures
Sparkling	Restricted areas of use Proper sealing
Human	
Smoking	Confined to quarters building Banned on rig or platform floor
Welding	Restricted to safe area Strict procedures for use
Systems	
Hot Pipes	Insulation
Lit Flares	Location restricted

Source: Committee on Assessment of Safety of OCS Activities

TABLE III-21 Fire and Explosion Prevention Measures Directed to Areas of Hazards

Area of Hazard	Preventive Measure
Quarters Building	Use of all-electric utilities Positively pressured Structural fire protections specified
Welding Areas	Fire walls Optimum locations Safe procedures
Gas Vents (Unlit)	Optimum locations Water spray Air dilution
Wellhead Areas	Piped blow downs
Enclosed Areas	Gas detectors Air pneumatics Positive procedures
Construction	Safe procedures Work plans and permits
Compressors	Insulated exhausts and lines Gas detectors
Motor Control Centers	Pressurized buildings
Microwave Buildings	Gas detectors
Generator Buildings	Insulated exhausts and lines Pressurized buildings
Pumps	Pulsation dampeners
Tanks	Optimum location of vent
Drip Pans	Adequate procedures
Unkempt Storage Areas	Adequate procedures
Trash Bins	Adequate procedures
Electrical tools	Limited use Full grounding
Heliports	Optimum location

Source: Committee on Assessment of Safety of OCS Activities

agencies in the exercise of these responsibilities make frequent reference to consensus standards. These standards, in turn, fre- quently refer to equipment approved by professional organizations and federal agencies such as the National Bureau of Standards.

The regulations governing fire extinguishing systems are listed in Table III-22. Fire sensing devices, heat, smoke, and flame detec- tors, are required (OCS Order 5 (Gulf of Mexico)). Table III-23 lists the requirements that pertain to structural fire protection.

Coast Guard regulations governing fire prevention on MODUs are more numerous, specific, and detailed than those of the Geological Survey for fixed platforms. Nevertheless, the close, parallel development of regulation and standard-setting for fire prevention and containment, and the keen interest of all parties in preventing fires and explosions, has manifested itself on the OCS shelf in generally expeditious application of available and emerging technology.

Indeed, complaints have been voiced against the Coast Guard's failing to approve a new development operators want to use. There is regulatory redress for these situations, but it has not been ade- quately explained to industry. Operators who have set the admin- istrative process in action for special approval have in many instances found it too lengthy to be useful.

An important point in considering the effectiveness of fire protection regulations is that their effectiveness in at least two important areas-structural fire protection and training--is con- tingent upon enforcement practices. Both agencies require operators to submit plans and specifications for approval. The review for structural and installed fire protection constitutes perhaps the most crucial aspect of regulatory responsibility in this area.

Regulations requiring training in the prevention and mitigation of fires and explosions are set out in Table III-24. Both the Coast Guard and the Geological Survey require training in fire fighting and emergency procedures at sea (the latter is discussed in the under "Emergencies" section), but these regulations are stated in general terms and enforcement procedures are usually limited to checking logs for the required number of drills. The annual Coast Guard inspections include witnessing drills. These regulations are less stringent than those governing the training of personnel in well control, the latter set of regulations requires training in approved schools, hands-on experience, certification, and periodic refresher courses. Because it is such an important concern offshore, some operators offer safety training in excess of what is required. The most popular courses offered are these on fire fighting and survival at sea.

Adequacy of the Technologies. The written regulations and enforcement practices pertinent to the prevention and containment of operational fires and explosions on the OCS have acted in concert with the efforts of industry and professional associations to ensure

TABLE III-22

Fire-Extinguishing Systems Required by Regulations for Operations on the Outer Continental Shelf

Area	Platforms	Mobile Drilling Units
General	Firewater system, rigid pipe, firehose stations, API standard, OCS Order 5-5.1.8	Fire main system, 46 CFR Ch. I, Subpart D
Production-handling equipment	" " "	" " "
Drill floor	" " "	" " " plus two portable extinguishers
Gas - and oil-fired boilers	Portable extinguishers, CO_2 or dry chemical, 33 CFR 145 (enforced by Coast Guard)	Fixed CO_2 system; two portable extinguishers (CO_2 or dry chemical), one extinguisher in each space for electrical fires, 46 CFR Ch. I, Subpart D
Corridors	Portable extinguishers, water 33 CFR 145	Portable extinguishers, water 46 CFR, Ch. I, Subpart D
Quarters	" " "	" " "
Radio room	Portable extinguisher for electrical fires, 33 CFR 145	Portable extinguisher for electrical fires, 46 CFR Ch. I, Subpart D
Galleys	Portable extinguishers, CO_2 mechanical foam, 33 CFR 145	Portable extinguishers, CO_2 or mechanical foam, 46 CFR Ch. I, Subpart D
Electric motors or generators	Portable extinguishers for electrical fires, 33 CFR 145	Portable extinguishers for electrical fires, 46 CFR Ch. I, Subpart D
Helicopter landing decks, fueling facilities		Portable extinguishers, CO_2 or mechanical foam, 46 CFR Ch. I, Subpart D
Cranes	(recommended by referenced standard, portable CO_2 or mechanical foam extinguishers)	" " "
Miscellaneous		Fireman's outfits and fire axes, 46 CFR Ch. I, Subpart D

Source: Committee on Assessment of Safety of OCS Activities

TABLE III-23

Regulations Requiring Structural Fire Protection

Fixed Platforms	Mobile Drilling Units
U.S. Geological Survey	U.S. Coast Guard
Plans must meet standards of Platform Verification Program, approval of certified verification agent, and district supervisor. Installation and construction also subject to Platform Verification Program and approval. OCS Order 8 and supporting documents setting out standards and procedures.	Plans must meet detailed specifications for hull superstructure, structural and boundary bulkheads, separations, accomodation spaces, hatches and tonnage openings, etc., and tonnage openings, etc., approval of Coast Guard. Ship must pass inspection and certification procedures. 46 CFR Subchapter I-A.

Source: Committee on Assessment of Safety of OCS Activities

TABLE III-24

Drills and Training Required in Fire Prevention and Firefighting

Fixed Platforms	Mobile Drilling Units
Employee orientation and motivation programs for personnel working offshore--references API recommended practice recommending fire prevention and fighting training; lists schools. OCS Order 5-8 (USGS)	Fire drills--at least once a week, all personnel must report to fire stations, bring out rescue and safety equipment, start each fire pump. 46 CFR 109.213 (USGS)
Emergency drills--once monthly. 33 CFR 146.05-25 (USCG)	Fireman's outfits--at least two people on board must be trained in their use. 46 109.337 (USCG)

Source: Committee on Assessment of Safety of OCS Activities

adequate technology fore fire and explosion protection on the OCS. The pattern of mutual interest has been far less successful in ensuring that workers are trained in the use of fire-fighting technology and the best prevention practices (with the exception of those pertinent to well control). This is borne out in a major study conducted for the Coast Guard that found the technology adequate, but the training inadequate, and recommended that offshore workers receive shore-based fire-fighting training.[41] This gap, if left unattended, will widen with the introduction of more complicated systems and equipment and the innovations that ongoing research and development are bound to produce.

Fires and Explosions in Frontier Areas. As oil and gas operations on the outer continental shelf move into the North Atlantic and Arctic, the environment will preclude some of the design features common to installations in the Gulf of Mexico and the Pacific. As in the North Sea and domestic operations in Cook Inlet, Alaska, offshore installations in frontier areas are likely to have more enclosed spaces than those in the Gulf. Thus, the hazard of gas entrapment is likely to be greater. Furthermore, fighting fires in enclosed spaces demands different extinguishing equipment and techniques from those used on open platforms. Another consideration in cold regions is the limited utility of water-based fire-fighting systems. Structural fire protection and detection systems are likely to be important in frontier operations.

Findings and Recommendations on Fires and Explosions

Findings and recommendations on fires and explosions are grouped with those concerning abandonment of OCS installations. They are located at the end of the next section.

Emergencies Requiring the Abandonment of OCS Installations.

Whether because of fire, explosion, blowout, catastrophic structural damage, or in advance of a major storm or hurricane, OCS workers must occasionally abandon OCS installations in emergency conditions. Abandonment of a facility becomes necessary when prevention, control, and protective systems fail and loss of life is imminent. Abandonment of a mobile drilling unit or fixed platform on the OCS entails leaving one life-threatening situation for another. Workers must effect a safe transfer from a relatively motionless structure to a constantly moving sea, and their lives must be safeguarded until they are rescued.

The Coast Guard has collected data on fatalities suffered in abandonment of ships and offshore installations (Table III-25). Relative to ship crews, workers abandoning offshore installations have a high survival rate.

TABLE III-25

Fatalities During Abandonment
1971 - 1973

	No. of Persons Onboard	No. of Persons Abandoning	No. of Persons Lost	Fatalities/ Abandonment (%)
Ships (Freighters, tankers, barges)	177	145	14	10%
Offshore Installations (MODU's and fixed platforms)	223	222	9	4%

Source: Adapted from the Stanwick Corporation, "Shipboard Training and Maintenance for Merchant Vessel Survival Training," U.S. Coast Guard Office of Research and Development, Report No. CG-M-1/80, Arlington, Virginia, 1979.

A Coast Guard review of abandonment casualty reports indicated that in 51 percent of the cases people jumped, but that when life rafts were used more lives were saved.[42] Jumping overboard was relatively more prevalent in abandoning fixed platforms or mobile drilling units than in abandoning vessels. In 17 marine casualties (12 ships and 5 drilling units) involving 6 fires and explosions, 8 sinkings, and 13 abandonments, the following were apparent: inadequate abandonment and survival training, poor assignment responsibilities for emergency response, confusion about the chain of command, and lack of leadership.

Abandonment Technologies. In the 1960's, growth in OCS activities and tanker traffic and the resulting increased hazard of fire on the sea created a need for fire-resistant, covered lifeboats. The result is the survival capsule--a self-righting, completely enclosed, self-propelled abandonment and life-support vehicle. Survival capsules are capable of protecting up to 52 people and maneuvering out of burning oil on the water. Capsule technology continues to evolve. Only two years ago, the Coast Guard approved the first inflatable survival capsule capable of davit launch.

Personal flotation and survival devices have also been improved in recent years. The old cork life jacket has become a sophisticated plastic foam device that resists mildew, rot, sunlight, vermin, and punctures. For Arctic conditions, body-enveloping survival suits are available that extend the life expectancy of a person in frigid water from a few seconds to hours. Foreseeable technological developments include the following:

- Improvements in reliability of launching systems.
- More comfortable life jackets that do not constrain the worker's mobility.
- Self-inflating work vests that will automatically inflate when a worker falls overboard.
- Personal emergency position indicating beacons that will help locate a man overboard.
- Individual descent systems to replace knotted man-ropes.
- Chute systems similar to those used for aircraft.
- Exposure suits that can be donned quickly.

Maintenance and Training. Effective response to an emergency, whether fire, explosion, or the need to abandon a facility, requires that the appropriate equipment be available and in good operating condition and that it be correctly used. Workers must be thoroughly familar with emergency procedures, trained to work together as a team, and effectively organized and led. The question of maintaining equipment is easily addressed by regulation and enforcement. The matter of training and establishing clear lines of decision-making in emergencies is another matter.

Some companies recognize the need for emergency training. Several offshore operators post safety specialists on platforms and drilling rigs to train workers in handling emergencies, to advise contract personnel and visitors of their stations in emergencies, and to maintain survival equipment. But the data seem to indicate that these actions are the exception rather than the rule, and that worker training in handling emergencies is often not given the attention by management that it deserves.

Quick and firm response to emergencies requiring abandonment may be frustrated in some instances by the occasionally complex chain of command on OCS installations. In combination drilling and production operations, common practice is to make the drilling foreman the "person-in-charge" of the operation, with both drilling and production operations under his control. On mobile drilling rigs, the "marine captain" would normally be in charge when the vessel is moved from one location to the next. When the rig is at a fixed location, the drilling foreman would be in charge.

After a decision by the person-in-charge to activate an alarm system, individuals on the platform or the drilling rig (including company personnel and contractors) should proceed to the station they should occupy for an emergency. Direct communication between the person-in-charge and each individual should not be necessary in the abandonment of an offshore installation. For these results, it is imperative that offshore workers be adequately trained and drilled in evacuation procedures. It is more difficult to achieve these objectives on mobile rigs, as the number of workers tends to be greater and their residency shorter.

Regulations that Address Emergencies and Abandonment of OCS Installations. Numerous regulations specify the equipment and procedures that are to be used in emergencies on OCS installations (Table III-26). With the exception of one Geological Survey requirement for training and drills, the Coast Guard is responsible for abandonment regulations on both fixed and floating installations.

The numerous requirements specifying items of equipment appear necessary. They probably improve the likelihood of survival. Existing requirements have tended to make MODUs better equipped for emergencies and abandonment than fixed installations. The regulations are being revised to require the same level of protective survival equipment on fixed platforms.

According to a study commissioned by the Coast Guard, on-site inspections reveal "inoperative or badly corroded survival equipment."[43] Table III-27 lists the regulations governing testing and maintenance of survival equipment. As a group, these regulations do not ensure that emergency equipment will be in working order in the event of an emergency. The two most frequent areas of neglect

TABLE III-26

Regulations Governing Emergencies and Abandonment, Oil and Gas Operations on the Outer Continental Shelf

	Fixed Platforms		Mobile Offshore Drilling Units
Survival Equipment or Procedure Required	U.S. Geological Survey	U.S. Coast Guard	U.S. Coast Guard
Alarms		Audible, general alarm system, 33 CFR 146.05-5 Emergency signal, intermittent, abandon signal, steady, 33 CFR 146.05-10	General alarm bell, marked "Go to Your Station," 46 CFR 108.623, 625 Locations of contact-makers for general alarm system, 46 CFR 113.25-5
Distress Communications		Radio or wire telephone, 33 CFR 144.01-40	Portable radio (international voyages) transferable to lifeboat, 12 flares, emergency position indicating radio beacon, approved typed (EPIRB), 46 CFR 108.519, 521, 523
Emergency Lighting and Power			Emergency lights, final emergency source loads, 46 CFR 112.05-10, 112.15-5
First Aid		First aid kit, litter, 33 CFR 144.01-30, 144.01-35	
Lifeboats, Liferafts, Survival Capsules		Two lifefloats (manned platforms), easily launched, with equipment specified, or approved inflatable liferafts, or lifeboats with specified equipment, 33 CFR 144.01-1 through 144.01-15	One lifeboat (30 people or less on board, two if more), liferafts to accommodate 100% of personnel, detailed specifications of release, launching, and provisioning, location, etc., 46 CFR 108.503 through 108.655 (Def. of lifeboat includes survival capsule, 46 CFR 108.501)
Life Preservers, Ring Life Buoys, Other Lifesaving Equipment		One approved life preserver for each person; four ring life buoys on each platform, with waterlight, 33 CFR 144.01-20, 25 Other lifesaving equipment must be approved, 33 CFR 144.10-10	Life preservers for 125% of people on board meeting stated specifications, at least eight ring life buoys with waterlights and smoke signals, 46 CFR 108.514, 515

TABLE III-26 (cont'd)

Regulations Governing Emergencies and Abandonment, Oil and Gas Operations on the Outer Continental Shelf

	Fixed Platforms		Mobile Offshore Drilling Units
Survival Equipment or Procedure Required	U.S. Geological Survey	U.S. Coast Guard	U.S. Coast Guard
Means of Escape		Two primary means of escape, uppermost to water level; when necessary, one or more secondary means of escape, accessible and approved, 33 CFR 143.05	Two means of escape, each working space and weather deck to water level, access to lifeboats, detailed specifications for vertical ladders, no dead-end corridor etc., 46 CFR 108.151 through 108.167
Chain of Command, Station Bill, Responsibility		Owner, operator, or agent designates (in succession), person in charge, 33 CFR 146.01-2	"Master or person in charge"
		Owner, agent, or person in charge assigns duties to each person in case of emergency, one person to launch each lifeboat, post station bills listing duties and duty stations in emergencies, 33 CFR 146.05-15 through 146.05-30	Master or person in charge ensure that persons on unit and all visitors familiar with duties and stations in emergencies, post station bill, assign seats in lifeboats, etc., 46 CFR Subpart E
Training and Drills	Training for emergencies, survival recommended by referenced API standards, OCS Order 5-8	Emergency drills once monthly, records maintained, 33 CFR 146.05-25	Boat drill once weekly, 46 CFR 109.215

Source: Committee on Assessment of OCS Activities

TABLE III-27

U.S. Coast Guard Requirements for Testing, Inspection, and Maintenance of Survival Equipment, Oil and Gas Operations on the Outer Continental Shelf

Item	Fixed Platforms	Mobile Drilling Units
General	Emergency equipment maintained in good condition at all times, periodic renewal of charges, batteries, etc., 33 CFR 146.01-15	All firefighting and lifesaving equipment maintained in operative condition, 46 CFR 109.301
Fire Extinguishers (Portable)	Shall be maintained, 33 CFR 145.01 Identifying mark of manufacturer, approval (name and address of approver), 33 CFR 145.05	Tested and inspected yearly, 46 CFR 109.223 Marine-type label, 46 CFR 162.028-4 Spare charges for 50% of extinguishers, 46 CFR 108.495
Lifeboats		Contain maintenance and repair instructions, schedule of periodic maintenance, diagram of lubrication pts., and recommended lubricants, log of records of inspection and maintenance, 46 CFR 108.503 Partially lowered, engine started, once weekly (boat drill), 46 CFR 109.215 Cleaned, inspected, fuel changed once yearly, 46 CFR 109.217 Radio tested, battery charged weekly, 46 CFR 109.217
Inflatable Life Rafts	Servicing and complete inspection of required equipment by marine inspector once yearly, 46 CFR 160.051	Servicing and complete inspection of required equipment by marine inspector once yearly, 46 CFR 160.051, 46 CFR 109.219
Life Floats	Grandfathered waterlights to be maintained in good condition, 33 CFR 144.01-10	
Work Vests	Examined for serviceability by marine inspector, 33 CFR 146.01-17	
Alarms, Distress Signals		Alarms inspected and tested within 12 hrs. of getting under way and once weekly, 46 CFR 109.201 Each distress and smoke signal replaced within 36 mos. of manufacturing, or by date of expiration, 46 CFR 109.317
Emergency Lighting and Power Systems		Tested once weekly, emergency generator once monthly, storage battery every six mos., 46 CFR 109.211

TABLE III-27 (cont'd)

U.S. Coast Guard Requirements for Testing, Inspection, and Maintenance of Survival Equipment, Oil and Gas Operations on the Outer Continental Shelf

Item	Fixed Platforms	Mobile Drilling Units
Emergency Position Indicating Radic Beacon		Tested once monthly, battery replaced by date indicated, or after use, 46 CFR 109.208, 307
Line-Throwing Equipment		Tested every four mos., 46 CFR 109.207
Records		Logbook--include time and date of each required test, condition of equipment, date of lifeboat inspection and condition of winch, 46 CFR 109.433 Record of all inspections of firefighting equipment to be maintained on board, 46 CFR 109.435 Report to be submitted of all repairs or alterations to emergency equipment, 46 CFR 109.425

Source: Committee on Assessment of Safety of OCS Activities

appear to be lubrication and corrosion control on lifeboat launching gear. However, in recent years some offshore operators have improved the maintenance of emergency equipment by instituting the Maritime Administration's Shipboard Maintenance and Repair System.

Findings and Recommendations on Fires and Explosions and Emergencies Requiring Abandonment of OCS Installations

There is a level trend in the incidence rates of fires and explosions per facility on the OCS over the last 10 years. The level incidence rate may indicate the limits of what technological approaches can achieve in mitigating fires and explosions.

The data base on fires and explosions is adequate to depict the overall hazard situation from such events, but not adequate for detailed analysis of causes and effects and the interactions among such possible factors as poor maintenance, personnel error, poor operating practices, faulty design, and insufficient training. Better incident reporting, more thorough investigation of incidents, and more comprehensive incorporation of cause and effect findings in the data base could provide better insight into the causal factors of fires and explosions.

The development of technology, its incorporation into regulations, and its application are adequate to prevent and control fires, and explosions, and for emergencies requiring abandonment of OCS installations. The critical problem is ensuring that offshore workers are adequately trained and sufficiently drilled in the individual and team procedures necessary to ensure survival.

Regulations prescribe an adequate level of technology for abandonment of mobile units but not of fixed installations. The Coast Guard has recognized this deficiency and is taking steps to rectify it.

Fire and explosion protection has historically been regulated through the development of highly specific, equipment-oriented requirements. While this approach has merit, there is room for performance-oriented requirements regarding fire and explosion protection. This is because total reliance on technology-specific regulations can have the effect of locking out new technologies that, while not meeting the regulatory requirements, may offer superior fire protection.

There have been some industry complaints that Coast Guard regulations have prohibited application of new technology in the area of fire protection. The committee's review of this issue indicates that the regulations do not prohibit the development nor use of new technologies, but the administrative process for their special approval is not completely understood by the industry and has been insufficiently explained by the Coast Guard. Even when followed, this process in many instances is untimely.

The Coast Guard should make it easier for new fire protection technologies to be used on the OCS. This can be accomplished by making a special effort to improve the understanding within the offshore industry of the Coast Guard appeal/approval process for fire protection equipment.

Regulations requiring training and drills have not been effective in ensuring that personnel can use the technology and follow the individual and team procedures necessary to ensure survival in an emergency and, therefore, are inadequate. Some drills are performed only perfunctorily for minimal compliance with regulations. Emergency equipment is often not used or demonstrated, and emergency situations are not simulated.

Response during emergencies is often complicated by lack of a well-defined chain of command for emergencies, rapid turnover of personnel in some occupations, and the frequent presence of temporary personnel. Station bills do not by themselves provide adequate organization for effective action in emergencies.

Loss of Installations

This section analyzes the adequacy of technologies and regulations concerning certain types of accidents that may lead to the loss of offshore petroleum installations. In particular it addresses the loss of, or major damage to, fixed and mobile platforms due to:

- environmental overloading, including the effects of design inadequacy, construction defects, and maintenance neglect; and
- accidental damage, including collisions, blowouts, and improper operations; and of course, combinations of these.*

OCS installations are designed, constructed, and operated for diverse uses, Including exploration and development drilling, oil and gas production, quartering of personnel, and storage and pumping of oil and gas. Fixed and mobile platforms have very different characteristics and are often subject to different environmental and operational regimes; therefore, it is appropriate to analyze them separately. Thereafter, the subject of accidental damage and consequent installation loss due to blowouts, fires and explosions, and collisions is addressed.

About 88 percent of the offshore installations are fixed structures; 12 percent are mobile installations. Since 1976, the number of fixed installations has grown steadily at the rate of 5 percent

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*Only those aspects of blowouts, fires, and explosions that bear directly on structural integrity are considered in this section; other aspects are analyzed elsewhere.

per year. The number of working drilling rigs has fluctuated from year to year, but on the average, has grown at an annual rate of about 15 percent over the 1975-1979 time period. The number of OCS installations that have been severely damaged or otherwise lost is small compared to the total population of OCS structures. This means that there are limited data on which to base the identification of trends and causal information. To increase the available data, worldwide installation loss data are occasionally employed. Further, data was obtained from private sources where these data were more extensive than the data contained in government files.[44] Table III-28 summarizes the loss rates for different types of offshore installations.

Fixed Platforms. An important element in the development of an offshore oil field is the design, construction, installation, and operation of fixed platforms. In simplest terms, a fixed offshore platform is a steel or concrete island providing above-water working space where conventional oil field operations can be performed in an air environment. Fixed platforms are used primarily for development drilling and production. The only alternative to basing production on a fixed platform is to employ more costly seafloor production technology. Seafloor production technology, which has been used to only a limited extent on the U.S. OCS, may be competitive with fixed platforms in deeper water, especially water depths greater than 1,500 feet.

While more than 3,500 platforms have been erected to date, the number of existing platforms is about 2,500 (Figure III-9).

Types of Fixed Platforms. Fixed platforms may be fixed-leg structures supported by deeply driven piles, gravity structures supported by a broad base resting on the seafloor, or compliant structures. The latter are held in a fixed bottom position but are designed to move to some extent in response to ocean forces.

- Fixed-Leg Structures. Fixed-leg platform design has evolved from the many-posted, shallow-water platforms of early offshore drilling. Steel construction provides strength and permits designs with good wave transparency (Figure III-10). Template construction enables the fabrication of the substructure onshore, followed by on-site driving of piles through the legs to achieve foundation support. In some cases, sleeves welded to legs of the platform provide for attachment of additional piles to strengthen the foundation.

  An example of the state of the art in fixed-leg platforms is the COGNAC Platform, which is in the Gulf of Mexico. Taller than the Empire State Building, the world's heaviest steel platform (59,000 tons) was constructed in three parts. The base section is 380 by 400 feet and is 175 feet high. It weighs 14,000 tons. The midsection is 282 by 310 feet and is

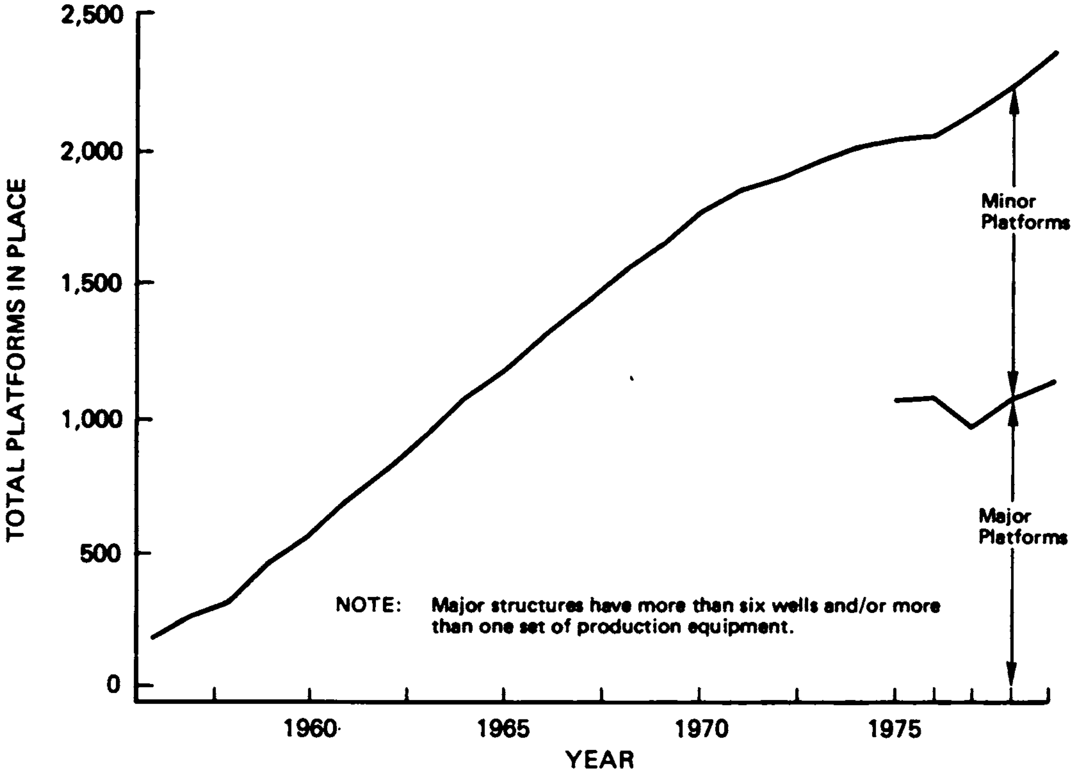
TABLE III-28

Loss Rates from Environmental or Operational Overloading for Different Types of Offshore Installations

Installation	Loss Rate (Loss: rig years of operation)
Jack-up	1:78
Semisubmersibles	1:184
Submersibles	1:221
Floaters	1:262
Fixed Platforms	1:875

Source: Committee on Assessment of Safety of OCS Activities

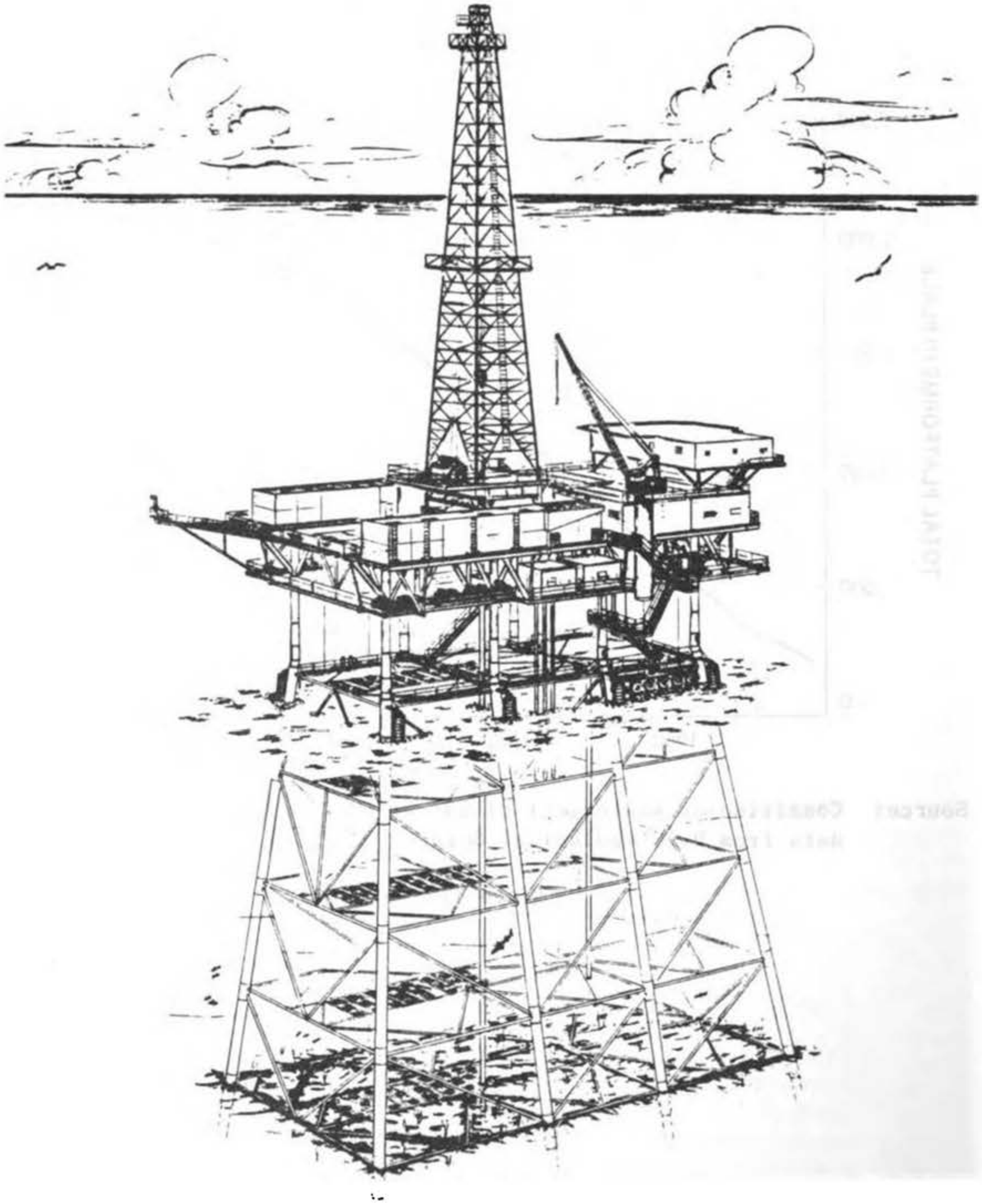
Fixed Platform Population
Northern Gulf of Mexico



Source: Committee on Assessment of Safety of OCS Activities; data from U.S. Geological Survey

Figure III-9

Fixed-Leg Jacket Platform



Source: McDermott, Inc.

Figure III-10

315 feet high. It weighs 8,500 tons. The 11,000-ton top section, which is 207 by 254 feet and 530 feet high, supports a 2,500-ton deck with two complete drilling rigs. COGNAC is attached to the seafloor by means of 24 piles, each 7 feet in diameter and 615 feet in length, driven through the base, 450 feet into the sea bottom. The platform is designed for 62 wells. The total investment in the platform is about $260 million.

Fixed-leg structures have been successfully designed to resist surface ice as encountered in Cook Inlet, Alaska. In this area, 6-foot-thick rafted ice floes can be expected during the severe winter months. The ice is carried up and down the inlet in large masses by strong tidal currents. Structures must be sufficiently strong to allow moving ice to break as it passes. A special form of fixed-leg platform was developed to cope with this seasonal ice problem (Figure III-11). In this structure, large legs provide buoyancy so that the structure can be floated and installed without the use of cargo barges. Multiple piles are driven through each of the large legs. Some of the piles also serve as conductor pipes for the wells. Approximately 15 structures of this type have been installed, beginning in 1964, and have operated successfully in Alaska state waters.

- Gravity Platforms. About 15 very large gravity structures, of concrete construction, have been erected in the North Sea (Figure III-12), but only two gravity platforms, of steel construction, have been placed in U.S. waters. Gravity structures require a firm seafloor to support their great weight.

- Compliant Structures. It is expected that the use of fixed-leg platforms will not extend beyond 1,200-1,500 feet, due to costs and other constraints.[45] As the fixed platform grows taller with increasing water depth, several factors combine to produce significant increases in foundation and steel requirements. Recognizing the existence of these limitations, the offshore indusry has searched for alternative deepwater platform concepts. Two promising practical solutions have emerged: the guyed tower and the tension leg platform. Both are referred to as "compliant" structures.

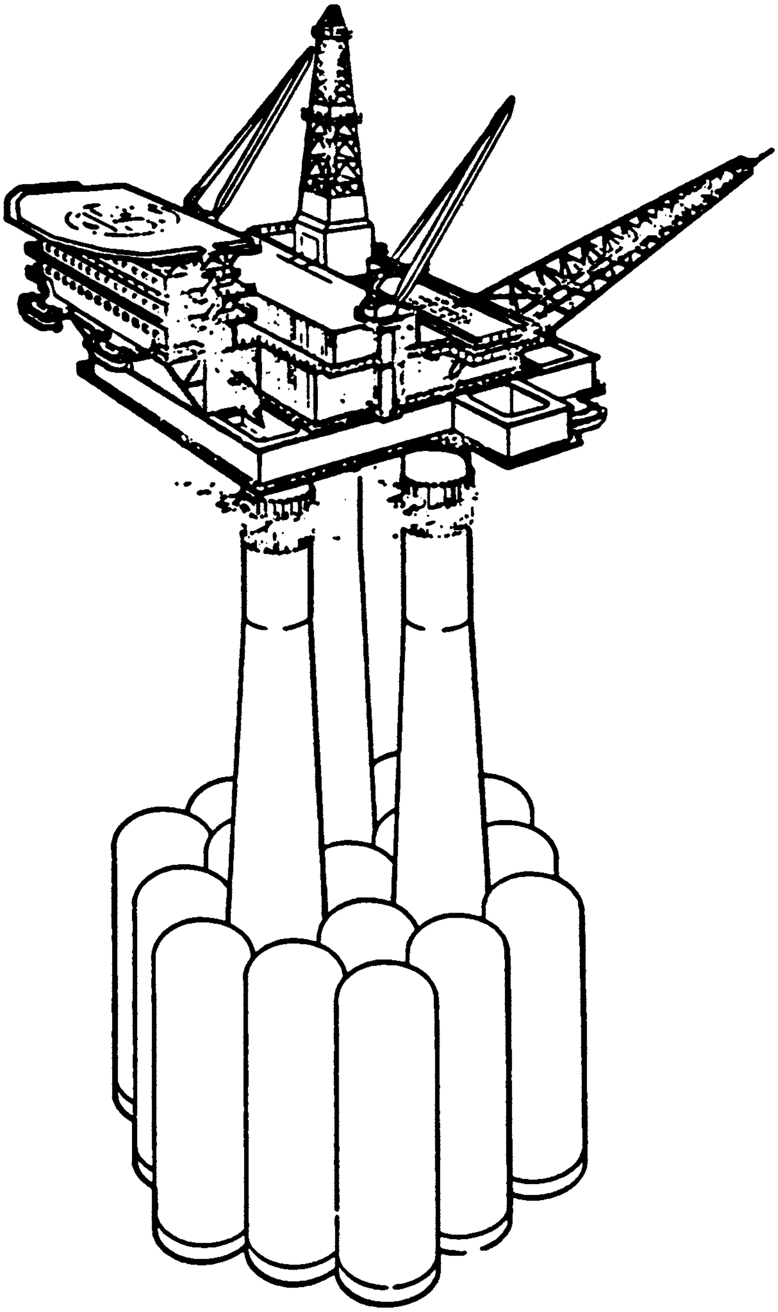
  The guyed tower concept is illustrated in Figure III-13. It is designed to sway slightly in response to the dynamic forces acting upon it. The tower transmits to the seafloor primarily vertical gravity loads imposed by the drilling and production equipment mounted on the surface decks. Support for the tower at the seafloor can be provided by either a vertical bearing foundation, (a "spudcan") or a more conventional piled foundation. A number of guylines provide horizontal support for the tower. The guylines run

Caisson-Type Platform in Cook Inlet, Alaska

Source: McDermott, Inc.

Figure III-11

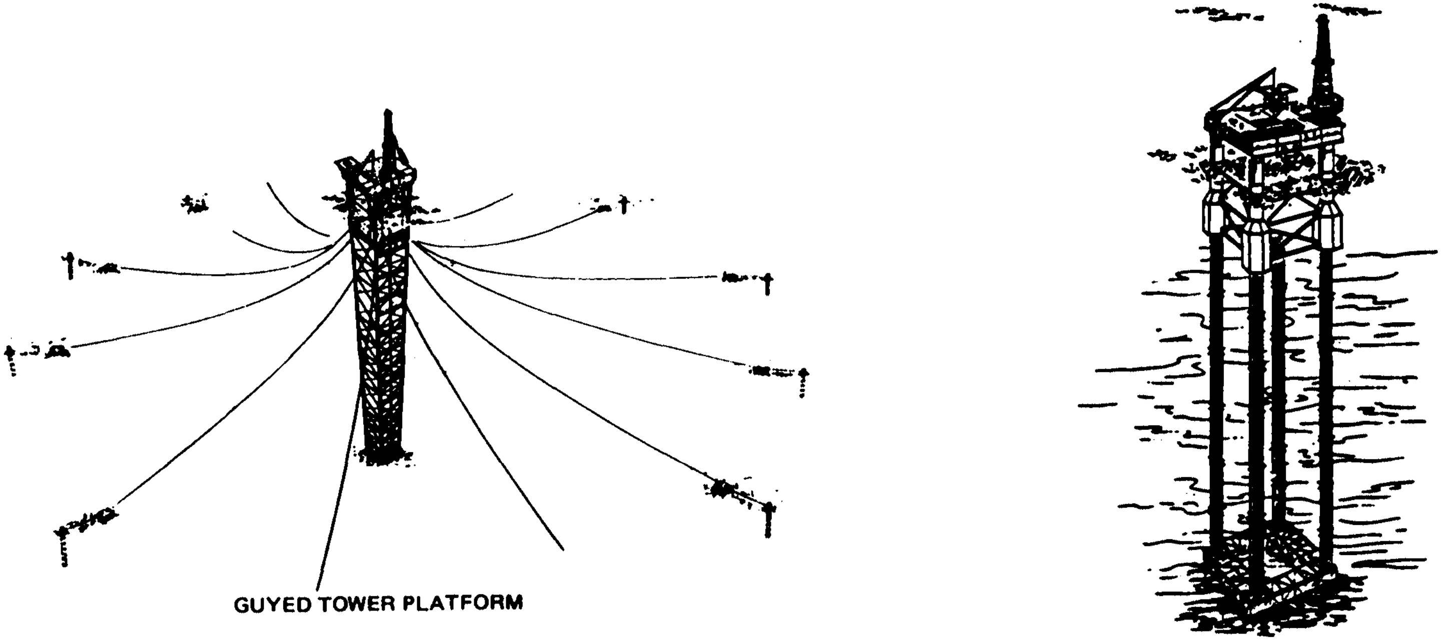
Gravity Structures



Typical Concrete Gravity Platform

Source: Dunn, F. P., "Deepwater Drilling and Production Platform in Non-Arctic Areas," Outer Continental Shelf Frontier Technology, Proceedings of a Symposium, National Academy of Sciences, Washington, D.C., 1980.

Figure III-12



GUYED TOWER PLATFORM

TENSION LEG OR VERTICALLY MOORED PLATFORM

Source: Griff C. Lee, McDermott, Inc.

Figure III-13

through fairleads to clump weights on the seafloor, with an additional extension to anchor piles. With the guylines attached to the tower near the surface, wave forces are passed directly to the guylines. As a result, the tower is not required to transmit large overturning moments to the base as does a conventional fixed platform.

In moderate sea states, the clump weights remain on the seafloor with the guylines in a taut condition. In more severe sea states, tower oscillations become larger and the clumps progressively lift off the seafloor, thereby causing a softening of the guying system. Although fabrication of the guyed tower calls for conventional equipment and procedures, its installation requires advances in technology, especially with respect to the guylines, clumps, and anchor piles.

Another form of compliant structure is the tension leg platform (TLP). The TLP is not a fixed-leg platform, but is a floating vessel moored to the seafloor with a vertical anchoring system, as shown in Figure III-13. In concept, a TLP is similar to a semisubmersible mobile drilling barge. The principal characteristics of this type of platform are a large amount of excess buoyancy designed into the platform for pretensioning of the anchoring system and a specially designed hull to minimize response to wave motion. Vertical tethers, or tension members, of wire rope or pipe are used to anchor the platform to the seafloor. The platform remains virtually horizontal under wave action while lateral excursions are controlled by the design of the tethers. Two types of seabed anchorages can be used--piled templates or gravity units.

An alternate concept of the fixed, floating platform is known as the vertically moored platform, in which the well conductors also serve as the anchor legs. This allows the use of a conventional wellhead at the platform deck level, but requires special connections for the conductor pipes at the deck.

A major advantage of these concepts is their relative cost insensitivity to increased water depth. However, mooring costs do increase with water depth, and substantial increases occur with remote operations and maintenance at extreme depths.

Development work is actively progressing for both tension-leg and vertically moored structures. Test structures of both guyed-tower and tension-leg structures have been erected on the OCS and left in place through significant observational periods to obtain design data. The test results are proprietary at present.

o <u>Arctic Structure Concepts</u>. In the Arctic, where at times ice reaches from the sea surface to the seafloor, man-made gravel islands are technically and economically attractive for operations (Figure III-14). They have been employed in very shallow Arctic waters, along the Beaufort Sea coast. Gravel islands can be constructed either by dredging or by trucking gravel over the ice in winter and dumping it through a hole excavated in the ice sheet. For operating in water depths beyond the economic limit of gravel islands (60 to 80 feet), mobile conical gravity structures may prove useful (Figure III-15). In some arctic regions, the hostile environment and remoteness of the sea ice areas may favor the use of gravity structures that can be preassembled at a construction site in temperate waters, towed to location, and installed quickly with all or most of the production facilities already in place.[46]

- Subsea Production Systems. Subsea production systems consist of wells completed on the seafloor and connected by flowlines and controls back to a surface facility. Subsea production technology will be an integral part of advanced deepwater platform systems.

  Subsea completion technology has been under development since 1943, when the first of over 300 underwater completions was made in the Canadian waters of Lake Erie.[47] These installations were for gas wells operating at relatively low pressure (less than 2,000 psi) in shallow water (less than 35 feet). Development of deep water, open-sea, subsea completion technology began seriously in the early 1950's. Since 1960, a total of about 275 such installations have been made. Eight different manufacturers are now supplying subsea completions of various types, and in late 1979 there were 59 units on order. Some subsea installations have been designed to operate either partially or completely below the mudline in order to minimize the amount of equipment exposed to possible damage above the seafloor.

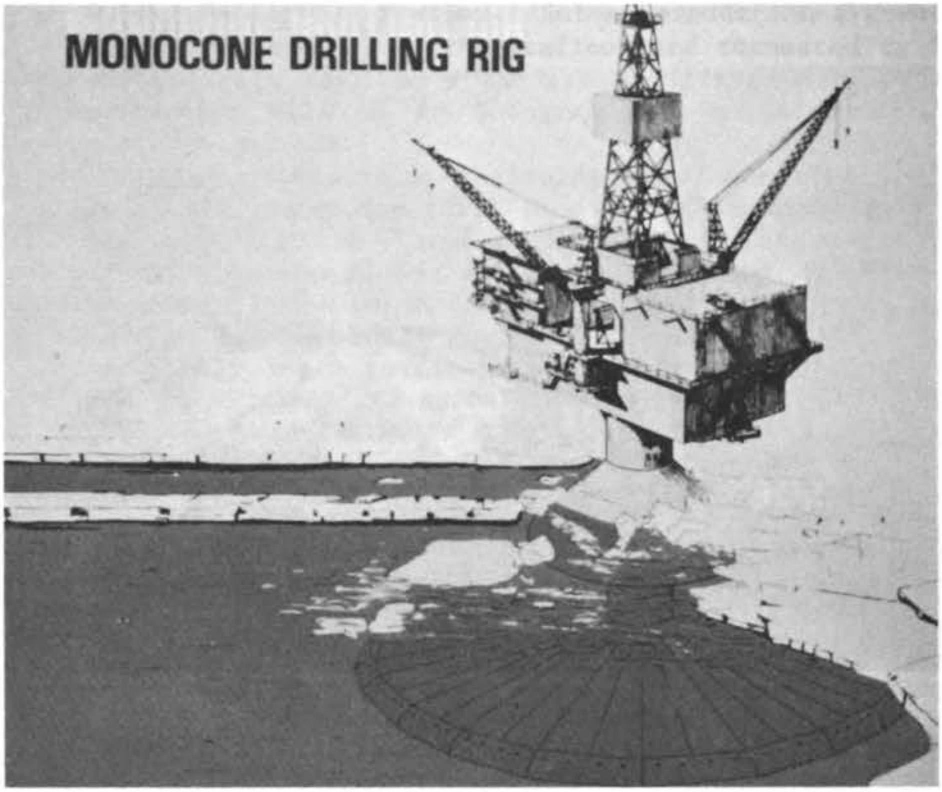
Platform Exposure. Offshore platform installation losses can be grouped into two major categories: environmental or operational overloading, which is related to design and environment; and accidents such as collisions, blowouts, and fires, which are usually related to operations.

Loss of installations from environmental or operational overloading is more directly related to the establishment of the design criteria and to the design of the structure than are operational accident losses. In the planning stages of an offshore facility, it is necessary to establish the acceptable level of risk and predict the intensity of environmental loading that will be used for the design of the structure. Environmental loadings that most seriously affect the design of offshore platforms derive from wind, wave, ice, and earthquakes. The ability of an existing structure to withstand actual environmental loading (established by hindcasting of environmental data) is a good indication of the adequacy of the technology

Gravel Island

Source: Jahns, Hans O., "Arctic Platforms," Outer Continental Shelf Frontier Technology, Proceedings of a Symposium, National Academy of Sciences, Washington, D.C., 1980.

Figure III-14



Proposed Mobile Conical Gravity Structure

Source: Jahns, Hans O., "Arctic Platforms," Outer Continental Shelf Frontier Technology, Proceedings of a Symposium, National Academy of Sciences, Washington, D.C., 1980.

Figure III-15

used to design the structure. Because of this, detailed studies have been made of the failures of offshore platforms. The information developed has been used to benefit the design of subsequent facilities.

Throughout the world, a number of platforms have been subjected to seismic loading. No major damage has been reported. The design of offshore platforms for seismic conditions has largely depended upon adapting improved technology from land structures, such as high-rise buildings.

Ice loading has been the principal design criterion for the approximately 15 platforms that have been installed in Cook Inlet, Alaska since 1964. These platforms are seasonally subjected to rafted ice floes up to 6 feet in thickness. To compound the problem, ice moves back and forth through Cook Inlet with the tidal currents, which reach up to 10 knots. Platforms in Cook Inlet have proven satisfactory although some polishing-by-ice has been observed in the surface zone where ice breaks past the platform. Also, conventional cathodic protection systems have not been as effective due to the cold temperature and high water velocities. Since the platforms have withstood numerous winters, observations indicate that the design criteria were satisfactory.

The primary testing ground to date for offshore installations has been the Gulf of Mexico. The most significant environmental loading in this region is from hurricanes. In the entire span of offshore operations in the Gulf of Mexico, 37 platforms have been so severely damaged by hurricanes that replacement was required. These have been primarily older platforms built before current technology became available.

- Focus on Hurricanes.[48] In the 15 years of OCS development prior to 1963, the offshore industry lost only seven structures to hurricanes, a ratio of one loss per 600 platform-years. Then in 1964 and 1965, hurricanes "Hilda" and "Betsy" caused considerable damage to at least 28 platforms. As a result of this, offshore operators made a complete reevaluation of their risk criteria and, without exception, elected to design future structures for more intense storms. Since that time, practically all permanent platforms in the Gulf of Mexico have been designed according to 100-year storm criteria rather than the 25-year storm criteria that had been common. The reevaluation effort after the two storms also resulted in increased emphasis on the need to improve technology. Additional time was allowed for improved engineering design of structures. Further, better determination in prediction of on-site conditions was made and development budgets to improve technology were increased.

  In addition, two other factors emerged as principal problem areas and were immediately improved. The methods used to design structural joints within the jacket were upgraded so that considerably stronger joints resulted.

> Also, in almost every instance failure occurred when waves reached the deck section. The maximum force in a wave is near the crest. Normally, offshore platforms are streamlined to minimize the area subject to this maximum force. If the deck section of a platform is too low and the full force near the crest of the wave strikes a platform, overloading is very likely. Following hurricanes "Hilda" and "Betsy", the deck elevations of platforms were raised to clear anticipated wave action.
>
> The failure of three structures due to mudslides during hurricane "Camille" in 1969 also initiated extensive research into that mode of failure. The fact that the soil near the mouth of the Mississippi River was unstable and that movement would occur was well known. What was not anticipated was the severity of the sliding motion and the magnitude of forces exerted on the platform. In the years after "Camille," the industry investigated this phenomenon and developed structures to resist this soil motion. A new breed of structure called a mud slide platform resulted. Approximately one dozen of these structures have been installed or are under construction. These are considerably heavier and stronger structures and therefore more expensive, but they make possible development of additional offshore resources.
>
> Table III-29 displays the exposure history of Gulf of Mexico platforms to hurricanes. Through 1979, the industry had accumulated over 32,000 platform-years of exposure, with 37 losses. This provides a ratio of approximately 1 platform loss for every 875 platform-years of exposure. No lives have been lost and little pollution has occurred from these events because wells are shut in and platforms are evacuated in the event of a hurricane warning.
>
> Most platform losses from hurricanes have been caused by the design criteria being exceeded. They resulted in some cases from immature technology in predicting wave heights and in others from acceptance of a calculated risk with respect to the maximum storm intensity that would be experienced. For both of these reasons, storms were experienced with wave heights exceeding design criteria, overloading the structures, and the failures resulted.

Offshore technology has advanced rapidly, both in the ability to devise environmental design loading criteria for hurricanes and mudslides and in the ability to analyze for these and seismic loadings.[49] It is significant to point out that, from 1965 to 1979, only six platform failures occurred and that approximately 1,000 pre-1965 structures still exist. These older platforms are subject to the same problems that occurred in "Hilda" and "Betsy," should storms subject them to forces greater than anticipated in the design

TABLE III-29

Offshore Platform Exposure to Loss* Northern Gulf of Mexico

Year End	Platforms In Place	Cumulative Platform Years	Losses To Date	Chance Of Loss
1947	-0-	-0-	-0-	-0-
1957	267	589	5	1/120
1961	701	2,442	9	1/270
1964	1,100	5,130	24	1/215
1965	1,200	6,280	32	1/200
1969	1,675	12,068	35	1/345
1979	2,420	32,370	37	1/875

* A platform is considered lost if it was totally destroyed or so badly damaged that it had to be replaced. Single-well caissons are not considered to be platforms, and are excluded from this tabulation.

Source: Griff C. Lee, McDermott, Inc.
(and the U.S. Geological Survey for data since 1969)

criteria. Based on present technology, all of the failures that have occurred were predictable. If present technology had been available when these structures were designed, it is doubtful that any failures would have occurred.

The North Sea experience has also provided information regarding environmental design. The waves in the North Sea are more severe than hurricane-generated waves in the Gulf. Although advances in design technology have been utilized so that no North Sea structures have suffered collapse or major damage as a direct result of North Sea storms, some problems have been encountered in a few platforms in fatigue of horizontal bracing members near the water surface.[50] Analysis of this phenomenon, caused by severe winter storms, has contributed to a better knowledge of fatigue aspects of the design of offshore structures. This damage has been repairable, although repairs have been expensive.

Loss of installations due to operational accidents does not involve events that are unique to fixed platforms. Similar accidents can occur on mobile installations or on land. The causes of and trends related to these accidents are discussed in other, more appropriate, sections of this report. Aspects of collisions, blowouts, and fires that bear directly on the loss of installations are discussed later along in this section, where it is possible to analyze the installation loss effects of operational accidents on both fixed and floating installations.

Technological Development for Frontier Areas. The term "frontier area" as it has been applied to U.S. operations is generally considered to mean any U.S. waters in Alaska, California (outside the Santa Barbara Channel), and the Atlantic, and as well as deepwater areas (over 200 meters) of the Gulf of Mexico. Not all of these areas should be considered engineering frontiers, however, since the ability, experience, and technology of the U.S. petroleum industry have been demonstrated in many similar areas in various parts of the world.

The North Atlantic area of the East Coast is often called a frontier area. However, from the standpoint of fixed platform operations, environmental conditions in this area are not as severe as the northern areas of the North Sea, where U.S. and European offshore operators work regularly. Of course, construction in the North Atlantic, off the East Coast of the U.S., or even in the Gulf of Alaska, will have to be tailored to site conditions. However, lessons learned in the North Sea provide excellent and transferable experience for these areas.

The same can be said for U.S. areas that are potentially subject to damaging earthquakes. Platforms have been successfully operated in seismic areas for many years. Although no severe earthquake exposures have occurred, the ability to analyze structures for seismic response has improved markedly in the past few years. In place of the elastic analysis that was the state of the art a few years ago, it is now normal procedure to consider at least two levels of earthquake loading and to take into account energy absorption by the structure past the elastic condition, utilizing nonlinear and postbuckling behavior. This takes into account the structure's ability to withstand additional loads after the first member has reached its ultimate loading.

It is also questionable to what extent deep water should be considered a frontier area as far as industry structural capabilities are concerned. With the HONDO platform on the West Coast in 850 feet of water, and the COGNAC platform in the Gulf of Mexico in 1,025 feet of water, the industry demonstrated the capability to build fixed platforms in substantial water depths. Work is presently under way for a structure for the East Breaks area, off the Texas Coast, at a water depth of 952 feet. It will be installed with the jacket in one section, which is a simpler and less expensive procedure than that used in the previous deepwater structures. This same technique can be applied to the 1,200 to 1,400-feet water depth ranges. Past this water depth, the guyed tower and vertically moored or tension-leg platforms are viable concepts. To ensure that these are practical structures, one of each type is being planned in water depths that are shallower than those for which they are economically attractive. The first of these, a guyed tower for use in the Gulf of Mexico, has reached the bidding stage and has been submitted to the Geological Survey for structural verification. Also, a tension-leg structure for the North Sea is in the final design stage and should be bid shortly. These are not test structures, but are intended to develop and prove that the technology is ready to move out into deeper water when required by economic considerations.

A true frontier, from the standpoint of fixed platform design, is the polar ice region. The industry has proven technology, developed in Cook Inlet, to cope adequately with rafted ice up to six feet thick moving at high velocities. However, in areas of polar ice, sea ice may comprise sheets up to seven feet thick with embedded ridges several times the thickness of the parent sheet. Designing platforms for these conditions will require new concepts that are now being developed. While gravel islands are being constructed for use in shallow water under these conditions, the design and construction of the fixed platforms for use in polar ice areas will certainly be a pioneering effort. Problems of particular concern in the Arctic are related to the nature and magnitude of ice loadings on fixed structures and foundations and the extreme operating temperature.

A similar pioneering effort is being developed for offshore production operations to be carried out off the east coast of Canada in the area known as "Iceberg Alley." The design of fixed platforms to resist the impact of moving icebergs requires an extrapolation of present-day technology. Consideration must be given to both passive and active means of defense. Well-heads or storm-choke valves will undoubtedly be located in caissons below the seafloor in order to ensure positive closure and safety despite possible scour from a large berg ploughing the seafloor.

Drilling and production may in some cases be carried out from floating semisubmersible platforms capable of quick disconnection and release so as to permit them to be moved in the event of bergs drifting into proximity.

Regulatory Regime. Regulation of the structural integrity of fixed platforms on OCS leases is the responsibility of the Geological Survey and is carried out through OCS Order No. 8, "Platforms and Structures," issued in January 1980.

Within this framework, two programs address the structural adequacy of OCS platforms. They are the Platform Approval Program, which is limited to platforms of standard or common design on the Gulf of Mexico OCS, and the Platform Verification Program, which is national in scope and which addresses the remaining platforms on the Gulf of Mexico OCS and all platforms in other OCS regions. However the structural design of every OCS platform, no matter which program it is subject to, requires the approval of the appropriate Geological Survey Deputy Conservation Manager. The difference between the two programs is in the detail and extensiveness of the review performed under each, with the review performed as part of the Platform Verification Program being more detailed and extensive.

On the Gulf of Mexico OCS, the platforms and any major modifications to them are subject to review by the Platform Verification Program if they meet any of the following conditions: installed in water depths exceeding 120 meters (400 feet); have natural periods in excess of three seconds; installed in areas of unstable bottom conditions; installed in frontier areas; and have configurations and designs that are unique in relation to typical Gulf of Mexico installations.

The key element of the Platform Verification Program, as described in OCS Order No. 8 and a series of related documents that the order incorporates by reference, is the requirement for third party verfication of each major phase in platform development. The program defines procedures by which individuals or organizations may become certified verification agents and identifies mandatory state-of-the-art performance standards that must be met. An important aspect of the verification program is the requirement for structural inspection immediately upon installation of a fixed structure.

Structural inspection practices are not regulated at present. Current industry practice for platform inspection generally follows the recommendations of the National Academy of Sciences.[51] Reports of post-failure analyses of fixed-leg platforms have not identified maintenance deficiencies as contributing significantly to any of the previous installation losses. The Geological Survey recently solicited comments through the Federal Register on the need for an inspection regulation.[52]

Another federal requirement pertinent to structural integrity is the authority of the BLM to withhold from leasing or to place constraints on construction in any lease blocks or tracts considered especially hazardous with respect to seafloor instability or other geological hazards.

Adequacy of Fixed Platform Technologies and Regulations. Fixed platforms, both steel and concrete, have been shown by experience in the U.S. OCS and in other more hostile marine areas, such as the North Sea, to have a high degree of structural reliability, equal to or better than that of comparable onshore structures. In particular, conventional pile-supported platforms on the U.S. OCS have shown a low and a declining failure rate, reflecting the advances in design technology during the last 30 years and establishment of adequate knowledge of environmental loads--whether associated with wind, waves, bottom movements, or earthquakes. Industry is moving forward with the development of new structural concepts for use in water depths greater than 1,000 feet and for use in Arctic areas.

The government is making progress in the regulatory area as evidenced by the establishment in recent years of the Geological Survey's Platform Verification Program and the intensive examination of other aspects of its regulatory program. These include reviews of its inspection practices, and also development of the Best Available and Safest Technologies requirement.

One regulatory area requiring attention is the technical base available to the government to make informed decisions about the adequacy of new structural concepts. A procedural approach for the development of verification requirements applicable to new structures needs to be developed. At every turn it will be important to administer the verification program in a manner that is sensitive to regional and site-specific environmental and operational conditions.

Findings and Recommendations on the Safety of Fixed Platforms

From 1947 to 1979, fixed-leg platforms on the U.S. OCS accounted for approximately 32,870 platform years of operation. There were 37 known installation losses (0.001/year) exclusive of those associated with blowouts, collisions, or other operational incidents. The loss of most of the platforms could have been anticipated given current technology and design criteria. All of the failed platforms were designed on the basis of criteria now considered obsolete.

About half of the existing platforms on the Gulf of Mexico OCS were designed prior to 1965 and do not meet contemporary design standards. Some would be lost if exposed to 100-year storm loads associated with current standards. Any such potential losses would not reflect adversely on the current state of technology or the adequacy of current regulations. Current hurricane warning systems, combined with well shut-in and platform evacuation procedures, justify con- tinued utilization of these important older structures.

The technology of fixed-leg structures is mature and provides adequately for the safety of OCS operations. The technology for the design and installation of subsea well completions, deepwater compliant structures, and fixed polar Arctic structures is still developing. It is not possible for the committee to conclude whether these developing technologies for fixed structures are currently adequate to provide for safety of OCS operations in frontier areas. However, regulatory procedures for the verification of the design of fixed OCS installations should provide adequate assurance for the safety of such OCS installations.

OCS Order No. 8, together with the related documents that it incorporates by reference, establishes adequate procedures for regulating the design and installation of fixed-leg platforms at all OCS locations and at all water depths where this form of construction is practicable. The third-party verification procedures established by OCS Order No. 8 also constitute an adequate framework for regulating the design of new structure concepts, such as guyed towers, and of structures in polar Arctic water, although procedures for arriving at design practices to be used in the verification program are not yet fully established. The structural inspection of fixed platforms is currently being considered in the regulatory process.

The Geological Survey should:

- Clarify the procedures by which operators are to submit and seek approval of the design bases they adopt on pioneeering projects for which mandatory design requirements have not yet been published.

- Ensure that verification agents for new structural concepts or for frontier areas have specifically applicable expertise.

- Move ahead to implement structural inspection requirements for fixed OCS installations.

Mobile Offshore Drilling Units. MODUs are used primarily as a base of operations for exploratory drilling and for well workovers. Types of MODUs include submersibles, floaters, semisubmersibles, and jack-ups. While all these may carry similar kinds of drilling equipment, their hull configurations and consequent diverse maritime capabilities suit them for distinct applications.

Submersible drilling units usually consist of a barge hull that is floated to the drilling location and then sunk to the seafloor by ballasting. This technique is limited to water depths that permit the upper structure of the barge to be high enough above water for drilling operations to be conducted. Submersible barges were used extensively in drilling the first shallow water wells in the Gulf of Mexico. Submersibles have only limited application to the OCS, however, because they are confined to shallow water operations. As a result of this lack of versatility, submersibles have been largely replaced by the jack-up type of rig discussed later in this section.

The term "floaters" is used in this report to refer to drilling rigs mounted on ship-shaped hulls and floating barges. Floating drill barges are towed on location and then moored with anchor and chain systems. Although they can be used at any depth at which they can be efficiently moored, out to 600 feet or more, the barge hull shape has poor motion characteristics. Therefore the preferred location for floating drill barges is in protected waters.

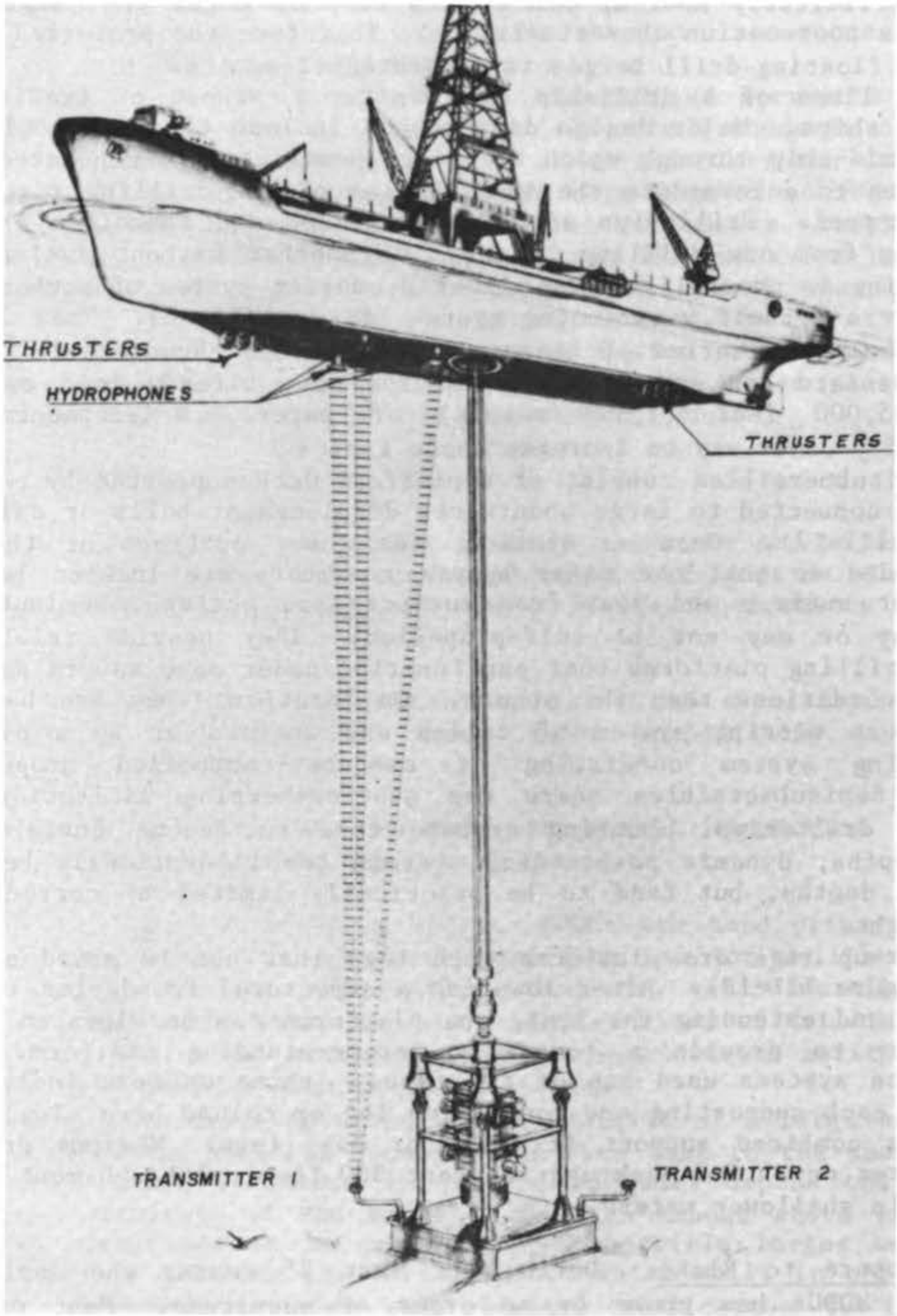
The lines of a drillship are similar to those of traditional merchant ships. Major design differences include the moon-pool, an opening mid-ship through which drilling operations are conducted, and ballasting to accommodate the installation of the drilling rig above the moon-pool. Drillships are self-propelled and therefore capable of moving from one drilling location to another without assistance. Positioning is accomplished by either a mooring system of anchors and chains or a dynamic positioning system (Figure III-16). This latter system employs a series of beacons, sensors, and thrusters to detect and compensate for movement. Drillships have already been used in almost 5,000 feet (1,500 meters) of water. Developments are continually under way to increase these limits.

Semisubmersibles consist of a platform deck supported by columns that are connected to large underwater displacement hulls or caissons (Figure III-17). Once on station, the lower portions of the rig are flooded so that the major buoyancy members are located beneath the water surface and away from surface wave action. Semisubmersibles may or may not be self-propelled. They provide relatively stable drilling platforms that can function under more severe sea and weather conditions than the others. On location, they are held in place by a mooring system of cables and anchors or by a dynamic positioning system consisting of computer-controlled propulsion units. Semisubmersibles share the station-keeping limitations of floating drillships. Mooring systems tend to become unwieldy at great depths; dynamic positioning systems can theoretically be used at great depths, but tend to be practically limited by current and wave height.

Jack-up rigs are platforms with legs that can be moved up and down (Figure III-18). After lowering a structural foundation to the seafloor and extending the legs, the platforms can be elevated above the water to provide a temporary bottom-standing platform. The foundation systems used are of two types: three or more individual footings each supporting one foundation leg or column or a single mat providing combined support to three or more legs. Maximum practicable water depth for jack-ups is about 300 feet, although most units operate in shallower waters.

Exposure to Risks. During the last 25 years, the worldwide fleet of MODUs has grown by an order of magnitude. Most of the growth has occurred in the last 15 years and has been concentrated in the jack-up and semisubmersible types of rigs. Figure III-19 illustrates this growth both worldwide and for the U.S. fleets. In late 1979, there were approximately 450 MODUs worldwide and about 148 in U.S. waters (Table III-30). The U.S. fleet is about one-third of the worldwide total.

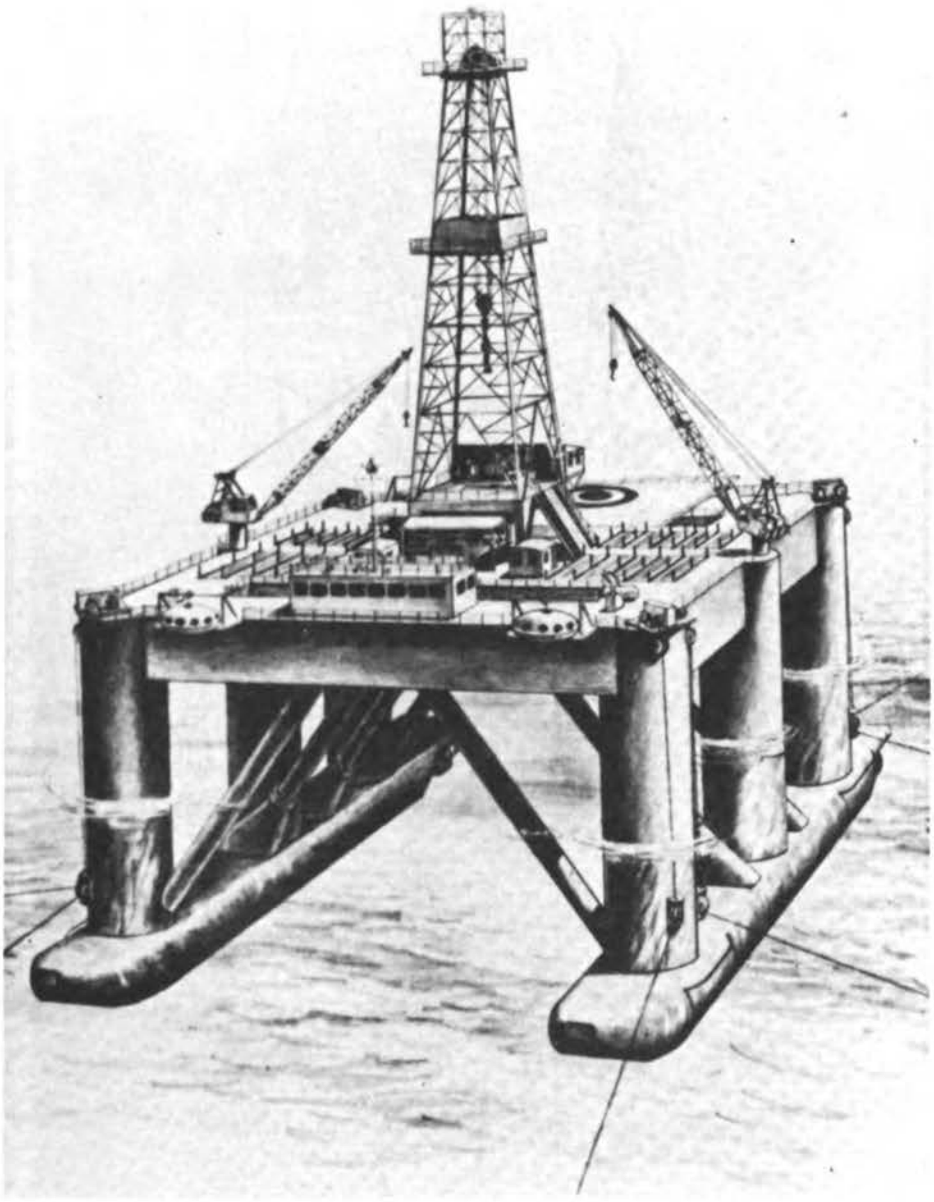
Dynamically Positioned Deep Water Drill Ship



Source: Kash, Don E., et al., "Energy Under the Oceans," University of Oklahoma Press, Norman, Oklahoma, 1973.

Figure III-16

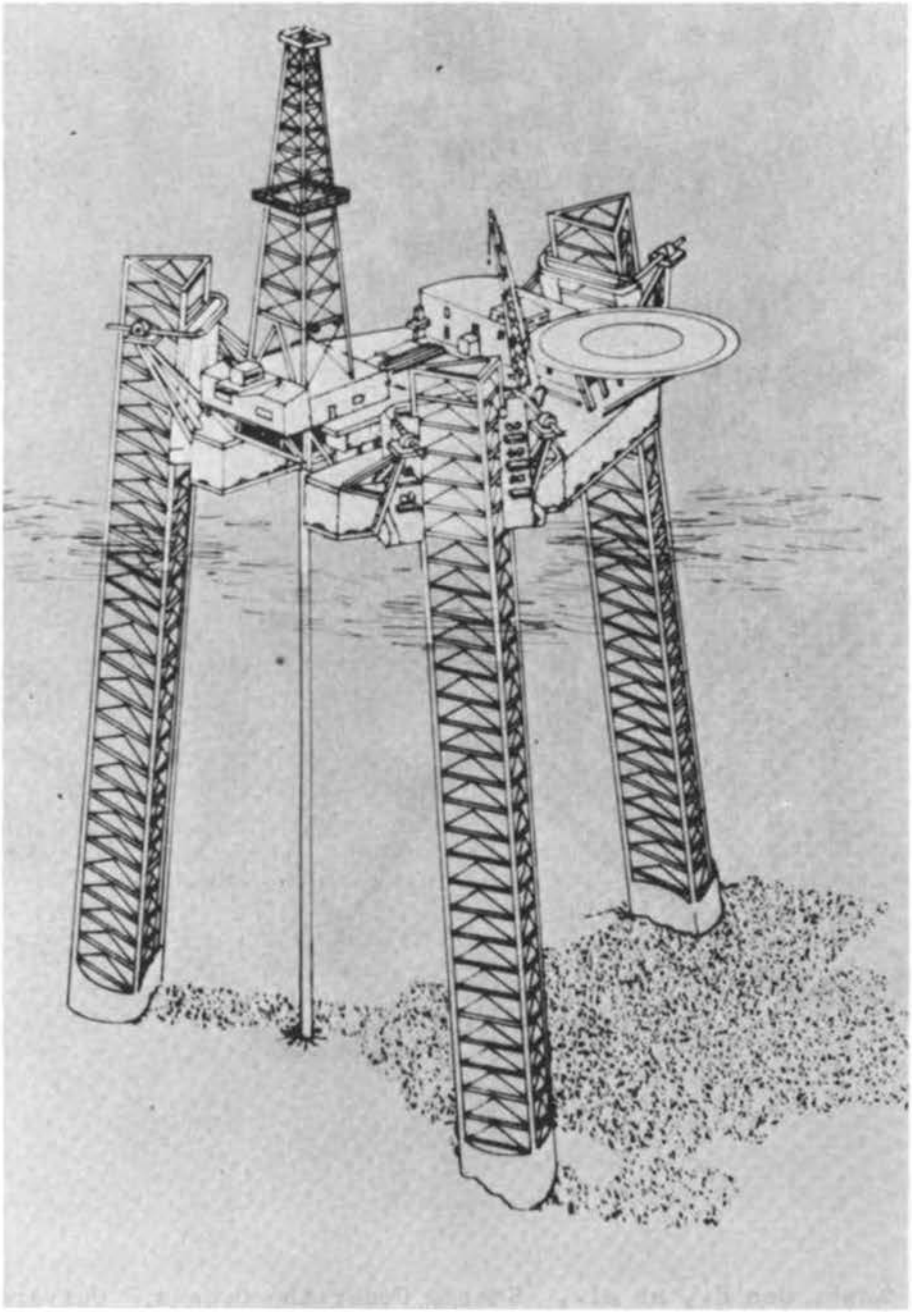
Semisubmersible Rig



Source: Kash, Don E., et al., "Energy Under the Oceans," University of Oklahoma Press, Norman, Oklahoma, 1973.

Figure III-17

Jack-Up Rig

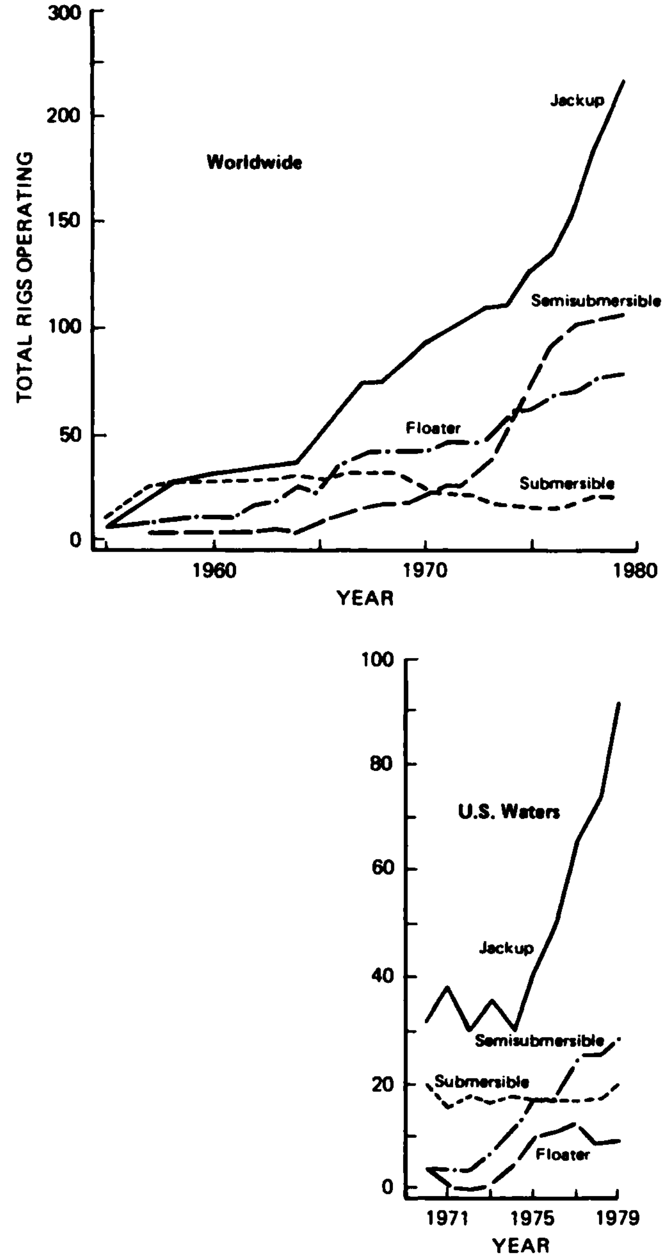


Source: Kash, Don E., et al., "Energy Under the Oceans," University of Oklahoma Press, Norman, Oklahoma, 1973.

Figure III-18

Mobile Offshore Drilling Units

Growth of the Worldwide and U.S. MODU Fleet



Source: Worldwide - Modified after Huff, John R., "Study Analyzes Offshore Rig Casualties," Oil and Gas Journal, Vol. 74, November 29, 1976.

U.S. Waters - Committee on Assessment of Safety of OCS Activities; data from Offshore Rig Data Services, Inc.

Figure III-19

TABLE III-30

Census of Mobile Offshore Drilling Units (1979)

TYPE	Worldwide	U.S.
Jack-up Units	229 (51%)	93 (63%)
Semisubmersibles	116 (26%)	27 (18%)
Floaters (ships and barges)	83 (18%)	8 (5%)
Submersibles	22 (5%)	20 (14%)
TOTAL	450	148

Source: Committee on Assessment of Safety of OCS Activities

Each of the MODU groups has unique characteristics when moving, setting up, or operating on location, which strongly influence the risks commonly experienced by each group. Some of the more significant of these characteristics are described below. A separate section comments on risks of blowouts, fires, and collision damage--risks to which all OCS installations are more or less equally exposed.

- Jack-ups. The extreme transformations that jack-ups must go through--between their bottom-resting state, with legs down, and their floating condition, with legs up--constitute a severe design requirement that must be met with compromise. These hazardous transformations are regularly and frequently experienced by jack-ups as they move on or off location, changing from a static to a dynamic condition or vice versa. Irregular development of or release from bottom support, resulting in unequal vertical movements in the foundation system, can lead to both structural and mechanical failures in the support system and, progressively, to overturn or capsize of the unit.

  Jack-up foundation systems are dimensionally fixed, except for depth of penetration below the seafloor, and are not custom fitted to a specific site. Definitive information on the engineering properties of sub-bottom materials is not always available for a proposed jack-up location. With footing-supported jack-ups, preloading of the foundation system by applying and then removing water ballast is relied upon to achieve a margin of safety under operating loads. Preloading is not practiced with mat-type jack-ups. Despite the uncertainty in actual soil conditions at some sites, very few accidents on location have been attributed to soil bearing failure after jacking up and preloading were completed.

  One type of accident that constitutes a unique risk for mat-type jack-ups, but which is not noted in the available summary accident record, is sliding. At least five instances have occurred during hurricanes of lateral movements of 2 to 100 feet, resulting in slight rig damage in only one case.[53] Lateral movements are also experienced at times during storms of less than hurricane intensity. Records of such movements apparently are not available, but the recent (August 1980) loss of the HARVEY WARD near the mouth of the Mississippi, several hundred miles from the center of hurricane "Allen," may be such an occurrence.

  Possibly the major risk with jack-ups occurs during their transit periods while they are afloat and under tow. Their tolerance of heavy seas is low in these conditions.

- Semisubmersibles. Semisubmersible rigs enjoy a good safety record. A very high percentage of accidents that do occur to them, whether on location or in transit, involve structural cracking. Units of this type are designed to operate in very rough waters. The major concern under these conditions is the fatigue life of welded joints in a corrosive environment.

It is of interest that a number of major accidents have involved major cracking or structural damage that was detected and repaired. While the cost of repair exceeded one-half million dollars, there apparently was no consequential loss beyond that of repair. Occurrences of undetected structural cracking leading to collapse or capsizing are few in number but can be disastrous when they do occur; one of the worst was the loss in 1980 of a quarters platform in the North Sea with 123 casualties.

o Floaters. Drillships and barges also have excellent overall safety records. There is only a single loss recorded while moving. The major loss category, except for an equal number of blowout accidents, has been storm damage on location.

o Submersibles. Since they are primarily intended for use in very shallow waters, submersibles represent a minor part of the MODU fleet, and the accident record is sparse. Unspecified storm damage on location is the most frequently reported accident. As in the case of mat-type jack-ups, submersibles are also subject to sliding under storm loading, with consequent hazard to wells and other installations but with only limited risk of major damage to the drilling unit itself.

The Safety Record. From 1955 to 1980, MODUs suffered 86 major accidents, including 42 losses, from environmental or operational overloads (worldwide). Table III-31 classifies these accidents, by activity, weather, and type of rig. Of the 86 major accidents 60 (70 percent) involved jack-up units, about half of which resulted in total loss of the unit. A breakdown of the data by general cause and activity indicated that the U.S. record and the worldwide record were similar. Consequently, in most of the remaining discussion, the worldwide data are utilized to provide a larger statistical base.

From Table III-31 it is clear that the major risks for jack-up rigs occur, as previously noted, in the transit and moving on or off location phases. A major influence of storms can be noted in the transit accidents, but not in moving on or off location. This difference is probably due to the fact that the brief moving on or off period cane be more easily scheduled to occur in good weather than the longer transit period.

Of 29 jack-up accidents occurring in transit, 15 were losses; 12 of the 15 were noted to have sunk, capsized, or capsized and sunk. Of the 29 incidents, 21 involved storms, 5 lost towlines, 4 had damage to the legs, and 7 had unspecified damage.

Of the 9 losses while moving on or off location, 2 were due to leg failures, 2 were foundation failures, and 5 were noted as "collapse" or "capsized" without specifying a more detailed reason.

TABLE III-31

Mobile Offshore Drilling Units
Accidents from Environmental or Operational Overload
(Worldwide)

Activity and Weather	Severity	Type Rig				
		Jack-up	Semisub-mersibles	Floater	Sub-mersibles	Totals
In Transit Storm	Major Acc.[1]	21	2	1	0	24
	Loss	9	1	1	0	11
In Transit No Storm [2]	Major Acc.	8	1	0	0	9
	Loss	6	1	0	0	7
Moving On Or Off Location	Major Acc.	21	2	0	1	24
	Loss	9	1	0	0	10
On Location Storm	Major Acc.	1	0	1	1	3
	Loss	0	0	0	1	1
On Location No Storm	Major Acc.	3	0	2	0	5
	Loss	3	0	0	0	3
Unknown Storm	Major Acc.	4	4	4	4	16
	Loss	3	1	3	2	9
Unknown No Storm	Major Acc.	2	3	0	0	5
	Loss	0	1	0	0	1
Totals	Major Acc.	60	12	8	6	86
	Loss	30	5	4	3	42
Total Rig Years Operation		2,332	921	1,048	662	4,966
Rig Years Per Loss		78	184	262	221	118

*1/ "Major Accidents" are those which involve over $500,000. Losses are included in this category.

*2/ "No Storm" means only that "Storm" was not mentioned in the available records.

Source: Committee on Safety of OCS Activities; data from Offshore Rig Data Service, Inc.

However, of the 12 accidents that did not result in losses, 5 were noted as leg failures, 4 as foundation failures, and only 1 additional one was noted as capsizing without a more detailed reason. This indicates that leg structures and foundation sediment failures were major causes of accidents while moving on or off location. It appears probable that some of the accidents that were noted as "capsized" or as "collapsed" were also leg or foundation failures.

The 12 semisubmersible accidents were largely associated with storms and structural cracking of the legs. Storms were noted in 7 cases, and "structural cracks from a previous storm" were noted in another. "Structural crack," "damage to legs," or "possible fatigue" were noted in 6 accidents. These results lend credence to the earlier discussion of structural cracking or fatigue as a major risk for semisubmersibles.

Floaters and submersibles have the best safety records of the four types of MODUs. Together they account for only 16 percent of the accidents (14 of 86 accidents and 7 of 42 losses). The data are too sparse to reveal anything about the influence of type of activity since that was "unknown" in 8 of the 14 cases (4 for each type). Storms, however, did appear to have a major influence since 12 of the 14 records noted storms.

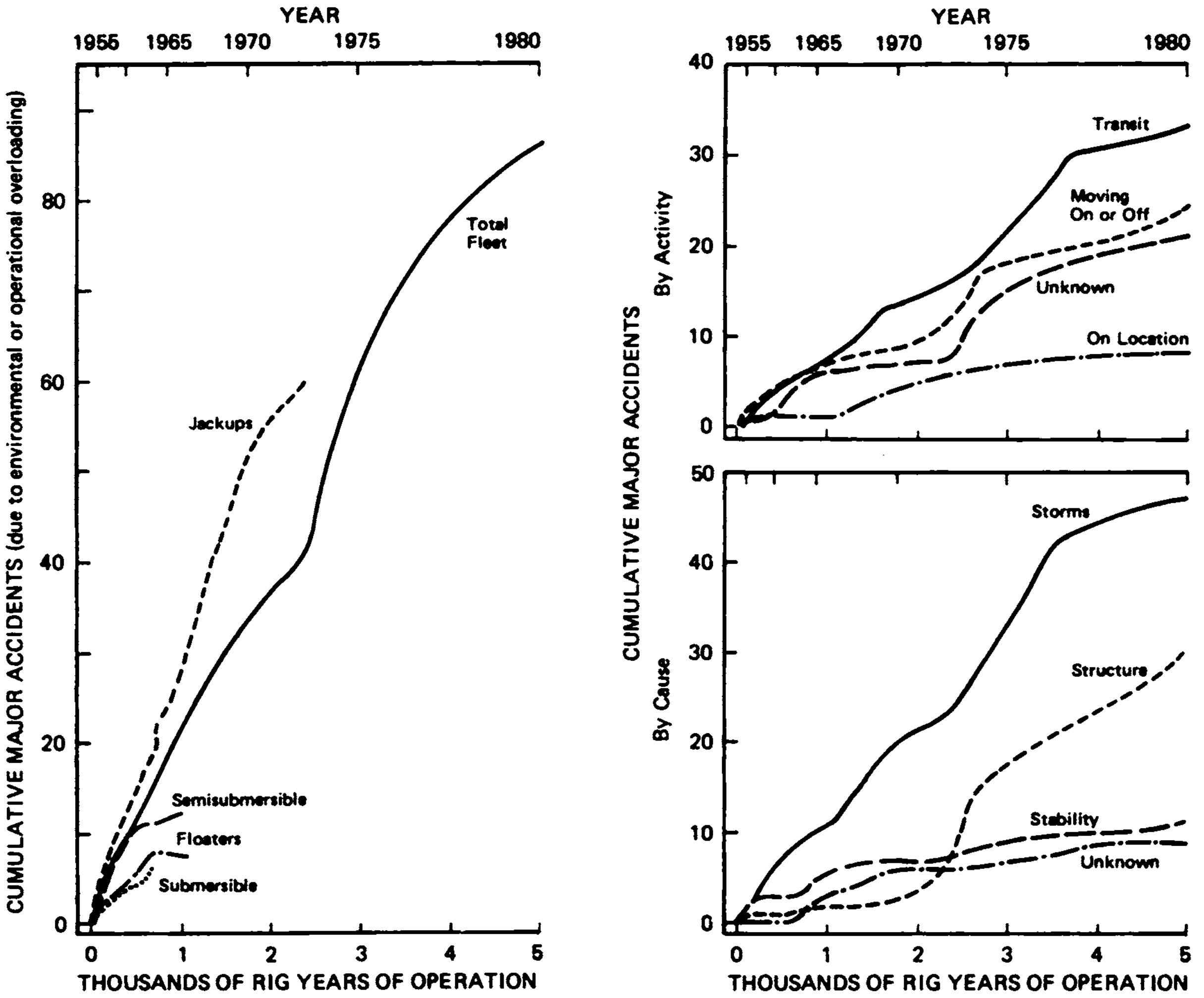
Causal data indicate that of the 86 major accidents involving MODUs, 47 were storm-related, 30 were structure-related, 11 were stability-related, and 9 were unknown (including 1 "human error"). The individual numbers do not total 86 since some of the storm-related cases were also structure- or stability-related, and some of the accident records contain no causal information beyond "damage in storm" or "lost in storm."

Figure III-20 plots cumulative accidents against cumulative rig years of operation. Most of the curves exhibit the general decreasing-slope shape characteristic of learning and/or improved technology. However, the curve representing the risk of moving on or off location and the curve for losses due to structural problems show a recent upward trend, in both cases due to the experiences of jack-up rigs. Also, the curves show rises in accident rates for the early 1970's when the rate of exploratory drilling increased and many new or less-experienced crew members joined the fleet.

MODU Technology Development for Frontier Areas. The greatest use of MODUs in frontier areas will probably be semisubmersibles and drillships in the deeper waters and jack-ups in the shallow waters and in the warmer regions of the Arctic. In the very shallow waters of the high Arctic, barge-type and mobile gravity-type platforms may be employed. In view of this probable usage, the primary technology developments that will be needed are as follows:

- Continued improvement in structural joint design methods to prevent stress and corrosion-induced cracking in both semisubmersibles and jack-up legs.

Trends in MODU Accidents



Source: Committee on Assessment of Safety of OCS Activities

Figure III-20

- Continued improvement in site survey procedures, analysis, and utilization to minimize jack-up foundation sediment failures;

- Continued improvement in low-temperature characteristics of structural materials and design for both types of units.

- Improved iceberg protection, which includes iceberg prediction, tracking, and removal techniques as well as some actual structural resistance to ice impact.

The Regulatory Regime for MODUs. The primary avenues of regulation to achieve safety in MODU operations are through the Coast Guard and the Geological Survey.

- Coast Guard. Coast Guard regulatory requirements for MODUs are covered in 33 CFR, Subchapter N, (OCS Facilities); 46 CFR, Subchapter I-A (MODU design); and 46 CFR 109.121 (Operating Manual).

  Since MODUs are vessels, their seaworthiness (structural strength and stability) is monitored by the Coast Guard through each unit being classed under the American Bureau of Shipping "Rules for Classification of Mobile Offshore Drilling Units." These standards are developed in the same manner as are other ship classification standards through cooperative industry, technical certification society, and Coast Guard efforts. The experience base relative to MODUs however, is more limited than that for many other types of vessels.

  MODUs of foreign registry that operate in U.S. waters must meet essentially the same safety requirements as those of U.S. registry. When a foreign unit enters the OCS, and prior to operating under a Geological Survey drilling permit, it must meet the Coast Guard's requirements in 33 CFR 143.207. If the unit is found to be acceptable, the Coast Guard issues a Letter of Compliance, which must be reviewed each year the unit continues to operate on the U.S. OCS. The Coast Guard determines the unit's equivalent safety through the process of reviewing safety certificates issued to the unit by other governments and agencies, by review of design plans and specifications, and by inspection of the unit. The level of plan review and inspection performed by the Coast Guard depends on the acceptability of any safety controls the unit was subject to by its flag state. A valid International Maritime Organization MODU certificate or a certificate issued by a government whose standards are considered equivalent to the Coast Guard's will receive minimum plan review inspection (33 CFR, Subchapter N). Otherwise, it is possible that the design, equipment, arrangement, machinery, electrical, and stability plans will be reviewed; thorough material inspection will be made of the hull, including dry docking or underwater examination; and operational checks and emergency drills will be performed.

Safety and health conditions, the adequacy of emergency procedures, and the operating manual are always checked. For as long as the unit operates on the U.S. OCS, the Coast Guard conducts periodic inspections of the unit.

o U.S. Geological Survey. With regard to safety of location, the Geological Survey requires, through OCS Order No. 2, paragraph 2, "Drilling From Fixed Platforms and Mobile Drilling Units," evidence of the fitness of a mobile drilling unit, including its capability to withstand oceanographic and meteorological conditions in the area of the drilling operation. The Order provides that, after a drilling unit has been approved for use in an area, the information need not be resubmitted, unless there are changes in the equipment that affect the rated capability of the unit. The Order further states that the Geological Survey may request the submittal of sediment and seabed data, e.g., seabed profiles, sediment consistency, allowable bearing and sliding loads, and nearby potential seabed hazards, i.e., sand waves, slumps, and mudslides. These data are always requested in frontier areas and in mature areas where the bottom conditions are unknown or questionable. The application of this requirement to floaters is to ensure the safety of mooring systems and wellhead installations.

The intermediate area of "moving on or off location" appears to be an ill-defined area and yet it is one that accounts for about 25 percent of the accidents. The data indicate that accidents while moving on or off location are probably rooted in some combination of faults in seaworthiness (stability), structural strength, foundation adequacy, and operational procedures. With the exception of the foundation sediment strength, these factors appear to be more related to the present responsibilities of the Coast Guard.

Adequacy of Technologies and Regulations. Considering the additional hazards associated with their mobility, as compared to fixed platforms, the safety record indicates that in general the status of MODU technology has continued to improve. The seaworthiness of jack-ups under tow is an area of safety concern; others are the integrity of leg structures and foundation for jack-up units moving on or off location and the integrity of leg and bracing joints of semisubmersibles under cyclic loading.

Some additional information on the safety of MODUs may become available from a review and development of uniform rules for semisubmersible vessels that was recently undertaken by the International Association of Classification Societies. The solution to the jack-up foundation problem should benefit from recent trends toward increased utilization of available geophysical and geotechnical survey and analysis methods and from more general recognition that the problem exists.

Weather is noted to have been a key factor in several major jack-up losses. In particular, it is a matter of concern for mobile rigs that must move over long distances and undergo critical transitions from afloat to fixed or vice versa. It would seem prudent for each operator to obtain and use the best weather data available for these operations. There are, however, some real limitations on the accuracy of such forecasts because of the inadequate data base for surface predictions offshore. The National Weather Service has recognized this deficiency and is taking steps to improve the situation.

The question of jack-up seaworthiness under tow may be more difficult to deal with. The primary improvements may have to be made in transit-planning and operational procedures to reduce the severity and frequency of storm exposure rather than by basic improvements in jack-up characteristics. Coast Guard regulatory authority over jack-ups provides an opportunity to bring about improvements in this accident category.

The jack-up operational phase of moving on or off location is clearly hazardous for a variety of reasons and is, therefore, extremely demanding of personnel skill and judgment. Tipping, capsizing, or overturning of jack-ups during this critical phase can result in loss of life, and even well damage in some cases. Recently, this area has been the subject of increased regulatory attention, including changes in Geological Survey rules and proposed increased regulatory coverage by the Coast Guard.

Floaters and submersibles are the least numerous of the MODUs in use today. They have exhibited the best safety record in terms of accidents per rig-year of operation and therefore appear to warrant little special attention. Floaters, especially drillships, represent a nominal departure from the design and operation of commercial ships--which have a very long history, a well-developed technology, and a firmly established regulatory framework.

While floaters and submersibles are somewhat safer than submersibles and jack-ups, all MODUs are less safe than fixed platforms, at least with regard to environmental and operational overloads.

Findings and Recommendations on the Safety of Mobile Installations

The following findings relate to MODU accident history covering the period 1955 through mid-1980 and exclude those accidents and losses related to blowouts, fires, and explosions. In general, the loss rate for MODUs exceeds that of fixed platforms by almost an order of magnitude. Over the record period, the loss rate steadily diminished in all categories of operation except when in transit or moving on or off location.

Since 1955, the worldwide fleet of MODUs of all types experienced approximately 4,870 platform-years and recorded 86 major accidents (0.017/year). Approximately half of these accidents (42) resulted in total loss of the installation (0.008/year).

Among the different MODU types, jack-up units have experienced the highest accident rate (0.026/year). Their two worst hazard exposures, accounting for 77 percent of jack-up unit accidents, occurred (1) while the units were in transit or (2) when they were moving on or off location.

The high incidence of damage to, or loss of, jack-ups while in transit indicates this to be the largest single accident category for MODUs. The causes of in-transit accidents appear to be related to stability under tow, particularly during storms. Only 5 of the 29 reported accidents resulted from broken towlines. Available reports do not identify the extent to which inadequate weather forecasting and human error were contributing causes in this accident category, but expert opinion identifies both of these as important factors.

The record indicates that jack-up mobile units are vulnerable also when moving on or off location, i.e., when undergoing the transformation from a floating vessel to a bottom-supported platform, or vice versa. Accident reports include numerous indications of leg collapse and also of soil failure beneath the legs. While most accident categories exhibit a clearly declining rate, this category does not. OCS Order No. 2, paragraph 2, "Drilling From Fixed Platforms and Mobile Drilling Units," provides the Geological Survey with the authority to require seabed data at any drilling site. Using this authority to require a foundation installation plan (and contingency planning) offers a possible means of reducing the risk of installation loss of damage when a jack-up unit moves on or off location.

The jack-up operational phases of transiting and moving on and off location are clearly hazardous and therefore demanding of personnel skill and judgment. The quality of personnel skill and judgment could possibly be improved through the establishment of manning provisions for jack-up units requiring (1) certification or licensing of persons, through examination, to establish their competence to serve in MODU command positions during specific operation phases and (2) the designation by each MODU operator of the person who has command and control of the unit during all operational phases and the identification of when the command responsibility shifts from one phase to the next.

Semisubmersibles experienced the second-highest accident rate (0.014/year) among the MODU groups. The record shows a vulnerability to structural cracking, resulting from the combined influences of structure configuration, severe cyclic loading, and corrosion fatigue. It is significant, however, that many of the major accidents reported for these structures consisted of storm-related structural cracking that was detected and repaired without installation loss. There were only five total losses of semisubmersibles (0.005/year), which is roughly comparable to the loss experience of floaters (0.004/year) and submersibles (0.005/year).

MODU accident frequency is serious enough to warrant continued industry efforts to seek technological and operational improvements.

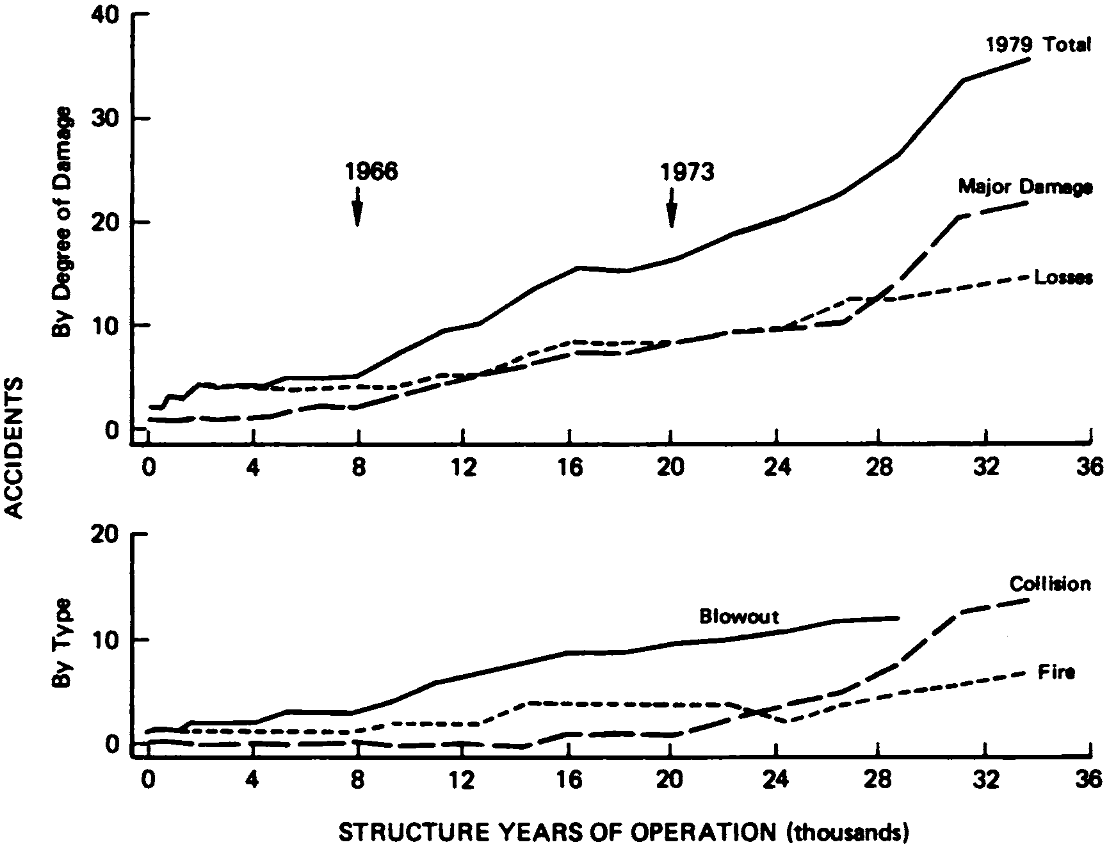
There is an adequate regulatory basis for administering the safety of mobile installations. Within the framework, specific regulatory steps can be taken by the Coast Guard and the Geological Survey to improve the safety of jack-up rigs.

> It is recommended that the Coast Guard consider establishment of manning provisions for jack-up units requiring the following:
>
> - Clear designation by each MODU operator of the person who has command and control of the unit during all operational phases and identification of when the command responsibility shifts from one phase to the next.
> - Certification or licensing of persons, through examination, to establish their competence to serve in MODU command positions during specific operational phases.
>
> It is recommended that the Geological Survey consider extending its authority under OCS Order No. 2, paragraph 2, to include requirements for a foundation installation plan compatible with the reported seabed conditions and a contingency plan to be followed if actual conditions are found to differ from those anticipated.

The Effect of Operational Accidents on the Safety of Installations. The safety of installations can be affected by operational accidents such as blowouts, fires and explosions, and collisions, as well as by design overloading. While other sections of this chapter analyze the causes and consequences of, and adequacy of technologies and regulations that apply to, blowouts, fires, and explosions, this section reviews these operational incidents to determine their effect on the safety of OCS installations. In addition, collisions between vessels and all types of OCS installations are discussed.

Figure III-21 presents data on operational accidents by type and by degree of damage. The shapes of the curves are possibly distorted for about the first 15,000 structure-years of operation due to incomplete records. The accuracy of the data improves after 20,000 structure-years (1973). All of the curves rise at that time, which may possibly be the result of a general increase in offshore activity that dates from the early 1970's. The sharper rise in total accidents at about 25,000 structure-years is primarily due to an increase in the incidence of collisions that cause major damage to structures. From 1956 to 1979, operational accidents have caused the loss of, or major damage to, 34 OCS installations. Fourteen of these have caused the total loss of the installation. Of these 34 accidents, 14 each are attributable to collisions and blowouts, and 6 were due to

Operational Accidents that Affected the Safety of OCS Installations (1956-1979)



Source: Committee on Assessment of Safety of OCS Activities; data from U.S. Geological Survey and Offshore Rig and Data Service, Inc.

Figure III-21

fires and/or explosions. The chances of an operational accident causing major damage to an installation are about a tenth of a percent based on total installation exposure (cumulative structure years).

- o Blowouts, Fires, and Explosions. Most OCS accidents in which installations are damaged or lost involve blowouts, fires, and explosions. Review of accident records reveals that the causes of installation-damaging blowouts, fires, and explosions roughly parallel the causes of all blowouts, fires, and explosions. It appears probable that the remedy for installation-damaging operational accidents lies in preventing the blowout, fire, or explosion rather than in attempting to design the structure to resist such occurrences.

- o Collisions. OCS operators report incidents of structural damage or installation loss to the Geological Survey. For the 11-year period, 1969-1979, 38 collisions of vessels with fixed platforms were reported. Eleven of these resulted in major structural damage to the platform, while three resulted in total installation loss. The Coast Guard requires that vessel operators report collision incidents. For the 4-year period, 1975-1978, Coast Guard collision files reveal 39 serious collisions of vessels with fixed platforms, with 29 of these being attributed to personnel error. Most of these accidents involved service vessels, and little installation loss resulted. From 1975 to 1980, only 3 of 115 accidents in which OCS installations were lost were identified as collisions, with 2 of the losses occurring in a single storm-related accident between two mobile units.

  While all fixed platforms and MODUs share the risk of collision, it appears from the accident record that major losses of this kind are rare. Collisions with supply boats and other support vessels are probably numerous but represent little risk to the installation itself. Collisions with fishing and recreational vessels also are infrequent and are unlikely to cause significant damage to the OCS installation. The major collision risk would be with a commercial ship of large tonnage. (Such an incident occurred in the Gulf of Mexico for the first time in 1980).

  Data from the North Sea tell a somewhat different though not incompatible story.[54] These data show that most (90 percent) infringements of the safety zones that surround OCS installations are perpetrated by fishing vessels, especially when the safety zones cover fishing grounds. On the other hand, the great majority (90 percent) of actual collisions involve vessels having business with the installation. The most common scenario for colliding is a supply boat berthing alongside a dynamically positioned rig. This is not surprising, for errors of judgment are likely if the

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installation being visited is itself moving. In fact, in the United Kingdom sector of the North Sea, the risk of collision for visits to mobile rigs has been estimated to be four times that for platforms. Visibility does not appear to be a major factor in the occurrence of collisions in the North Sea.

For both safety-zone infringements and actual collisions, the perpetrating vessel is most likely to be small simply because the majority of vessels in the vicinity of the installations are also small. Collisions with small vessels such as supply boats and support vessels represent little structural risk to the OCS installation because of the disparity in size.

o Regulations Applicable to Operational Accidents. The regulations pertinent to blowouts, fires, and explosions have been presented and assessed in other sections. Safety against collision is regulated by the Coast Guard through 33 CFR 67, which specifies lights and fog signals to be used by mobile drilling units. The Corps of Engineers issues permits covering the location of offshore installations.

Through 33 CFR 209, the Corps of Engineers has the authority to establish shipping safety fairways and anchorage areas. The Coast Guard has the authority to establish vessel traffic control systems (akin to an air traffic control system) where the marine traffic warrants such measures. The use of fairways and traffic control systems by ships is not mandatory. Alternatively, the location of OCS installations in fairways is not necessarily prohibited. It is decided by the Corps of Engineers on a case-by-case basis.

o Adequacy of Technologies and Regulations. The most practical course of action to mitigate the structural damage and loss effects of blowouts, fires, and explosions is to prevent the accident in the first place, rather than to attempt to design structures to resist such occurrences.

Collisions in OCS operations occur most frequently during berthing of supply vessels to installations, especially mobile installations. While this type of collision is not a threat to the structural integrity of the rig, it can damage risers and corrosion protection systems, as described in the "Pipelines" section. These injuries can lead to marine pollution and structural damage at a later date. A related technological problem is the damage that small boats can inflict on pipelines if they anchor into or trawl across a pipeline. Both of these operational problems could probably be lessened through the application of systems analysis techniques to the operation of relatively small boats in the vicinity of large offshore installations.

While small vessels are the ones most likely to be involved in collisions with offshore installations, the risk of collisions between large ships and offshore installations is growing commensurate with the increase in offshore activity, as evidenced by the proliferation of offshore installations and higher volumes of marine traffic. As with blowouts and fires, from an engineering standpoint, it is impractical to design a platform to be able to withstand head-on impact from a moving ocean-going vessel. The only procedure that can eliminate the risk of collision is to ensure that vessels do not operate in areas of offshore platforms. As platforms have evolved through the years, they have gradually become larger, heavier, and stronger. As such, while not able to withstand a collision from a ship, today's platforms have reached the point where as the result of the collision the ship also withstands major damage. Due to this fact, ship operators appear to be exercising more caution than in the past when operating in areas of offshore oil and gas activity.

Findings on Operational Accidents

The causes of blowouts, fires, and explosions that result in major damage to or loss of installations roughly parallel the causes of all blowouts, fires, and explosions. It is more practicable to prevent operational accidents than to attempt to design OCS installations that can withstand them.

The likelihood of the use of tankers in some frontier areas raises the possibility of increased risk of collision between vessels and OCS installations.

Experience suggests that collisions between vessels and OCS installations result from willful or careless disregard of both voluntary and mandatory navigation restrictions and that a problem exists with respect to identifying and penalizing violators.

There is insufficient evidence to conclude that either improved technology or regulatory changes in the absence of improved attentiveness and compliance by ship operators would reduce the incidence of collisions of ships with OCS installations.

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38. See, for example, Department of Commerce, Maritime Administration, National Maritime Research Center. Characteristics of the Chronic Repeater of Illnesses and Injuries Onboard U.S. Ships and A Survey of Operator Claims Costs. National Maritime Research Center, Kings Point, N.Y., July 1979, a report prepared from statistics of the Marine Index Bureau. Available from the National Technical Information Service, Springfield, Va.
39. Data from Norwegian Council for Scientific and Industrial Research, and the U.S. Geological Survey Events File.

40. This pattern can be traced back to the congressional investigation of the MORRO CASTLE, which burned off the coast of New Jersey in 1934.
41. The Stanwick Corporation. *Shipboard Training and Maintenance for Merchant Vessel Survival Training.* Report prepared for the Office of Research and Development, U.S. Coast Guard, U.S. Department of Transportation, Arlington, Va. The Stanwick Corporation, October 1979. Available from the National Technical Information Services, Springfield, Va. (Report No. CG-M-1/80).
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CHAPTER IV

UNDERLYING CONSIDERATIONS

A number of safety considerations came to the fore repeatedly in the areas of safety concern in the previous chapter and are addressed in a broader context here. These considerations relate to the following:

- The coupling of resource discovery and technological development wherein neither tends to move forward without progress in the other.
- The critical role that human performance plays in the safe use of technology in OCS development and in the effectiveness of regulation.
- The complex interaction of multiple legal authorities, regulatory approaches, technology, and a highly variable environment.

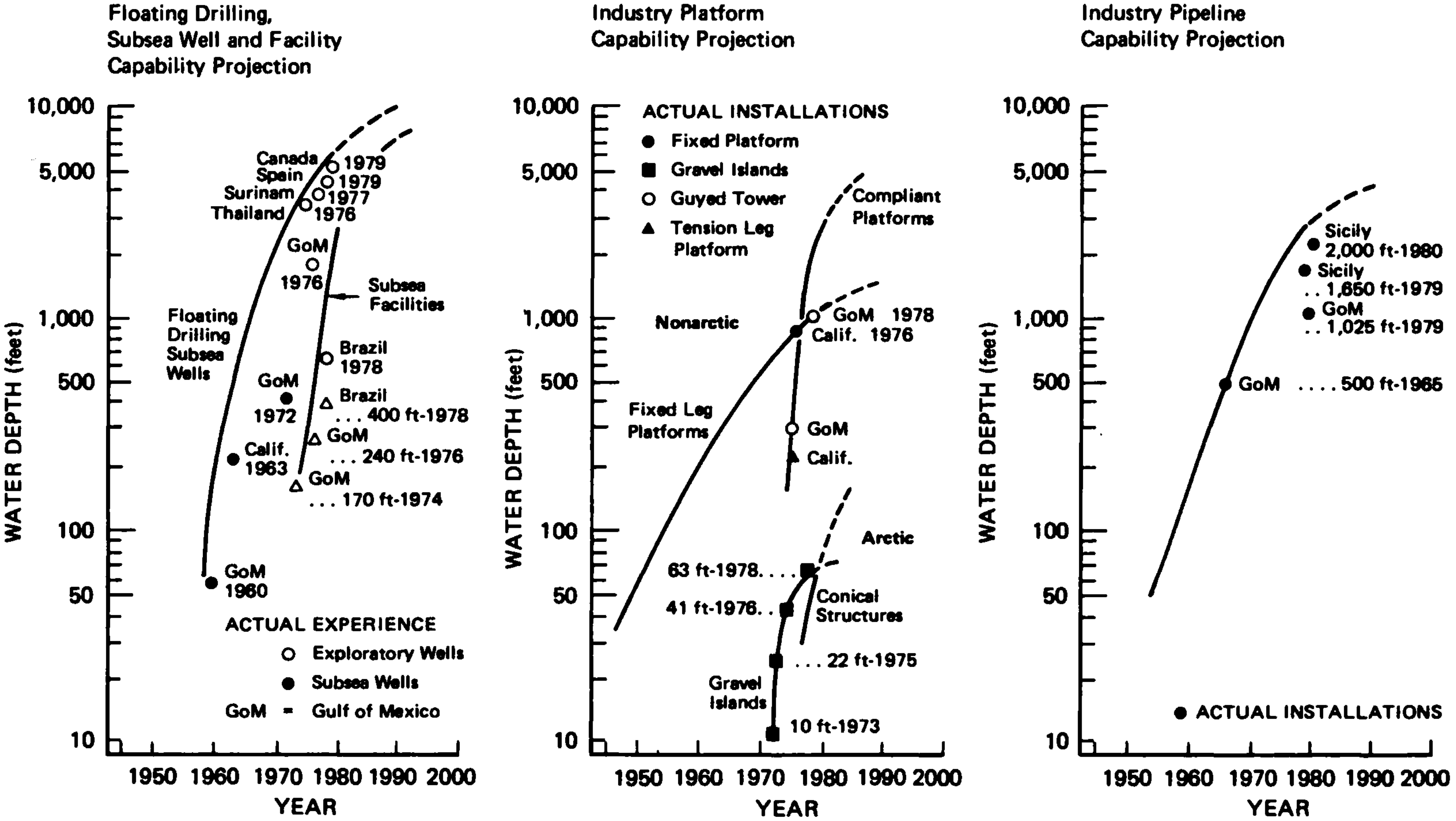
The Coupling of Resource Discovery and Technological Development

The fundament for all offshore development has been the development of technology capable of safely producing oil and gas from beneath the sea. In early exploration in the Gulf of Mexico, sunken barges and jury-rigged ironwork sections of scrap bridges were used as drilling platforms of convenience. These technological measures provided the starting point for the development of the offshore oil and gas industry. Just three decades later, platforms that serve the same purpose in deep water as those early shallow-water makeshift installations are designed to withstand hurricanes or ice floes and to stand taller than the Empire State Building.

The offshore industry may be predominantly American in origin but it is now international in scope. The U.S. offshore industry has developed the majority of all offshore technologies. The primary means by which these technologies have been developed and through which they can be advanced is the result of actual offshore experience.

Water depth has been an important limit in terms of costs and technological capability in the past. Figure IV-1 depicts the gradual extension of technological capability to operate in deeper waters. This figure is an industry projection of technical capability that has been widely circulated and accepted.

EXTENSION OF TECHNOLOGICAL CAPABILITY TO OPERATE IN DEEPER WATER



Source: "Outer Continental Shelf Frontier Technology," National Research Council, Washington, D.C., 1980, pp. 7, 9 & 11.

Figure IV-1

Currently, the deepest water in which an exploratory well has been drilled from a floating structure is 4,876 feet (about 1,500 meters), off Canada (1979). The greatest water depth in which a subsea completion has been installed is 620 feet (about 190 meters), off Brazil (1978). The present capability for installing subsea facilities extends to about 5,000 feet (1,500 meters).[1] The reason that subsea well completions have not been undertaken in greater water depths is not because of lack of technology but simply because of the lack of appropriate commercial discoveries. The tallest fixed-leg platform stands in water 1,028 feet (310 meters) deep, in the Gulf of Mexico (1978). It is expected that the cost of fabrication and certain installation constraints will limit the use of fixed-leg platforms to a water depth of 1,200-1,500 feet (360-450 meters). However, new types of platforms, such as guyed towers and tension-leg platforms have the potential to substantially extend platform capability, to about 2,000 feet (600 meters) and 3,000 feet (900 meters), respectively. A guyed tower was installed at a depth of 400 feet (120 meters) in the Gulf of Mexico for test purposes. Similarly, a test tension-leg platform was deployed off California in water 200 feet (60 meters) deep. Gravel islands have been constructed to a water depth of 63 feet (20 meters) in the Canadian Arctic. The costs of this technology are expected to limit its use to about 80 feet (24 meters). Beyond this depth, fixed Arctic installations are expected to be gravity-type conical structures. Subsea pipelines have been laid off Sicily in 2,000 feet (600 meters) of water.

Deepwater Technology

Oil and gas development in deep water will require the continued development of technology and also the use of emerging technology. A major driving and limiting factor in technological development and use is economics. An obvious technical challenge in deep water is the very distance itself between the ocean surface and the seafloor. Structures that span this distance must be designed and anchored to accommodate wind and wave forces at the surface and the effect of currents throughout the water column. Operations conducted at the seafloor are subjected to large water pressure forces and are controlled through long flowlines or by means of sophisticated electronics. Increasing water depth compounds all these problems and requires increasing strength or sophistication in the technology. Costs thus rise as the water depth increases.

In 1979, there were approximately eight semisubmersibles capable of drilling in water depths of 2,000 feet (600 meters) and at least three drillships designed to drill in waters up to 6,000 feet (1,800 meters).[2] However, no more than two of these vessels are equipped with sufficient riser, controls, etc. to work in such deep waters.

The industry is probably capable of developing the technology to drill wells at much greater depths. The government is planning a program that might accelerate this technology development. This involves the conversion of the EXPLORER into a drilling vessel, complete with deep-sea, well-control equipment and risers.[3] If this program proceeds as planned, the capability for drilling exploratory wells in waters depths up to 13,000 feet (4,000 meters) could be available in the 1985-1990 time frame.

It is a giant step from drilling a well in deep water to producing oil or gas there. As has been described, the use of fixed-leg platforms will be limited by cost and installation considerations. Using compliant platform designs, fixed platforms can be used out to perhaps 3,000 feet (900 meters). Beyond these depths a shift to subsea completions will probably be necessary.

Deepwater oil and gas production must be transported from the seabed oil fields to markets. This can be accomplished by pipeline or by vessel. To date, large pipelines have been laid in up to 2,200 feet (660 meters) of water using modified present generation lay barges. A method has been developed for laying large-diameter pipe in 3,000 feet (900 meters) of water.

Transportation by vessel requires a production riser to bring the oil and gas to the surface for processing and transfer and also a floating vessel terminal. There are at least three major production riser test programs under way or being considered for funding by industry.[4] The current record for floating offshore loading terminals is 520 feet (160 meters). Most floating offshore terminal experts believe that existing technology can be extended to water depths of about 2,000 feet (600 meters).[5]

Arctic Technology

Technology for Arctic oil and gas development is advancing rapidly. The major proving ground is the Canadian Arctic, where offshore oil and gas development is ahead of U.S. Arctic offshore oil and gas activities. The Canadian experience has shown that several things are needed before Arctic offshore oil and gas proceed. For example, it must be shown that acceptable knowledge exists of ice forces and of the performance of a production platform system subject to such ice forces. Confidence must be achieved in the cost expectations of constructing such a platform system. Acceptable knowledge also must be demonstrated of the predicted performance and cost of transportation systems. Finally, it must be shown that environmental risks can be reliably predicted for both production and transportation activities and that the risks are acceptable.

Ice presents the major technical challenges in Arctic offshore development, where very large masses of ice move relative to the well or installation location. Sea ice displays a complex variety of forms and properties. Studies of sea ice are in progress and in planning.[6] There are three major types of sea ice formations that Arctic offshore engineering designs must take into account: level ice with pressure ridges extending to 35 meters; multiyear hummock fields 15 to 30 meters thick and several kilometers in diameter; and ice islands, which can be 60 meters thick and several kilometers in diameter. Moving under the influence of currents and winds, sea ice can generate large lateral forces on offshore installations, and the ice must be caused to flow around and pass an installation.

Arctic ice is a certainty about nine months of the year, and it can be present at any time. The likelihood of encountering large ice forces requires that Arctic offshore platforms be different from those in other regions. To cope with the large lateral shear forces, industry has turned to the construction of artificial earth islands. Seventeen exploratory drilling islands have been built in water as deep as 63 feet (20 meters), and none have been adversely affected by ice. Production islands in deeper water will have to be more substantial than the temporary exploratory structures that have been constructed so far. While the existing exploratory islands are about 300 feet (100 meters) in diameter, a production island would be about 1,500 feet (500 meters) wide. Therefore, semipermanent production islands capable of withstanding years of ice shear and override attack will be signficantly more costly than temporary exploratory islands.

Building production islands will require extensive dredging and marine construction. The volume of material required for a production island may reach 70 million cubic meters as opposed to 2 million cubic meters or less of material used in exploration islands.[7] By way of comparison, the Netherlands' Zuyder Zee Dike required more than 40 million cubic meters of dredged material. Arctic dredging and construction operations on that scale will require advances in dredges to extend the working season in ice, work at greater depths, and with larger quantities; new construction techniques must be developed to create steeper underwater sand slopes, stabilize the Arctic seabed, and create protection in the ice attack zone. Such large-scale dredging will result in the suspension of a great deal of sediment in the water column. This in turn will impact on the biota in a number of ways, including smothering of benthic biota.

Studies indicate that movement of oil from the Arctic to Central North American markets is economically more attractive by tanker than by pipeline until oil throughputs reach the 750,000-barrels/day range.[8] More important, the use of tankers will permit Arctic development to proceed at a much earlier date since the marginal reserves required to justify tanker transportation are an order of magnitude lower than those required for a pipeline. Arctic tanker operations will require the development of ice-breaking tankers. This development is well under way. Also, ice-breaking tankers must be manned by well-trained, Arctic-experienced officers and crew. The safety of Arctic navigation can be improved by continuous navigational assistance. However, the risk of spills and other catastrophes is higher with tanker transport than with pipelines.

Arctic ecosystems would be slow to recover from accidental or intentional degradation as the result of oil and gas operations. In considering Arctic offshore oil and gas operations, it is necessary to understand the ecosystems so that development plans can be built around environmental mitigation strategies. In addition, technology and contingency plans for spill containment and cleanup must be developed.

All of these Arctic problems should be viewed as technical challenges and not as forestalling development. In neighboring Canada, the first Beaufort Sea production is anticipated about 1985.[9]

Economic Limitations

The economics of deepwater and Arctic development will bear little resemblance to the Gulf of Mexico pattern. The Gulf of Mexico has been characterized by the incremental development of a large number of relatively small but adjacent producing reservoirs and progressively deeper water. A large producing well in the Gulf may produce 1,000 barrels of oil a day. By way of contrast, production rates in the North Sea, where environmental conditions are not dissimilar to those encountered in the North and Mid Atlantic frontier regions, are an order of magnitude higher.

The cost of Arctic and deepwater development will be much higher than the cost of Gulf of Mexico development because harsher environmental conditions--deeper water, harsher climate--will be encountered. This means that a frontier area discovery can only be commercially attractive if it is very large and able to return enough revenue to support the high costs of development. For purposes of comparison, projections of the Kopanoar field in the Canadian sector of the Beaufort Sea indicate that, based on current prices and technology, at least 40 million barrels of oil reserves must be recoverable from one production platform in order for an Arctic discovery to be commercial.[10] The commercial reserves tapped by the COGNAC platform in the Gulf of Mexico are estimated to be about 100 million barrels of oil (and an equivalent amount of natural gas).

Environmental Conditions

Of crucial importance in offshore operations are such environmental conditions as sediment stability, seismic activity, winds, waves, currents, and ice and snow, and the biological sensitivity and productivity of the area. These provide the physical framework in which offshore development must take place. They control whether or not existing technologies can be deployed in each OCS area. They also dictate the character and pace of technological development.

These conditions, collectively termed environmental exposure, need to be understood and accommodated in the design, fabrication, deployment, and operation of every offshore structure because they provide the environmental criteria to which structures must be designed. Failure to design and/or construct an offshore structure that meets or exceeds the environmental design criteria will place the integrity of the structure in jeopardy. Equally important, it jeopardizes the safety of operating personnel, the integrity of equipment, and the preservation of the environment. Designing and constructing to (at a minimum) the environmental design criteria results in a structure that achieves the desired operational and functional requirements in a particular environment while maintaining an appropriate balance between safety and costs. Thus, a thorough understanding of environmental conditions provides a basis for designing structures to operate in a reliable, safe, and economic manner.

Another aspect of the environment that imposes constraints and limits on the development and use of technology is the existing environmental quality of the operating area and its renewable resources. The committee made no attempt to evaluate the effect of OCS development on these resources. Even so, it recognized that some of the frontier areas scheduled for OCS leasing are extremely productive and valuable. Bristol Bay, off Alaska, for example has been described by the Department of the Interior as possessing "the greatest concentration of birds, fish, and marine mammals found anywhere on the North American Continent."[11] It is "The richest fishing ground in the world."[12] Georges Bank, in the North Atlantic, supports a fishery whose yield is worth $229 million a year at dockside.[13] The area is the most productive fishing ground in the world. It is one of the most significant nursery areas in the world, producing fish that are found throughout the North Atlantic.

It will be prudent to schedule OCS activities in certain specific locations so as to safeguard migrating whales or birds or to minimize interference with commercial fishing. Controversies regarding the multiple uses of the OCS are more appropriately resolved prior to than after the auctioning of OCS leases and the commitment of capital to their development.

Table IV-1 provides a synopsis of controlling environmental conditions on the OCS and the technological options and feasibility of OCS development. Information on water depths has largely been excluded because it is very site-specific. Generally, the shallowest OCS frontier region is the nearshore portion of the Beaufort Sea, where depths are measured in tens of meters. The deepest frontier region under consideration for leasing is the Mid Atlantic, where a submerged cretaceous reef lies beneath the continental slope at a water depth of about 6,000 feet (2,000 meters). The information in this table is necessarily tentative because environmental information in a number of frontier areas is preliminary and development has yet to be undertaken.

Findings on the Coupling of Resource Discovery and Technological Development

Many discrete technologies are used in the exploration, development, and production of oil and gas from beneath the oceans. Failure of any particular technology to provide for the safety of oil and gas operations can have a wide range of consequences to people, property, and the environment.

TABLE IV–1 Synopsis of Environmental Conditions and Resources of the OCS and the Technological Options and Feasibility for OCS Development

	Environmental Conditions					Technological Feasibility of Conducting Exploration and Development Within Specific Time Periods		Estimated Time Periods Required to Achieve Initial and Peak Production After a Discovery is Made		
OCS Area	Sediment Characteristics	Seismic Activity	Winds, Waves, and Currents	Ice and Snow	Environmental Resources	Exploration	Development	Initial Production	Peak Production	Transportation Strategy
North Atlantic	*Sediment erosion and deposition.* Sandy bottom material in shallow waters of Georges Shoal is subject to scour. Large active sand wave fields exist in the Nantucket and Georges Shoal areas. *Soil properties.* Glacial outwash, organically rich pockets of clay and silt. *Sediment instabilities.* Potential for mass movement and shallow faulting at shelf edge, especially around canyon heads.	*Earthquakes.* Scattered low-level epicenters in the region. Mass sediment liquefaction is a significant hazard in the event of an earthquake.	*Rapid weather changes.* Severe winter storms. Occasional hurricanes. High ocean current speeds are attained during storms. Fog occurs occasionally. Current patterns create a gyre at certain times of the year that may concentrate pollutants over extended periods of time.	*Infrequent icebergs.* Accretion of ice on offshore structures can be expected during winter. Snowfalls may impair visibility.	One of the most valuable commercial fisheries in the U.S. Major fish nursery for North Atlantic. Many species of marine mammals in the area.	Moderately explored geophysically to date. Geological and geophysical technology is adequate. Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platform presently feasible to at least 1,200 feet. Subsea and/or compliant structure systems are feasible to 2,000-3,000 feet.	Conventional platform. Initial production 6-8 years after discovery. Subsea and/or compliant structure systems will require 6-10 years.	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Offshore loading with offshore storage most likely. Gas - Pipeline to shore to existing systems.
Mid Atlantic	Sediment erosion and deposition occurs as the result of storm conditions. *Soil properties.* Overconsolidated silts and clays. *Sediment instabilities.* Mass Movement has taken place along the walls of many canyons. *Gas in sediment.* Shallow gas deposits in some locations.		Severe winter and tropical storms and attendant high sea state, strong winds, and storm surge current near the coast.		High-discharge freshwater aquifer approximately 200 m below mudline. Extensive commercial fishery. Many marine mammals. High winter population of water fowl.	Hydrocarbons established in basin. Geology fairly well known. Geophysical technology well established. Operational bases have been established. Deep water production technology would have to be implemented. Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platform presently feasible to at least 1,200 feet. Subsea and/or compliant structure systems are feasible to 2,000-3,000 feet.	Conventional platform development. Initial production 5-7 years. Subsea and/or compliant structure systems will require 6-10 years.	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore and to refineries for large production rates. Offshore loading with offshore storage for smaller rates. Gas - Pipeline to shore to existing systems.
South Atlantic	*Soil properties.* Favorable for foundations, although dense sand may pose problems for pile driving. *Sediment instabilities.* Scattered slumps at the base of the Florida-Hatteras slope. *Erosion and deposition.* Strong currents are responsible for some sand waves and other erosional features.	*Shallow faults present.* A deep-seated growth fault has been mapped along the Blake Plateau margin. A major earthquake occurred in the region in 1886.	Tropical storms generate high waves and wind along the southern Atlantic coast and strong currents on the shelf.		Commercial fishery. Localized patches of rich sub-tropical sea-bottom life.		Fixed-leg platform presently feasible to at least 1,200 feet. Subsea and/or compliant structure systems are feasible to 2,000-3,000 feet.	Conventional platform development. Initial production 5-7 years. Subsea and/or compliant structure systems will require 6-10 years.	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore terminal for tanker shipment to demand areas. Offshore storage and loading may be more attractive in some cases. Gas - Pipeline to shore to existing systems.

Eastern Gulf of Mexico	*Soil properties.* Underlying karst may pose drilling and foundation problems. *Sediment instabilities.* Slumping has occurred on the Florida escarpment.				Commercial and recreational fishery. Localized patches of rich sub-tropical sea-bottom life.	Initial exploration done. Geology well known in some areas. Geophysical technology well established in some areas, less so in others. Production bases already well established in Central Gulf of Mexico. Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platform presently feasible to at least 1,200 feet. Subsea and/or compliant structure systems are feasible to 2,000-3,000 feet.	Initial production 5-7 years. For conventional platforms. Subsea and/or complaint structure systems will require 6-10 years.	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline connection to existing systems. Offshore loading with offshore storage may be more attractive in some cases. Gas - Pipeline to shore to existing systems.
Central and Western Gulf of Mexico	*Soil properties.* Biogenic methane can cause excess pore pressures. Undercompacted muds may fail when they are subject to cyclic loading by storm waves. *Sediment instabilities.* Submarine landslides, slumps, and mud flows occur in regions of rapid deposition. *Gas.* Ubiquitously distributed shallow gas creates hazardous conditions, both as high pressure accumulation, and, dispersed as bubbles, as excess pore pressure.	Some faults associated with diapiric features and oversteepened depositional slopes. Little seismic activity.	The probability of a hurricane affecting the area in any given year is 1 in 6.		Commercial and recreational fishery. Localized patches of rich sub-tropical sea-bottom life.	Mature Province. Geology well known. Geophysical technology well established. Production capabilities well established. Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platform presently feasible to at least 1,200 feet. Subsea and/or compliant structure systems are feasible to 2,000-3,000 feet.	Conventional platform development. Initial production 2-3 years on shelf and 3-6 years on slope. Subsea and/or compliant structure systems will require 6-10 years.	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore through tie-in to existing pipeline networks. Gas - same.
California	*Soil properties.* Expansive soils and rocks. *Sediment instabilities.* Slumps, sediment flows and creep have been identified. Mass movement may be earthquake-induced.	*Severe earthquake hazard.* Potential problems include sudden fault displacement and fault creep.	*Occasional tropical-type storm.* Tsunamis have reached the area.		Commercial fishery. Large marine mammal population. Some areas relatively close to shore, including areas of heavy recreational use. Natural hydrocarbon seeps occur in the Santa Barbara Channel. Central California coast is nationally famed for its scenic beauty.	Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platforms feasible to at least 1,200 feet. Compliant structure systems and/or subsea systems are feasible to 2,000-3,000 feet.	5-10 years	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore in some cases to existing systems. Off-shore loading with either offshore storage or on-shore storage may be more attractive in some cases. Gas - Pipeline to shore to existing systems.

TABLE IV-1 (continued)

OCS Area	Environmental Conditions				Environmental Resources	Technological Feasibility of Conducting Exploration and Development Within Specific Time Periods		Estimated Time Periods Required to Achieve Initial and Peak Production After a Discovery is Made		Transportation Strategy
	Sediment Characteristics	Seismic Activity	Winds, Waves, and Currents	Ice and Snow		Exploration	Development	Initial Production	Peak Production	
Gulf of Alaska and Kodiak Shelf	*Soil properties.* Rapid sediment accumulation in the Copper River delta and elsewhere create areas of low bearing capacity. Volcanic ash sediments also have low bearing strength. *Instability.* Occasional slides and slumps occur. These may pose the most problems on the uppermost continental shelf off Kodiak Island. *Erosion and deposition.* Some bed-load movement of sand has been documented in Cook Inlet and elsewhere. *Gas.* Anomulous amounts of gas in surface sediment have been measured.	One of the world's most seismically active areas. Experience with damaged buildings on land shows that structural failure is often caused by dynamic shaking of foundation failure resulting from ground rupture or soil instability. High intensity aftershocks can also cause damage. Active volcanoes occur in the Cook Inlet area. These pose a danger of lava flows, nuees ardente, ash falls, seismic shaking, and tsunamis.	Storms generate high substantial wind speeds. Frequent and intense storms occur, especially in Autumn. Large tidal ranges occur in Cook Inlet.	Ice accumulation on structures in winters. Cook Inlet freezes to a depth of several feet.	Major commercial fishery. Many marine mammals. Major bird migration and nesting routes.	Feasible now to drill in water depths to 6,000 feet.	Fixed-leg platforms feasible to 1,200 feet. Compliant structure systems and/or subsea systems feasible to 2,000-3,000 feet.	6-10 years	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore terminal for tanker shipment to demand areas. Offshore storage and loading may be applicable in a few cases. Gas - If sufficient quantity, pipeline to shore and liquify for shipment to demand areas.
Southern Bering Sea	*Sediment instabilities.* Massive slumps have been identified.	Seismically active area, especially along the Aleutian Ridge. Earthquakes are caused both by tectonic deformation and volcanoes. Seismic hazards include strong-motion ground shaking, fault offset, and mass sediment movement.	Severe wind and wave conditions can be encountered at any time of the year.	Ice accumulation on structures in winter. Cook Inlet freezes to a depth of several feet.	Major commercial fishery. Vast numbers of marine mammals.	Seasonally feasible with mobile rigs.		6-10 years	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	**Bristol Basin** Oil - Pipeline to south side of Aleutians for tanker shipment to demand areas. Gas - If sufficient quantity, pipeline to shore and liquify for shipment to demand areas. St. George Oil - Offshore storage and loading tankers to demand areas. Pipeline to Aleutians for tanker shipment to demand areas may be applicable for very high production rates. Gas - If sufficient quantity, pipeline to shore and liquify for shipment to demand areas.

										Navarin Basin Oil - Offshore loading to ice breaking tankers-storage may be off-shore or on an island. Gas - Pipeline to an island and liquify for shipment to demand areas if sufficient quantity. (Ice breaking LNG carrier.)
Northern Bering Sea	*Erosion and deposition.* Scour depressions and sand waves, ridges and sheets exist at various places, especially near Nome and Port Clarence. Knowledge of these conditions is especially important for pipeline siting. *Gas.* In Norton Sound, buried gas is vented through craters in the seafloor. Sediments near vents are susceptible to liquefaction.	Faults have been mapped south of Nome, in the Bering Straits, near St. Lawrence Island, and offshore of the Yukon delta. While these faults are probably still active, the seismic hazard is not as great as further south.	Severe temperatures in the winter.	Bering Sea ice cover is all first-year accumulation. Thin pancake ice, often modulated by ocean waves, covers the Bering Sea during the Spring melt. Ice gouging is prevalent in water depths less than 20 m.	Commercial fishery. Many marine mammals.	Seasonally feasible with mobile rigs.	Gravel islands feasible to 60+ feet. Ice resistant structures feasible to 200 feet.	8-10 years		Oil - Pipeline to shore for storage and ice breaking tanker to demand areas (possible tanker transhipment point from ice breaking tanker to normal tanker in Southern Alaska). Gas - Pipeline to shore and liquify for shipment to demand areas if sufficient quantity (ice breaking LNG Carrier).
Beaufort and Chukchi Seas	*Erosion and deposition.* Coastal thermal erosion can occur when relatively warm ocean water attacks frozen coastal soils. Also, wave action on thawed permafrost can accelerate erosion. These factors are especially important in pipeline siting. *Instabilities.* Slumps have been detected near the shelf break in the Chukchi Sea. *Gas.* Frozen gas hydrates are widely distributed. These are perceived as hazardous to drilling if expansion of the gas is not contained.	Seafloor faulting has occurred in Hope Basin. Minor seismic hazard overall.	Autumn and winter storms can be severe.	Compressional and torsional ice forces are severe. Multi-year pace ice covers many areas. Ice keels can extend many meters into the seafloor and pose a hazard to pipelines and foundations.	Many marine mammals. Native American subsistence hunting grounds.	Chukchi Sea Seasonally feasible with mobile rigs. Beaufort Sea Gravel islands feasible to 60 feet. Feasibility expected to be extended to 200 feet by the early 1980's with ice resistant structure. Ice islands feasible to 20 feet in areas of minimal ice movement.	Gravel islands feasible to 60+ feet. Ice resistant structure should be feasible to 200 feet by the early 1980's. Gravel islands feasible to 60+ feet. Ice resistant structures feasible to 200 feet by the mid 1980's.	8-10 years	Normally 1-5 years after initial production. Quite dependent on field size, number of structures, etc.	Oil - Pipeline to shore for storage and ice breaking tanker to demand areas (possible tanker trans-shipment point from ice breaking tanker to normal tanker in Southern Alaska). Gas - Probably line to tie to Alaska Pipeline near Prudhoe Bay. Oil - Alaska Pipeline System. Gas - Alaska Highway Gas Pipeline System.

SOURCE: Committee on Assessment of Safety of OCS Activities: Data on Environmental Conditions from "Environmental Exposure Conditions Taken into Account in Lease Sale Decisions," Paul Teleki, Background Paper IX, Section II, *Environmental Exposure and Design Criteria for Offshore Oil and Gas Structures.* National Research Council, Washington, D.C., 1980. Technology and Feasibility information developed by Shell Oil Company (1977).

Today's technology for offshore development has been forthcoming in response to the opening of new OCS areas and the discovery of hydrocarbons. It is not possible for the committee to conclude whether developing technologies will provide adequately for OCS safety operations in frontier areas until the technologies are known and have been demonstrated. It is also difficult to evaluate fully their environmental risks and economic costs.

Thus, it is especially important that technologies and operational procedures be carefully and continually assessed as offshore operations move into untested regions to ensure that they are in line with the environmental conditions. Many existing technical standards to which OCS operations adhere were not originally developed for application to Arctic, deepwater, and sensitive biological areas. They do not take specific account of the environmental conditions in these areas and therefore require special consideration to adapt them.

The Human Element in OCS Safety

Most accidents do not "just happen." People bring them about through inattention, errors, or by inadequate engineering. Workers need to be motivated and trained for safe performance, and safety must be a principal concern of their employers.

The data reviewed by the committee show little change over the last decade in the rate of accidents on the OCS (with the exception of releases of petroleum in the environment). The static level of safety performance appears to result from inadequate attention to motivation, training, and experience of offshore workers, rather than from lack of regulations on this subject.

Characteristics of the OCS Work force

The size of the offshore work force fluctuates according to economic conditions. Historically, low oil prices and low availability of acreage for exploration have brought about extended layoffs of trained workers. High prices for hydrocarbon fuels and the opening of large offshore areas for exploration have increased the demand for offshore workers in recent years, and the demand is expected to grow in the future.

The demand for offshore drilling rigs increased about 13 percent per year from 1975-1978. Based on forecasts of energy consumption, footage drilled, and rig supply and demand, the need for new rig crews is likely to increase by about 10 percent per year. Taking into account the high rate of attrition in the offshore work force (see below), as many as 2,000-3,000 new drilling workers must be hired each year.

High rates of employee resignation and discharge constitute serious operating problems in some segments of the offshore industry.[14] Job changes are more common in the lower skill classifications; however, because of growth in the industry, many positions requiring more experience and/or skill, are being filled by people with fewer years' experience than in the past. The most pressing need in present and future manpower is for qualified people in skilled job classifications.

The continuing demand for new recruits and the high rate of turnover in the labor force affect safety in a number of ways.[15] A high rate of turnover means that the labor force has a high proportion of new and inexperienced workers. Because of the large volume of new recruits, companies may have come to treat the initial tours of offshore duty as a screening or selection process; entry-level workers have traditionally received little formal training prior to going offshore.

A profile of the typical entry-level worker in the offshore industry is a person who is in good physical condition, married, has 11.5 years of school, is 20-25 years old, was active in high school sports, and who grew up in a small town or rural area in the south. This typical offshore worker continues to like living in a small town or rural area, enjoys outdoor work and outdoor recreation, has mechanical aptitude, and a good work record.[16] The South has enjoyed an expansion of jobs in the past years.[17] Many of these jobs are suited to the worker profiled above. While all of the jobs may not offer the opportunity to work outdoors, they do not demand lengthy periods of time away from home. The recruiting efforts of all enterprises constituting the offshore industry are concentrated in these areas as well. The demands of the offshore enterprises (services, transportation, and construction) for trainable entry-level and skilled workers expand with those of drilling and production. Thus the expansion of offshore oil and gas entry-level jobs in drilling and production coincides with increasing competition from other growing economic sectors.

Many unskilled workers move in and out of the OCS workforce. The critical period of turnover is in the first 4-9 months. If a worker stays 9 months, he is likely to stay at least 18 months.[18] For some companies, the turnover rate of workers in entry-level positions is 100 percent, the ratio of resignations to discharges is 4:1.[19] The reasons most frequently given for quitting include "personal problems, isolated living conditions, long-term separation, lack of control of social activities, and too much supervision."[20] Some of these conditions are so central to the offshore working environment that it is difficult to know how they might be changed. The industry has chosen to concentrate on improving personnel selection and altering the rig environment to one more accommodating to new personnel. "The 'environment' to be altered," one industry specialist states, "is basically that of the attitudes of the supervisory personnel, many of whom come from a different generation and consequently, have different values and ideas regarding work."[21] But this is a rapidly changing state of affairs as well.

A tight manpower situation is also evident at the supervisory and engineering levels. As the vice president of a large offshore drilling company commented, "Due to the rapid expansion of the worldwide rig fleet, another force has been working against the average performance levels of the higher skilled people. So many have been promoted so fast to fill the key positions on newly constructed rigs--as well as to take superintendent and rig manager positions--that a large percentage of these key people are working in responsibilities beyond their training and experience."[22] An engineer said, similarly, "It used to be, until the last seven years or so, that all engineers in supervisory positions in the oil and gas industry had 15 to 20 years experience. Now many have 3 to 5."[23]

Selection, Motivation, and Training of Offshore Workers

Personal attitudes and tendencies towards safety vary. Careful selection of personnel can be important in building a safety-conscious workforce. It has been shown, for example, that human performance can be affected by the arrangement in time of working hours: some workers may perform more safely at night than others; the twelve-hour shift may call for too much exertion over too long a period of time for some individuals; rotating shifts, which are common in maritime endeavors but are not often found in OCS work, can adversely affect body chemistry and physiology and this may be manifested in safety performance. It is possible that careful selection of workers to take these considerations into account could contribute to a more safety-conscious workforce.

Careful selection of new hires is also important. Important selection characteristics for the OCS include a positive attitude toward work, ability to withstand long hours, willingness to accept sometimes harsh supervision, ability to work and contribute as part of a team, and the ambition to advance in offshore work.

Given a work force that has been screened and selected for pertinent characteristics, the strongest personal motivation for individual workers to observe safe practices, according to safety experts, is a system of motivations and responsibilities directly related to performance that reach the individual as part of a tough, vigilant program implemented by operators and their contractors at all levels of management.

There are several ways to recruit and retain workers, e.g., company development programs, hiring from other firms, and the use of outside schools. Company programs are the most common means of developing qualified personnel.[24]

The balance between on-the-job training (OJT) and formal or other training courses varies from company to company. This balance is determined by the depth of the in-house manpower pool, the acquisition of new equipment, regulatory requirements, the OCS leasing schedule, and other factors.

Training on the job and advancement through the ranks are long-standing and probably close-to-irreplaceable parts of developing experienced OCS workers. While ideal for hands-on experience, OJT is occasionally difficult in the conditions of the OCS workplace. Some companies send professional trainers directly to installations. It is important to supplement OJT with more formal training to enable workers to develop trained responses without the risk of catastrophic early errors, as well as for other reasons.

Most offshore operators do supplement OJT with their own training courses. Table IV-2 presents information on these courses. As indicated in the table, there is no set pattern. Courses are developed and used in response to particular needs, augmenting OJT on an as-needed basis and supplementing it when the qualifications of workers must be developed. Review of the courses contained in the table reveals another use for company training courses. Many deal with some aspect of safety, either the use of safety equipment or familiarization with safe practices in activities such as crane operations, where the "how-to" may be picked up on the job.

External training programs are used by companies when they need to develop their manpower at a more rapid rate or in directions that OJT and company courses cannot achieve. Other reasons for employing external training are to cope with demand for training that exceeds company resources, to develop career skills in higher-level job classifications where opportunities for OJT may be infrequent, and to facilitate the introduction of new techniques and equipment into company operations.

The introduction into the offshore oil and gas industry of new technologies increases the demand for external training courses. Examples of recent far-reaching technological changes include extensive use of hydraulic and electronic systems on newer drilling rigs.[25] Systems such as motion compensators, hydraulic riser tensioners, electromechanical ballast controls, thrusters, monitors, and controls for dynamic positioners are frequently installed on new or updated floating drilling rigs, and the offshore work force must be trained in their use.

Extensive external training opportunities are available to the offshore oil and gas industry. Table IV-3 lists the kinds and numbers of courses available on a continuing basis. The information in the table is neither definitive nor comprehensive. Many equipment manufacturers offer courses in the use of their equipment that are not included in the table. College programs in petroleum technology (at least 21 colleges) are also not listed.

Training programs are generally directed at individuals. Even though workers often operate as teams on the OCS, there do not seem to be many formal training efforts directed at developing team skills or upgrading performance or capability at the team level.

In considering the role of training in offshore operations, it is perhaps wise to consider that, while training is often a prerequisite to experience, it is not a substitute for it. Hiring experienced personnel away from competitors does not increase the depth of the offshore work force; it allows redistribution of experience. Over the years, some large offshore companies have developed reputations as training grounds for offshore workers. The large companies (Company "B" in Table IV-2, for example) have extensive training programs. Smaller firms often hire workers from the larger companies by offering them higher salaries.

TABLE IV-2

Examples of In-House Company Training Courses (Drilling Industry)

Course	Company						
	A	B	C	D	E	F	G
Offshore Orientation (API RP T-1)	Y[1]	Y	50/50[2]	Y	Y	Y	Y
First Aid	Y	555/781	72/317	Y	177/517	390/780	Y
CPR	Y	555/781	32/261		204/517	195/780	Y
Safety Device Certification	220/353	55/265	260[3]		48/475		
Firefighting	Y	382/781	235		210/517		Y
Crane Certification	Y	Y			68/517		Y
Well Control	104/169	128/231	156		Y	376/470	Y
Ableseaman/Lifeboatman (USCG)						23/298	
Buoyancy/Stability						80/80	Y
Defensive Driving	Y	115/118		Y	Y	Y	Y
Survival Capsule		572/572	143			Y	Y
H_2S Drilling	Y[4]	67/133	Y[4]	Y[4]	Y	Y	Y[4]
Production/Drilling Skills		662/662					Y
Water Survival Training		388/781					Y

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1. Means course is available in-house but data could not be readily assembled.
2. An entry such as 555/781, means 555 employees took the course in in 1979, out of 781 employees in the job classifications which normally take this training.
3. An entry such as 260 means that 260 employees took this course in 1979.
4. As needed.

Source: Offshore Operators Committee

TABLE IV-3

External Training Courses in the Petroleum Extraction Industry[1]

Type of Course	Number of Offshore Offerings (1979)
Corrosion and Corrosion Control	10
Drilling Operations	28
Economic Analysis and Evaluation	29
Energy Conservation	9
Exploration Operations	15
General Training	26
Instrumentation, Control and Automation	19
Land (Lease) Management	6
Maintenance Planning and Scheduling	6
Measurement Techniques	7
Metallurgy, Materials, Welding	12
Natural Gas Operations	24
Offshore Operations	22
Pipeline Technology, Operation and Maintenance	3
Pollution Control Operations	10
Production Operations	39
Project Management, Computer Systems and Application	21
Reservoir Engineering and Formation Evaluation	20
Safety and Fire Protection	23
Supervisors' and Managers' Training	9
Well Control	14

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1. These courses serve the worldwide oil and gas extraction industry, both on and off shore.

Source: Adapted from "Compilation of Training Courses and Materials," American Petroleum Institute, Production Department, Dallas, Texas, September, 1979.

In periods of high labor demand, manning offshore platforms at ideal strength with persons who are fully qualified is difficult. As operations expand, new installations must be manned. The burden is on management to respond to periods of high demand by increasing the availability of qualified people as rapidly as possible, by applying available experience as prudently as possible, or by designing the system to minimize the need for laborers.

Applying available experience as prudently as possible means putting the best people where problems are anticipated. While this is good operating practice, it is no substitute for increasing the quantity and quality of available manpower. Without that, key positions will be filled by workers who may have potential, and who may even have the necessary qualifications, but who will nonetheless be shouldering responsibilities that exceed their training and experience. While there are insufficient data to document whether this situation prevails in the industry, the opinions of a number of experts indicate that it may.[26]

The prospect of designing the workers out of the system as a solution to a tight manpower situation raises a basic question about the design of offshore systems from a human factors standpoint. Which design philosophy will produce a greater degree of safety offshore: one that maximizes or minimizes the role of the offshore worker in operations? The historical record points to human actions as an important contributing factor in many offshore accidents. Designing the operator out of drilling and other systems may in certain instances increase the system's vulnerability to the consequences of unforeseen events. In some other situations, the elimination of the potential for operator error may be advantageous.

The Government's Worker Resource Pool

The committee excluded review of the quality or capability of government organizations to execute their regulatory responsibilities. Nevertheless, it is important to point out that the government competes with industry for personnel to man its offshore programs. To a substantial degree, the government requires workers--especially personnel with scientific and engineering training and experience--whose knowledge of offshore technology is comparable with that of industrial workers. This knowledge is acquired through work experience and training, and industry is the major source of such experience and training. When industry is expanding its work force, and competition among companies is influencing wages and other working conditions, the availability of workers to government is also affected. In no way can this influence be characterized as benign to the public interest, and the committee raises it as a legitimate concern, though it is outside the limits of this study.

Options For Improvements in Safety Performance

The marketplace has a direct bearing on OCS safety. As the price of oil has risen, it has become more economical to recover incidental oil spills with gutters and so forth than to irrevocably release a valuable commodity into the marine environment. Similarly, the application of the Jones Act to the OCS has caused operators to pay somewhat greater attention to worker safety because of the high court settlements that usually result from Jones Act litigation. High insurance costs can also motivate company management to pay greater attention to safety. Another existing incentive (for all its faults) for management to pay attention to OCS safety is the current system of government regulation and inspection and enforcement for compliance.

The introduction of the subsurface safety valve provides an example of how economics and regulations exert different and complementary influences on OCS safety.[27] Subsurface safety valves were introduced commercially in 1954, but were not required by regulation on the OCS until 1973. From 1954-1973, the development of this technology was therefore driven primarily by economics. This resulted in continued improvements in the technology, but not in its universal application. In contrast, the 1973 Geological Survey requirement that subsurface safety valves be installed on all producing wells (OCS Order No. 5-3) resulted in rapid application of the technology to all relevant OCS operations and has sustained an economic climate conducive to continuing refinements and improvements of the technology.

There are a number of options open to the government that could possibly increase the attention that OCS operators pay to their safety record and that could possibly be translated in the workplace into enhanced management interest in the safety performance of OCS workers. In exploring these options, the committee did not investigate legal and other obstacles to their implementation.

Public Visibility and Accountability. During the 1971-1975 time period, a system for public reporting of accidental oil spills was established and reporting of them became accepted practice. Congruent with the development, implementation, and acceptance of the reporting system, the occurrence of accidental spills dropped dramatically. The number of accidental oil spills in 1975, for example, was only 25 percent of that for 1971. The simple act of entering unsafe acts into a public record is apparently a powerful motivator to draw attention, especially management attention, to problems. Many OCS safety incidents are the subject of reporting requirements; besides spills, these include blowouts, fires and explosions, pipeline accidents, deaths, and injuries.

Establishing Expectations of Safety Performanance. The government has consistently tried to establish a level of expectation for safety performance in OCS operations. This level usually takes the form of a safety floor, a minimum performance level to which all operators should adhere. The means of establishing expectations of performance is through statements of policy and both specific and performance regulations. Once a publicly accountable record is established, it is possible for the government to use safety performance as a criterion for permission to operate and as a basis for penalties and enforcement sanctions. The suspension of operations can be costly. An enforced suspension for safety reasons could be a powerful motivator of management attention.

Selective Enforcement. A publicly accountable safety record would provide an opportunity to document operators' and contractors' safety performance and to target the poor performers for close and continuous inspection and scrutiny, while subjecting companies with stronger safety records to less regulatory attention. Areas where the consequences of an accident are of greater concern could also be a locus of regulatory monitoring.

The system seems to be moving in this direction. The Environmental Protection Agency (EPA) is directing its implementation of the National Pollutant Discharge Elimination System and ocean discharge criteria (40 CFR 122-125) to environmentally sensitive areas. The Geological Survey conducts more frequent inspections of platforms with a history of inspection violations than of those that have no recent violations. The Coast Guard is developing a safety information and analysis system that will have the capability to rate the safety performance of each industry, company, and unit (e.g., platform, mobile offshore drilling unit, ship).[28] The difference between the existing tentative leanings toward such flexibility and that which may produce meaningful safety improvements is a difference of degree, not of kind. The targeting of regulatory attention must be sufficient for good performers to view their safety performance as a benefit, while less safe operators would have to direct considerable effort (which would presumably result in greater safety) to regulatory compliance. The emphasis on safety would, presumably, reach individual companies, crews, and workers.

Limited Entry. While many firms are able to operate in the Gulf of Mexico, where operating conditions are well known, it can be argued that only a few operators have the technological and managerial capability to explore, develop, and produce offshore oil and gas in the Arctic and in deep water. Would it not be appropriate to screen the capabilities, experience, and safety records of the prospective offshore operators for newly leased tracts? Would it be possible to certify only the safest and best-qualified operators to perform in offshore areas where design criteria and other operating conditions are not firmly established?

Personnel Standards. Industry and/or government could develop standards of worker safety qualification and performance. The standards would address the selection, motivation, training, and qualification of offshore workers and would presumably have an effect similar to other consensus standards. They would establish a basic level of management attention to safety, and safety performance, to which all OCS operators would be expected to adhere.

Analytical Review of Operating Experience. A sure way to improve safety performance is through the lessons of experience. These can be learned in a haphazard manner (in which case some lessons will be lost and others learned too late) or a deliberate effort can be mounted to ferret out the lessons that experience teaches us and to apply them. Such an effort must consist of the compilation of basic safety incident data, including cause and trend information, and the thorough investigation of untoward incidents. This is in fact the safety program that companies often impose on themselves, and it is the one that government and industry have developed for the maritime transportation sector. In contrast, the government's OCS safety program has only pieces of the essentials. Information gathering systems are in place for most kinds of OCS accidents, but the information gathered is not complete, especially with regard to causal information, and the analysis of the accident information is not consistent. The Coast Guard has a long tradition of extensive investigation of accidents, but analogous investigative machinery by the Geological Survey is just now being developed.

Findings and Recommendations on the Human Element in OCS Safety

The overall experience level (and possibly the skill) of the OCS work force appears to be adversely affected by both slack and high demand periods, i.e., by instability in the level of OCS activity. Industry measures that may compensate (when necessary) for inexperience in the work force include training, tighter procedures, and closer management surveillance. Management emphasis on safety must be established unmistakably by top management, and it must be effected through a system of motivations and responsibilities that is unmistakable and that reaches every supervisor and worker.

The present regulatory system is not structured to take best advantage of the whole industrial management system to motivate concern for safety at every level. As currently constituted, the federal program comprises regulations based on the idea that if a law commands all will obey in a fully satisfactory fashion and that inspection will ensure compliance.

There are a number of options open to the government that could reasonably be expected to enhance management interest in the safety performance of OCS workers.

> Government agencies should incorporate into the regulatory system alternative techniques that could better utilize the potential of the industrial management system to

promote safe industrial and worker performance. In developing these, the government should consider such mechanisms as public visibility and accountability, establishing expectations of safety performance, selective enforcement, limited entry, personnel standards, and analytical review of operating experience.

Interaction of Regulations, Technologies, and the Environment

Resources, technology, and people are the building blocks of OCS development. They are brought together through industrial initiative. Government regulations complement and guide OCS petroleum resource development.

Types of Regulations

The spectrum of OCS regulations can be broken down into four categories: general statements of policy, specific regulations, performance regulations, and preparation and submission of equipment and operating plans by the operator with review and approval by the government.

Statements of Policy. Many OCS regulations are worded very generally. An example from the Geological Survey is the prohibition of pollution and harm to aquatic life (30 CFR 250.43). In the workplace safety area, the Geological Survey requires that all operations be performed in a safe and workmanlike manner (30 CFR 250.56). The Coast Guard stipulates that operations shall be conducted in compliance with Occupational Safety and Health Administration regulations and be free from recognized hazards (33 CFR 142.1). These regulations and others like them are not capable of detailed enforcement but that is not their purpose. These general regulations are intended primarily as statements of policy. They provide direction to the government's OCS safety program.

Specific Regulations. A host of regulations leave no room for interpretation; they spell out exactly what actions are required for compliance. Many of them are concerned with the safety of personnel and derive from Coast Guard experience with marine safety. Examples are the Coast Guard rules on the use of approved electrical equipment (46 CFR 111.92-3), and fire-fighting equipment (46 CFR Ch.I) which require that items of equipment carry evidence of Coast Guard approval. The Geological Survey also has specific regulations covering fire-fighting equipment (33 CFR 145). Reporting requirements are another type of specific requirement. An example is the requirement that all oil spills be reported (30 CFR 250.43 (Geological Survey), 33 CFR 153.203 (Coast Guard), and 40 CFR 110.9 (EPA)). Specific regulations have a long history of use and are appropriate and justified in situations where leeway for interpretation would be counterproductive.

Performance Regulations. An alternative to regulations that specify the means of compliance is more general standards based on desired overall performance levels. Often these are derived from industry standards. This approach leaves the regulated firm free to find the most efficient means of compliance. An example of a performance regulation is the EPA's effluent limitation standards (40 CFR 435). With performance regulations, compliance may be more difficult or expensive to monitor than with specific regulations.

Plan Preparation, Review and Approval. The requirements for plan content are usually stated only generally in regulation, as statements of policy, or references to industry-developed recommended practices or standards. The operator is required to prepare a plan that demonstrates that operations will be conducted in accordance with the stated or referenced policies or standards. The plan is reviewed for approval by government technical personnel. The permitting of wells and preparations for oil spill containment and cleanup are typical instances where regulation is accomplished through the preparation, review, and approval of plans. This approach is intended to give the government a disclosure of the operation, and provide industry with flexibility in meeting regulatory requirements and site-specific conditions. It also permits new and better technology to be introduced on a timely basis.

Each of these types of regulations performs a useful function in the regulation of the safety of OCS operations. The task before the government is to match the appropriate regulatory means to the ends.

A New Focus for Regulatory Activity

The OCS Lands Act Amendments of 1978 (P.L. 95-372) establish a potential focusing mechanism for the government's OCS safety regulatory program. Section 21(b) of the act provides:

> ". . .The Secretary (of the Interior) and the Secretary of the Department in which the Coast Guard is operating shall require, on all new drilling and production operations and wherever practicable on existing operations, the use of the best available and safest technologies, which the Secretary determines to be economically feasible, wherever failure of equipment would have a significant effect on safety, health, or the environment, except where the Secretary determines that the incremental benefits are clearly insufficient to justify the incremental costs of utilizing such technologies."

This requirement, known as the BAST requirement, has the capacity to better ensure the adequacy of technologies and regulations to provide for OCS safety. The opportunity that lies before the Department of the Interior (DOI) and the Department of Transportation (DOT) is to utilize the BAST requirement, as required by law.

Development of the BAST Requirement, Organization and Procedures. The BAST requirement applies to the DOI and DOT and these departments are responding to BAST in separate ways. At the request of the Geological Survey, the National Research Council's Marine Board attempted to bring specificity to the broad concepts of BAST and to show how BAST might be applied to OCS oil and gas operations.[29] This effort laid the groundwork for the implementation of the BAST requirement by the Geological Survey and the Coast Guard.

- o Geological Survey. The Geological Survey has established and is implementing a BAST program.[30] The components of the BAST program are:

    - oo Documentation of the Requirement. The requirement for the use of BAST is stated in certain regulations and its use is implied in others, which prescribe certain things to be done and certain criteria to be met in OCS operations.

    - oo Application of BAST to OCS Operations. The Geological Survey has identified several programs that can assist in determining what is BAST or if BAST is being applied. These include exploration and development and production plan approval, platform verification, quality assurance, inspection and enforcement, training, and the safety alert program.

    - oo Development of Information for BAST Determinations. In order to determine areas where there are problems or deficiencies, the Geological Survey has established certain information and other programs. These include the failure inventory and reporting system (FIRS), accident investigation and reporting, and research and development.

    - oo Organization and Procedures. To shape the several elements into a program, the Geological Survey established three new organizational units. An Operations Technology Assessment Committee (OTAC) was established in each OCS region. The OTACs are composed of technical personnel who operate from a regional perspective. They are charged with the analysis and utilization of technical information on OCS safety, including the review of information in the FIRS, results of accident investigations, inspection reports, and so forth, as well as the examination of new technologies and concepts. A national OTAC, composed of senior engineers and scientists, oversees the work of regional OTACs and conducts similar analyses at a national scale. A BAST unit was created at the Geological Survey's headquarters to ensure an ongoing, consistent program.

- Coast Guard. The overall approach of the Coast Guard to BAST is similar to that of the Geological Survey, but the implementation to date has been quite different. Like the Geological Survey, the Coast Guard recognized that the BAST requirement must be backed up with a program to determine what is the best available and safest and to ensure its use. The Coast Guard considers BAST to be synonymous with good management principles that have been built into Coast Guard regulatory activities over many years. Examples are the extensive investigation of accidents that the Coast Guard conducts and its research and development program on oil spill containment and cleanup and other technologies. To apply BAST to OCS operations, the Coast Guard considers BAST to be one more analytical requirement, similar to environmental and regulatory impact requirements, that must be explicitly addressed and documented in regulatory and decision-making activities. To this end, it intends to issue program guidance that will require that the BAST requirement be addressed and documented in all relevant regulatory and decision-making actions. This action will be initiated after the safety study required by the OCS Lands Act Amendments is completed.

Implementing BAST on the OCS. BAST is a process consisting of a regulatory requirement and a program to apply the requirement to OCS operations. Both are needed to achieve the intent of the law.[31] The question raised by the limited time of application is whether the agency programs will be properly constituted to achieve the intent of the law.

An important step in implementing BAST is to define adequately the requirement. There is still some lack of clarity concerning the definition of certain terms. For example, the definition of technology is not clear as to whether it extends to safety practices, maintenance procedures, etc. The terms "economic feasibility," "practicable," "significant effect on safety, health, or the environment," and "incremental benefit vs. incremental costs" have yet to be substantively defined in the context of programs and activities. Better definition of these terms, as well as the scope and context of the entire BAST program is essential and may evolve through experience. Such further definition will provide clearer guidance to industry relative to compliance and technology development and to regional supervisors in their application of BAST.

Once the BAST requirement has been defined, it must be documented and applied in existing regulations and activities. An important element of this is providing for a detailed analysis that demonstrates that specific regulations or actions in fact constitute BAST. The Geological Survey is proceeding with this aspect of BAST implementation, as described.[32] The Coast Guard is developing its documentation and application strategy.

The next, and perhaps the most important, element of implementing BAST is for the government to have the independent capability to determine the best available and safest technologies. This requires the acquisition, analysis and utilization of safety information. The success of this depends on the commitment of the government and also the technical capabilities of government personnel.

Safety information includes information on the extent of OCS activities, accident data including causal and trend information, and the fruits of accident investigations, as well as research and development relative to technological development and reliability. One of the most powerful information tools is the investigation of accidents. The Geological Survey has identified its information base for BAST determination as primarily FIRS, accident data and investigations, and research and development. The Coast Guard has not yet explicitly identified its information sources for BAST determinations. Even so, it is constructing an automated OCS safety data base (Appendix C) and has a long history of conducting thorough fact-finding investigations of marine accidents.

The gist of the agencies' plans for providing the technical data and information that are necessary to determine the best available and safest technologies is to rely on the existing information fabric of the OCS safety program. For this reason, it is useful to review the existing data and technical information situation to determine whether existing information arrangements are suitable for this purpose.

The task of assembling and organizing safety information is complicated by several attributes of existing data. One complicating factor is that the DOI is the only agency for which "the OCS" is a major and separate information category. Other collectors of data lump OCS data into an offshore (as opposed to onshore) category or include it in state or regional tallies. The Coast Guard's marine pollution reporting system, for example, includes inland and territorial waters as well as the deep ocean. The best source of data on injuries and deaths during drilling, the annual safety report of the International Association of Drilling Contractors, does not separate OCS accidents from other offshore accidents. The result of this is that, without parallel organization, it is very difficult to correlate between data sources. Also, without a specific OCS data category, it is necessary to review individual records to establish OCS-specific data.

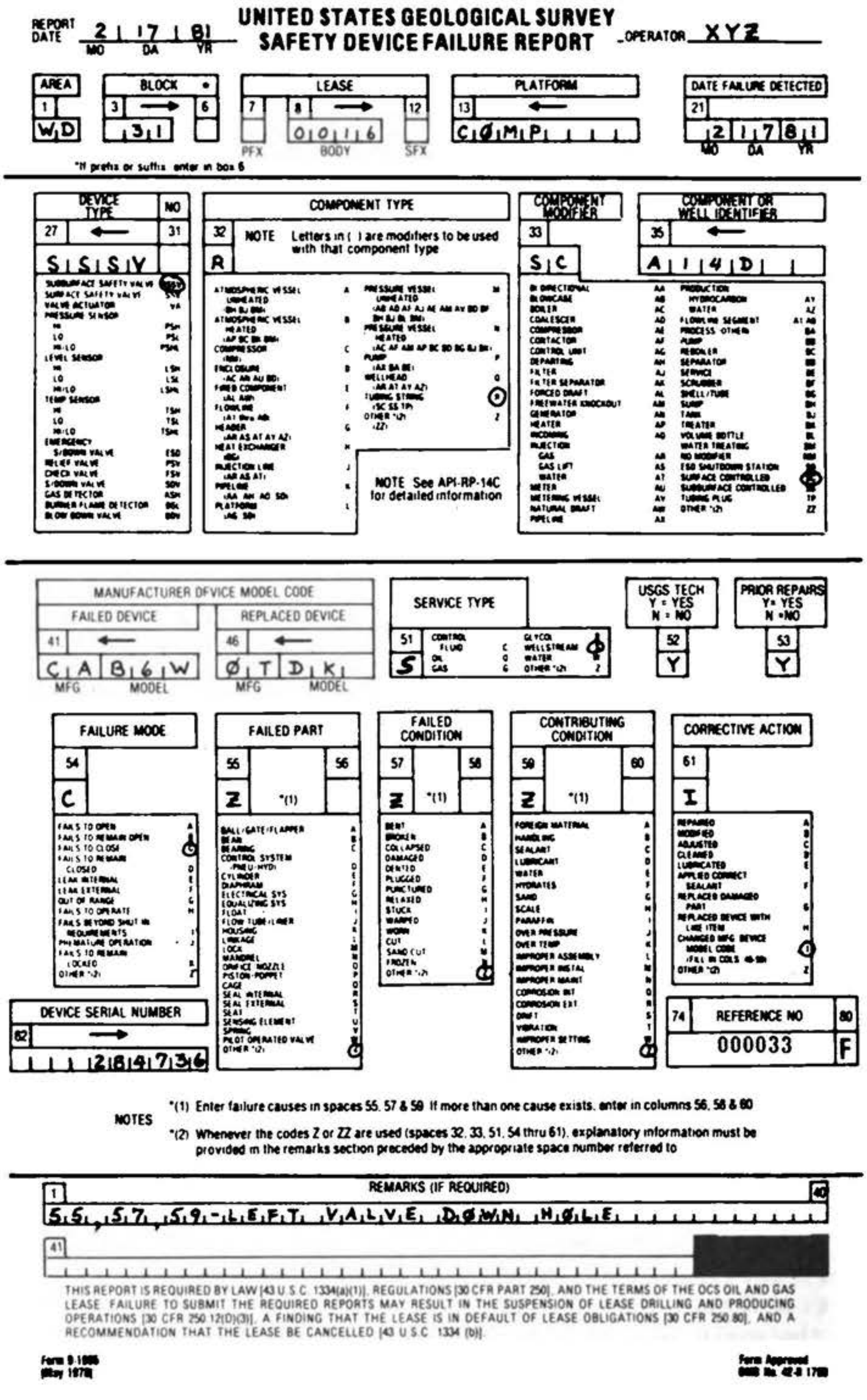
Another complicating factor results from the manner in which data are often collected. Data are compiled by requiring the regular reporting of certain items. All of the major OCS regulatory agencies have their own reporting requirements and collect their own data. These many requirements have been designed and implemented in response to each agency's needs, which is appropriate. However, the separate development of information systems has led to a number of overlapping requirements, especially in the reporting of pollution incidents (a minimum of three agencies) and lost-time injuries (at least two agencies and one private system). Furthermore, the end use of some information that is collected is not always clear.

This points to the crux of the information problem. Information collection should be neither an afterthought nor an end in itself. Rather, it should be acquired in response to the needs of decision-makers. To be useful, information systems should consist of both information acquisition and analysis/utilization components. These program elements must be designed with decision-makers' needs in mind so that the information in the system can and will be used to promote safety. At this juncture, it is useful to consider the relative ease of government's requiring the submission of data against the relative difficulty of data analysis and the drawing of useful conclusions. Without the latter, the consumer (who ultimately pays the cost of data collection) will have been mulcted and the intent of the law will have been frustrated.

While the federal government has in place some necessary OCS safety information elements, they have never been deliberately integrated to support the regulation of the safety of OCS activities. The result is inconsistent reporting of safety incidents and, more importantly, extreme difficulty in making practical use of historical and other safety informtion acquired in the government's OCS safety program.

A common inadequacy of information acquisition in both the environmental pollution and workplace safety areas is the lack of attention that is paid to causal information. While it is often possible to learn what happened from the data, it is much more difficult to discern why the reported incident happened. This is because, without exception, the reporting requirements fall short on asking for causal information. This is shown in Figure IV-2, which is a copy of a Geological Survey FIRS safety device failure report form. It provides information on the failure of a subsurface safety valve. From the form, it is possible to tell that a downhole valve failed to close; however, the form contains no information on why or how the problem occurred.

It would be far more useful if reporting requirements, such as those in the FIRS system, developed information on the causes of mishaps. In this respect, the most productive methodology is one that acquires information on all possible causes of an accident. All-cause analysis concentrates on the fact that accidents often have a number of causes, any of which can be the prime contributing factor in the occurrence of the event. In all-cause analysis, all causes to an accident are recognized as important. This approach differs from the more conventional system of analysis in which a primary cause is sought for every accident, and the primary cause becomes the focus of subsequent investigation. Identification of all causes on an equal basis is the only way to ensure thorough consideration of all elements essential to the prevention of accidents. After all possible causes are identified, it is of course quite appropriate to select some for immediate correction, some for long-term correction, and so on. The point is, no cause is neglected, ignored, or overlooked.



REPORT DATE 2 17 81 (MO DA YR)

UNITED STATES GEOLOGICAL SURVEY
SAFETY DEVICE FAILURE REPORT

OPERATOR XYZ

AREA	BLOCK *	LEASE	PLATFORM	DATE FAILURE DETECTED
1	3 → 6	7 PFX · 8 → BODY · 12 SFX	13 ←	21
WD	31	00116	CØMP	2 17 81 (MO DA YR)

*If prefix or suffix enter in box 6

DEVICE TYPE 27 ←	NO 31	COMPONENT TYPE 32	COMPONENT MODIFIER 33	COMPONENT OR WELL IDENTIFIER 35 ←
SSSV		R	SC	A 14D

NOTE Letters in ( ) are modifiers to be used with that component type

SUBSURFACE SAFETY VALVE	[✓ SSSV]
SURFACE SAFETY VALVE	SSV
VALVE ACTUATOR	VA
PRESSURE SENSOR	
HI	PSH
LO	PSL
HI/LO	PSHL
LEVEL SENSOR	
HI	LSH
LO	LSL
HI/LO	LSHL
TEMP SENSOR	
HI	TSH
LO	TSL
HI/LO	TSHL
EMERGENCY S/DOWN VALVE	ESD
RELIEF VALVE	PSV
CHECK VALVE	FSV
S/DOWN VALVE	SDV
GAS DETECTOR	ASH
BURNER FLAME DETECTOR	BSL
BLOW DOWN VALVE	BDV

ATMOSPHERIC VESSEL UNHEATED (BH BJ BM)	A
ATMOSPHERIC VESSEL HEATED (AP BC BK BM)	B
COMPRESSOR (BB)	C
ENCLOSURE (AC AH AU BD)	D
FIRED COMPONENT (AL AW)	E
FLOWLINE (A1 thru A9)	F
HEADER (AR AS AT AY AZ)	G
HEAT EXCHANGER (BG)	H
INJECTION LINE (AR AS AT)	J
PIPELINE (AA AH AO SD)	K
PLATFORM (AG SD)	L
PRESSURE VESSEL UNHEATED (AB AD AF AJ AK AM AV BD BF BH BJ BL BM)	M
PRESSURE VESSEL HEATED (AC AF AW AP BC BD BG BJ BK)	N
PUMP (AX BA BE)	P
WELLHEAD (AR AT AY AZ)	Q
TUBING STRING (SC SS TP)	[✓ R]
OTHER *(2) (ZZ)	Z

NOTE See API-RP-14C for detailed information

BI-DIRECTIONAL	AA	PRODUCTION	
BLOWCASE	AB	HYDROCARBON	AY
BOILER	AC	WATER	AZ
COALESCER	AD	FLOWLINE SEGMENT	A1 A9
COMPRESSOR	AE	PROCESS (OTHER)	BA
CONTACTOR	AF	PUMP	BB
CONTROL UNIT	AG	REBOILER	BC
DEPARTING	AH	SEPARATOR	BD
FILTER	AJ	SERVICE	BE
FILTER SEPARATOR	AK	SCRUBBER	BF
FORCED DRAFT	AL	SHELL/TUBE	BG
FREEWATER KNOCKOUT	AM	SUMP	BH
GENERATOR	AN	TANK	BJ
HEATER	AP	TREATER	BK
INCOMING	AQ	VOLUME BOTTLE	BL
INJECTION		WATER TREATING	BM
GAS	AR	NO MODIFIER	NM
GAS LIFT	AS	ESD SHUTDOWN STATION	SD
WATER	AT	SURFACE CONTROLLED	[✓ SC]
METER	AU	SUBSURFACE CONTROLLED	SS
METERING VESSEL	AV	TUBING PLUG	TP
NATURAL DRAFT	AW	OTHER *(2)	ZZ
PIPELINE	AX		

MANUFACTURER DEVICE MODEL CODE		SERVICE TYPE	USGS TECH Y = YES N = NO	PRIOR REPAIRS Y = YES N = NO
FAILED DEVICE 41 ←	REPLACED DEVICE 46 ←	51	52	53
CA B6W (MFG MODEL)	ØT DK (MFG MODEL)	S	Y	Y

CONTROL FLUID	C	GLYCOL	[illegible]
OIL	O	WELLSTREAM	[✓ S]
GAS	G	WATER	W
		OTHER *(2)	Z

FAILURE MODE 54	FAILED PART 55 · 56	FAILED CONDITION 57 · 58	CONTRIBUTING CONDITION 59 · 60	CORRECTIVE ACTION 61
C	Z *(1)	Z *(1)	Z *(1)	I

FAILS TO OPEN	A
FAILS TO REMAIN OPEN	B
FAILS TO CLOSE	[✓ C]
FAILS TO REMAIN CLOSED	D
LEAK INTERNAL	E
LEAK EXTERNAL	F
OUT OF RANGE	G
FAILS TO OPERATE	H
FAILS BEYOND SHUT IN REQUIREMENTS	I
PREMATURE OPERATION	J
FAILS TO REMAIN LOCKED	K
OTHER *(2)	Z

BALL/GATE/FLAPPER	A
BEAN	B
BEARING	C
CONTROL SYSTEM (PNEU-HYD)	D
CYLINDER	E
DIAPHRAM	F
ELECTRICAL SYS	G
EQUALIZING SYS	H
FLOAT	I
FLOW TUBE/LINER	J
HOUSING	K
LINKAGE	L
LOCK	M
MANDREL	N
ORIFICE NOZZLE	O
PISTON-POPPET	P
CAGE	Q
SEAL INTERNAL	R
SEAL EXTERNAL	S
SEAT	T
SENSING ELEMENT	U
SPRING	V
PILOT OPERATED VALVE	W
OTHER *(2)	[✓ Z]

BENT	A
BROKEN	B
COLLAPSED	C
DAMAGED	D
DENTED	E
PLUGGED	F
PUNCTURED	G
RELAXED	H
STUCK	I
WARPED	J
WORN	K
CUT	L
SAND CUT	M
FROZEN	N
OTHER *(2)	[✓ Z]

FOREIGN MATERIAL	A
HANDLING	B
SEALANT	C
LUBRICANT	D
WATER	E
HYDRATES	F
SAND	G
SCALE	H
PARAFFIN	I
OVER PRESSURE	J
OVER TEMP	K
IMPROPER ASSEMBLY	L
IMPROPER INSTAL	M
IMPROPER MAINT	N
CORROSION INT	O
CORROSION EXT	R
DRIFT	S
VIBRATION	T
IMPROPER SETTING	W
OTHER *(2)	[✓ Z]

REPAIRED	A
MODIFIED	B
ADJUSTED	C
CLEANED	D
LUBRICATED	E
APPLIED CORRECT SEALANT	F
REPLACED DAMAGED PART	G
REPLACED DEVICE WITH LIKE ITEM	H
CHANGED MFG DEVICE MODEL CODE (FILL IN COLS 46-50)	[✓ I]
OTHER *(2)	Z

DEVICE SERIAL NUMBER 82 → 2847 36

74 REFERENCE NO 80
000033 F

NOTES
*(1) Enter failure causes in spaces 55, 57 & 59 If more than one cause exists, enter in columns 56, 58 & 60
*(2) Whenever the codes Z or ZZ are used (spaces 32, 33, 51, 54 thru 61), explanatory information must be provided in the remarks section preceded by the appropriate space number referred to

REMARKS (IF REQUIRED) 1 – 40
55, 57, 59-LEFT VALVE DØWN HØLE
41 [redacted]

THIS REPORT IS REQUIRED BY LAW [43 U.S.C. 1334(a)(1)], REGULATIONS [30 CFR PART 250], AND THE TERMS OF THE OCS OIL AND GAS LEASE. FAILURE TO SUBMIT THE REQUIRED REPORTS MAY RESULT IN THE SUSPENSION OF LEASE DRILLING AND PRODUCING OPERATIONS [30 CFR 250.12(D)(3)], A FINDING THAT THE LEASE IS IN DEFAULT OF LEASE OBLIGATIONS [30 CFR 250.80], AND A RECOMMENDATION THAT THE LEASE BE CANCELLED [43 U.S.C. 1334 (b)].

Form 9-1886
(May 1978)

Form Approved
OMB No. 42-R 1780

Source: U.S. Geological Survey

Figure IV-2

A weak factor in the federal government's safety information activities is the lack of a systematic approach to acquiring, analyzing, and utilizing safety information. Most important, there needs to be a means of collecting safety information and then employing that information in the analysis of safety problems and in advancing OCS safety. A short-hand term for such a system is a "feedback mechanism."

The closest thing to a feedback mechanism at present is the FIRS which falls short of the mark. Through reporting requirements, the FIRS provides information depicting the number of safety and pollution prevention devices that are in service on offshore platforms. It also provides information relative to failures of safety devices. The ostensible purpose of the FIRS is to have the Geological Survey foster an industry-wide exchange of expertise and information regarding the use and performance of safety devices, rather than having to rely on each operator's reaction to his own safety record. Through FIRS, much safety-related information is generated on a regular basis. However, as was shown in the discussion of Figure IV-2, FIRS does not ask all the right questions. The causes of safety-device failures cannot be discerned from the information in the system. Another weakness of the FIRS is that the uses to which the reported information is supposed to be put are often not clear. While the stated purpose of the program is laudable, until the creation of the OTACs in 1980 there was no group within the Geological Survey specifically tasked with using the FIRS system to identify safety problems for analysis and correction.

The comment made above that information should be acquired in response to needs is particularly appropriate to FIRS. FIRS takes a shotgun approach and requires reporting on all production and processing system components. This generates a large volume of data that only has the possibility of becoming useful when failure of a valve occurs. In other words, the wide net cast by the FIRS inventory requirement does not contribute regularly or directly to the safety of OCS operations, although the failure reporting requirement does. An alternative way of gathering FIRS information that could reduce the compliance burden on industry while not compromising the government's access to information would be to require regular reporting on those valves and other system components that, if they failed, would probably trigger a discharge or some other unsafe condition. Reporting on other system components would be required on an as-needed basis, in response to accidents, investigations, reports in the technical literature, and so forth, i.e., as needed in requiring and determining BAST.

The best source of information on deficiences in conventional technologies is investigation of serious accidents. The Coast Guard has investigated maritime accidents for many years and maintains specialized teams and procedures for this purpose. The information that results from such fact-finding investigations could document needed changes in OCS technology to conform to BAST, if the information were applied to that purpose. The Geological Survey has an accident investigation procedure, that is rapidly being strengthened. In a recent investigation of a blowout and explosion, the Geolgical Survey conducted a formal investigation with the assistance of a Coast Guard fact-finding team.

The effective utilization of safety information in OCS regulation is dependent on having the necessary programmatic commitment, including the manpower and technical expertise to identify and analyze problems and to develop and implement mitigating strategies.

Technical Capability of the Government to Administer Offshore Resource Development

The documentation and application of the BAST requirement, the development of information for BAST determinations, and the organization and administration of BAST procedures will require the highest level of technological capability on the part of the government in order to administer responsibly industry's development activities and to protect the public interest in OCS resources. The components of this are an independent engineering capability; coordination of technical programs within government, with industry, with states, and even at the international level; and the capability to initiate, develop, and implement new technical initiatives as needs arise.

To elaborate on just one area, the government must have competent technical manpower to utilize safety information. It needs a wide array of engineering talent, especially engineers with immediately applicable offshore experience and who can relate on a peer level with their counterparts--the engineering designers, operations engineers, company men, rig superintendents, and toolpushers, who prepare documents and applications for government review and approval and who manage offshore operations.

While an evaluation of the government's technical capability to administer offshore resource development was beyond the scope of the committee's endeavor, the matter is of such overriding importance to the safety of OCS activities that a few comments are in order. In the Geological Survey, plans and permit applications are typically reviewed by a number of individuals who concentrate on different aspects of a plan. Thus the technical aspects of a plan or permit application may be reviewed by engineers, geologists, and environmental specialists who are all mid-level staff in the district offices. The responsible official overseeing this activity is the district supervisor. The Geological Survey's OCS inspectors are also mid-level employees. A general characterization of this work force is that the more senior employees have some industry experience, whereas less experienced employees are hired from college. Out of 1,700 employees in the Conservation Division of the Geological Survey, only about 300 have experience in the oil and gas industry. Of approximately 390 Conservation Division employees in the Gulf of Mexico, only about half have more than five years' experience. These characteristics of the government's OCS work force, relative inexperience generally, and specifically regarding a hands-on appreciation of the industry, have been exacerbated by the rapid growth of the government's OCS work force, which has been necessary to keep pace with the increase in OCS regulatory duties. In the Gulf of Mexico, the government's OCS work force has doubled in the past five years. During this time, the Geological Survey also had to establish or strengthen district and regional offices elsewhere, such as in the frontier regions.

The need to strengthen the government's technological capability to administer OCS development becomes more pressing as the government assumes additional technical responsibilities to provide for the safety of OCS activities. Examples of recent and needed technical programs in addition to BAST are described below.

Verification. Independent (third party) review of a structure's engineering characteristics to provide initial assurance of the integrity of a structure, especially as related to the environmental forces it may be exposed to, the safety of personnel, protection of the environment, and conservation of resources.

Inspection. Periodic performance analysis and engineering review of offshore structures to detect incipient and real structural and system failures.

Risk Analysis. Establishment of a probabilistic basis for design, inspection, and regulatory criteria to ensure efficiency and reliability.

Environmental Exposure Engineering. Acquisition and analysis of environmental exposure data, and the development of design criteria based on the data, to support the design and verification of offshore structures.

Research and Development. Identification and solution of technical problems directly related to the exploration for, and development, production, and transportation of, offshore oil and gas.

Environmental Studies. The development and implementation of scientific research programs to determine the fate and effects of petroleum and operational discharges in the marine environment, and for other purposes.

A Final Look at the Government's OCS Safety Program

The government's OCS safety program can be summarized as follows: at least eight bureau-level agencies administer scores of separate requirements that are directly concerned with safety on the OCS. Furthermore, a number of memoranda of understanding are in force that purport to sort out responsibilities among agencies. The absolute count of agencies and requirements varies according to how one aggregates them.

Even though many of the individual elements of the government's OCS safety program are of singular value, the current arrangements for offshore safety are complex. For example, both the Geological Survey and the Coast Guard administer workplace safety regulations. Geological Survey regulations mandate safety; require submittal of a comprehensive plan of operations, including steps taken to prevent or mitigate accidents, and require reporting of accidents. The Geological Survey and the Coast Guard maintain separate inspection staffs and logistics operations and conduct regular and unannounced inspections of operations independently of one another. For their part, large operators regularly inspect their own operations. Regarding these separate government inspections, it should be noted that the major oil companies are able to determine if, in all likelihood, they are in compliance with government regulations by means of just one company inspection.

While all these regulatory arrangements may possibly be effective, they are complex and inefficient for the government and for industry. Inefficiency probably does not lead directly to safety problems, but it may increase the costs of operation offshore.[33] The complexity of the regulatory system may also place obstacles in the path of strong safety standards. For example, a preoccupation of operating personnel with mandatory equipment checks or inspection may reduce the time available for surveillance to insure the safe operation of a facility.

Inefficiency is therefore of concern, even though the effectiveness of the regulatory situation is more important. The point is that the regulatory regime should be both effective and efficient. A safety program that is simplified to the maximum extent would serve the interests of all. Common sense dictates that the government should have a focusing mechanism for all OCS safety activity, so that the plethora of requirements can be coordinated and harmonized to a greater degree than at present.

Findings and Recommendations on the Interaction of Regulations, Technologies, and the Environment

The regime for regulation of OCS petroleum operations is an admixture of four distinct regulatory philosophies. The first comprises general statements of policy intended to provide direction to the OCS program. Another is equipment-specific, or applies specific maxima or minima--e.g., producing wells shall be equipped with a surface-actuated downhole safety device. The third philosophy generates performance-oriented requirements that describe the result that must be achieved to comply with the regulation--e.g., the requirement for shutdown of pipeline pumps when abnormally high or low pressures occur. The fourth philosophy calls for preparation and submission of equipment and operating plans by the operator, followed by government review and approval. The requirements are usually only generally stated in regulation--e.g., the American Petroleum Institute's recommended practice for fixed platforms transformed into regulation by the Geological Survey.

The committee is aware of a wide range of opinions on which of the regulatory approaches is the most efficient and effective and therefore preferred. The committee concludes that no single approach is feasible and that the current regulatory approach of using all four is more likely to be an overall strength than a weakness. Major overhaul of the OCS regulatory program is not needed to provide for the safety of OCS activities. This conclusion is not intended to obscure the fact that there is need for improvement in several important areas.

Government regulation, especially that which relies on the review and approval of plans and that which relies on inspection and monitoring for compliance with standards, can only be as effective as the technical and enforcement capabilities of government personnel. Since the committee was not equipped to evaluate the capabilities and effectiveness of government personnel (and deliberately did not do so), this critical aspect of the effectiveness of regulation--the adequacy of the numbers of, or technical and enforcement capabilities of, the personnel who man the regulatory programs--was not considered in the committee's findings. This determination on a continuing basis does not appear to have been adequately considered or provided for in legislation or in executive action.

Section 21(b) of the OCS Lands Act Amendments (P.L. 95-372), the BAST requirement, is intended to provide a focusing mechanism for the many elements of the OCS safety program.

The ability to determine which technologies are the best available and safest requires having adequate safety information. Some type of information reporting, analysis, and utilization system (including environmental information as discussed in Chapter III) is therefore a central element in the implementation of the BAST requirement. The FIRS is intended to contribute to this purpose; however, as currently constituted and utilized, FIRS is inadequate. Improvements in FIRS data collection and utilization are needed and ought to be based on continuing review of safety information requirements and of the performance of FIRS.

The government's mechanisms are inadequate for developing important information on safety problems and innovations and promoting its dissemination and use. Without a strong safety information component in the OCS regulatory program, it is not readily possible for the government to identify safety problems and courses of action to resolve them, as would seem to be required by the BAST requirement. Nor is the government able to identify the poorer performers and target them for close and continuous regulatory scrutiny, while subjecting companies with strong safety records to less regulatory attention.

The Department of the Interior, the Coast Guard, and the Environmental Protection Agency should take steps to strengthen the safety information elements of the government's OCS regulatory program. They should:

- Review and revise existing reporting requirements (e.g., those covering accidental discharges, workplace accidents, and fires and explosions) to ensure that the information gathered for safety purposes is limited to that which is necessary for the regulation of safety; is useful in monitoring and analyzing the safety of OCS activities; and includes causal information, e.g., in the reporting of accidental spills and in the implementation of FIRS.

- Conduct more comprehensive and frequent investigations of OCS accidents (and near misses) in order to develop information relative to the causes and consequences of accidents.

- Make use of the safety information that is gathered in the identification, analysis, and resolution of safety problems, in the continuing evaluation of the adequacy of technologies in the application of BAST, and in evaluating the efficiency of the regulatory process.

- Conduct additional research on the fates and effects of discharges on a generic and site-specific basis.

There is an inseparable link in the safety performance of OCS technologies between the interaction of people, equipment, and operating procedures. It is necessary to include these interactions in evaluating technologies to determine whether they are the best available and safest and in ensuing regulatory actions.

The Geological Survey and the Coast Guard should define the scope of the BAST requirement and program to include the interaction of people, equipment, and operating procedures in the evaluation of OCS technologies, and to take account of these interactions in their regulatory actions.

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APPENDIX A

DESCRIPTION OF THE WORKSHOP CONVENED BY THE COMMITTEE

The committee convened a workshop to assist it in its work, especially by providing a forum for participation of technical experts and others in the committee's analysis of OCS safety. The workshop was convened at the Mt. Ada Marine Conference Center, Santa Catalina Island, California, June 18-24, 1980, with a follow-up meeting in Reston, Virginia, September 16-19, 1980.

I. Objective of the Workshop. The objective of the workshop was to conduct an analysis to identify and characterize technological and regulatory areas of concern that bear on OCS safety.

II. Preparation for the Workshop

  A. Information Base. The committee assembled an information base that was placed at the disposal of the workshop attendees. The information base consisted of two parts: technological information and a regulations file.

    1. Technological Information. The following kinds of information were assembled (Appendix C):

      a. Incident information (frequency, magnitude, causes and consequences).

      b. Information on elements of risk.

      c. Data on the cost of providing or not providing for safety and on compliance with government regulations.

      d. Conclusions and recommendations of past safety studies.

    Since this was the first attempt ever to pull this information together, it suffered from the kinds of difficulties expected to encounter in a first try. Coverage was incomplete, occasional inconsistencies were encountered, etc. Nevertheless, the workshop had at its disposal a large amount of (to some extent) new information on the safety of OCS operations.

    2. Regulations File. The regulations information base included the basic set of national regulations that governs offshore oil and gas operations (Appendix D). This set of rules, however, provided only a framework for the complete set of rules with which industry must comply. This is due largely to the fact that rulemaking power and enforcement are to a great

extent delegated to the regional level. Field offices have a good deal of flexibility in interpreting and applying national regulations and even in establishing their own independent requirements. In addition, many of the regulations are written in general terms and rely on approval of plans, applications, or permits to give them substance. These factors limited the extent to which the collection of formal regulations could be used in a realistic assessment of the total effect of regulatory action on OCS safety.

3. Identification of Public Concerns. As one element of the study, a request for comments appeared in the Februrary 28, 1980 issue of the Federal Register. Nearly two dozen thoughtful responses were received in which a number of safety concerns were raised (Appendix B). The responses were available at the workshop.

B. Methodology for Assessment of OCS Safety. The committee developed an analytical method, for use at the workshop, of assessing the adequacy of regulations and technologies (Chapter II). The central element of the methodology was the application of a list of questions concerning classes of events, regulations, and technologies, to OCS safety data. It is important to understand that the existence of the methodology did not constrain the analytical approaches that were employed at the workshop. Rather, workshop participants used the methodology as a back up to ensure that the right issues were addressed and the necessary questions asked and answered.

III. Organization of the Workshop. Workshop attendees convened in teams, each of which independently undertook a portion of the analysis of OCS safety. Teams were organized by area of concern and analyzed fires and explosions, workplace safety, operational discharges, well control, loss of installations, and spill containment and cleanup. An additional working group integrated the work of the analytical teams.

Since there was potential for overlaps between the interests of the groups, the areas of interest of each group were specified at the outset. The operational discharges team was the focus for analysis of all matters concerning environmental safety. Similarly, the workplace safety/fires and explosions team was the center for analysis of human safety. The well control/installation loss teams were responsible for structural safety.

The team structure consisted of a chairman, rapporteurs, and team members. Team assignments were made on the basis of professional background to ensure that each team had at its disposal the technical knowledge necessary to work efficiently the problems put before it. The rapporteurs served as staff to the chairmen. They assisted in accessing the information base, in recording the progress of the analysis, and in preparing a written report describing the analysis and findings for the use of the committee in preparing the final project report.

IV. WORKSHOP PARTICIPANTS

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Mr. Don Kash
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APPENDIX B

PUBLIC COMMENTS ON OCS SAFETY

As one input to the study, the committee was interested in obtaining public comment on the adequacy of OCS safety. To this end, the Geological Survey and the Coast Guard jointly sponsored publication of a "Request for Comments" notice in the February 28, 1980 issue of the Federal Register. The notice described the study and asked for comments concerning its content and scope.

Respondents were asked to identify the root causes of OCS accidents and the policy objectives that regulations governing the safety of these activities should seek to achieve, to comment on existing regulations, to indicate whether existing regulations are compatible with the best of existing technology, and to determine whether regulations encourage or impede safety innovations.

Twenty responses were received. The responses are summarized, and respondents listed, in Table B-1.

Most respondents identified human factors such as error, lack of training, inadequate supervision, high rate of turnover and consequent scarcity of experienced personnel, and other human factors as the principal causes of accidents. As a group, the respondents, who included federal administrators, OCS operators, insurance executives, state officials, drilling contractors, and oil company employees, thought action could and should be taken to reduce the incidence of human error.

Some respondents articulated special concerns. A drilling contractor asked that environmental effects of oil in the marine environment be explicitly included in the study. Another respondent requested that the study take up the disposal of drilling muds, the adequacy of the platform verification program, and the adequacy of available technology for cleanup after blowouts and spills, particularly under adverse weather and sea conditions. One response brought to public attention the hazard to navigation brought by the proliferation of offshore pipelines and facilities.

The strengths and weaknesses of existing regulations were discussed. The need for flexibility--allowing federal regional officials considerable discretion in regulating OCS safety--was seen as a sensible source of relief by some respondents and as a source of concern by others. A frequent comment was that regulations should specify a desired level of performance rather than regulate the equipment or systems to be used. OCS Order No. 2 was singled out for attention by a number of respondents. One respondent thought that the order enhanced OCS safety, while five others condemned the section

TABLE B-1

Principal Observations and Recommendations on Regulations Governing OCS Safety and Environment (Numbers Refer to Respondents--See Below)

Main Problem	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance Safety	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
Human Error.2 Worker safety: training supervision, and proper mental attitude most important. Regs. do not address this; instead, try to effect safety by specifying equipment and rules for its use.5 Carelessness, poor judgment, lack of perception by personnel. High rate of turnover means not enough trained, experienced personnel, especially for contract services.9 Arbitrary, unsafe acts of people.11 (implied) Not equipment failure malfunction.12	"Sheen" of oil water, EPA, GS.9 Production lines, DOI, DOT/Between DOT and DOI for producer-type offshore pipelines.9, 13, 14/ For pipelines across and under shipping safety fairways.18 Occupational health and safety, CG, DOI, OSHA.9/Still some problems, even with MOU between CG and OSHA. 13, 14 Regulation of fixed platforms, DOI, DOT.9/Regulation of fixed installations on OCS, GS, CG.13, 14 Potential for overlap if DOE issues regs. under authority granted under OCSLAA.13, 14	Parts of OCS Order 2 on blowout prevention.5 Pipeline regulations are adequate.6, 7 Casing setting depts of Order 2--prevent unwise extremes, but grant latitude to meet specific well needs.11 USGS Quality Assurance and Performance of Safety Pollution Prevention Equipment (but could be counterproductive if not carefully managed). 11	CG requirement for MODU certification--2 ABSs, e.g., 5 FIRS--too expensive, time-consuming no benefit that wouldn't have been achieved in the natural course of things. 5, 9, 11, 13, 14 "Sheen" of oil on water harmful.9 Some alarm requirements on unmanned facilities.9 Third-party platform verification. 9, 11, 13, 14/ Should be examined carefully, compared to that of other countries.16 Shielded ignition system.9 Regulatory approval of various downhole activities.9 Spill prevention	Offshore and onshore rates (worker accidents) neither improved by regulation nor significantly different from one another.5 OCS leaseholders can put up their rigs wherever they like on their lands--a hazard to navigation.8/Proliferation of platforms and pipelines near and across anchorages and shipping safety fairways a hazard to navigation.18 Exploitation of OCS oil and gas not being expedited by regulations.9 Some CG firefighting requirements neither allow for nor recognize latest technology.9, 13, 14	Concentrate on developing sound training programs, performance criteria (reduce accidents by X, e.g.)5/Emphasize employee awareness, joint programs of industry and reg. personnel 9/Require ongoing safety program.11/ Worker education--explain why regulations, etc., necessary. 15 Regulations should deal with major factors only--preventing disasters or significant environmental damage.9/Need for regulation should be established first. 11, 13/By experienced personnel.14	Include environmental effects in review.5 Include Materials Transportation Board (of DOT) regulations on pipelines.4, 5, 7 Proposed study too broad-based for effective evaluation; ask some professional organizations to participate.10 Study all agencies involved in OCS with a view to projected as well as present operations, and taking into account geographical differences.16

TABLE B-1 (cont'd)

Principal Observations and Recommendations on Regulations Governing OCS Safety and Environment (Numbers Refer to Respondents--See Below)

Main Problem	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance Safety	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
Lack of knowledge of safety, lack of safety consciousness.13 (specific areas of concern): --disposal of drilling muds and cuttings: are stipulations (shunting) adequate to protect drilling environment? --no provision for calculating environmental costs and benefits in regulatory analyses --adequacy of technology for clean up operations after blowout or spill, especially under adverse weather or sea conditions.16	Potential for conflict between state and Coastal Zone Management programs and federal regs.13/ May be conflicting state and federal regs.15 Between CG and CS on:--buoyant installations --fire and gas detection equipment --welding and burning control (by item repaired) --casualty investigations --investigations of complaints and alleged violations --marking of structure --accident investigations --inspection --structural integrity.14 CG, EPA, and GS write and enforce oil pollution regs. 14		requirements.9 Some are so complicated, specialized personnel must be hired, but compliance yields no benefit; e.g., --detail on mud material reserves.9, 13, 14 New 10,000 psi requirement for annular preventers too much. 5, 9, 11, 13, 14/ Equipment not available for the larger-bore (18-3/4"+) to comply. Reliability of the equipment for smaller-bore (13-5/8") not regarded as reliable by all operators.11a/ Probably not a single case of an annular preventer of any kind ever successfully used to control a blowout if surface pressure more than 5,000 psi.13	Some flexibility in existing regs., particularly in asking Dist. Super. for departure, but they should be more performance-oriented. 9, 13, 14/Broad range of discretion of Dist. Super. a matter of concern.16 Surface requirements for a particular area seem to dictate subsurface requirements: the relationship does not hold. 9, 13, 14 Requirement to report spills has not brought about any improvement in performance.14	Regulations should be objective-oriented/performance oriented/ refer whenever possible to industry standards, 5, 9, 11, 13/Level of safety to be achieved should be set for documented industry-wide hazards.14 Conduct periodic review of how well regulations have performed in the workplace and how much compliance, enforcement, etc., costs. 13 Establish unobstructed shipping safety fairways.8/ Establish uniform national policy for pipelines under and near anchorages and shipping safety fairways:	

Main Problem	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
The proliferation of facilities —rigs and pipelines in and near anchorages and shipping safety fairways constitutes a serious hazard to maritime industry and waterborne commerce (Gulf of Mexico).18 Accidents on the OCS can be attributed to human error, environmental conditions, and equipment failure. Human error contributes significantly. Proper precautions will avert serious mishaps. 19	Overlaps can be expected as CG takes on design, specification, testing, and operation of cranes. GS already has a great many rules for cranes. Gaps often result from regulations of same area (of interest) by more than one federal agency; e.g., CG and EPA on hazardous substances).15 Not altogether clear that the high technology required by operations in the Atlantic compatible with existing regulations: implementation of BAST will help.19		Pipe-ram actuation requirements of OCS Order 2: although "recent accident" quoted as reason, no causal relation stated. Will this expansive time-consuming daily or every-other-day test actually prevent blowouts? 5, 13, 14 OCS Order 5 requires a certain design of safety valves --discourages technological improvements.13	Existing regulations are not efficient. This is manifest in their results: no improvement in safety and reserves are lost.11/Existing regulations no more effective than self-regulation in the past.13 Regulations too often aim for a checklist that can be used by an unqualified inspector.11 Regulations more for office than field personnel. 11 Exxon's good offshore safety record's direct result of emphasis on safety. 12/Same goes for Sun.13 Study showed pollution reduced by 8 bbl/yr at cost to industry of $81 million.13 14	provisions should be explicit in bidding.18/ —Conduct anchor penetration tests in West Gulf to determine safe depths for pipelines, specify in permits. Until then, --20 ft. minimum for pipelines in areas where vessels navigate --Pipelines that cross s.s. fairway or anchorages covered for 3,000 ft. either side of bounded area --No platforms closer than 3,000 ft. to s.s. fairways or anchorages --Owner of pipeline accept all financial and other consequences of laying pipeline in anchorage area. Shipowners and ships indemnified against damages to pipelines in anchorage.18	

TABLE B-1 (cont'd)

Principal Observations and Recommendations on Regulations Governing OCS Safety and Environment (Numbers Refer to Respondents--See Below)

Main Problem	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
				Gas and oil extraction had good safety record in 1978 compared to other industries. 14 Regulatory analysis not required unless cost of compliance $100 million: many OCS regs. not analyzed, but should be added up. 14 Transport of refined products from onshore supply bases to offshore rigs should be examined. 15 Would like to know standards for determining when experimental technology becomes operable --does not want deep-water testing conducted off the coast of South Carolina. 15	Detailed examination of traffic congestion, control in ports, and interaction between fishing and oil interests for OCS operations. 15 Detailed examination of whether stipulations governing disposal of drilling muds and cuttings adequate and how they are determined. 16 Technology of disposal of drilling muds and cuttings seems rudimentary. Examine feasibility of other disposal methods, particularly for area where mud disposal remains an issue. 16 Cost/benefit analyses not actually carried out for true costs of environmental effects. Examine methodologies to evaluate environmental costs and benefits. 16	

Main Problem	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
				The efficient, well-managed drilling company does not need more regulations. The regs. in effect are adequate.[17]	Examine effectiveness of clean-up operations following oil spills and blowouts. Identify constraints of existing equipment and recommend incentives to improve design.[16]	
					Examine platform verification program carefully.[16]	
					Required safety meetings and training help control avoidable accidents. Regulations should give due consideration to the human factor. Some possible areas for regulation: --availability of safety harnesses --availability of life vests --Tie-down lines on various items --Guards on moving parts --Guard rails --Safety clamps on cables and pressurized lines --Eye protectors and gloves for mixing chemicals and hammering steel	

TABLE B-1 (cont'd)

Principal Observations and Recommendations on Regulations Governing OCS Safety and Environment (Numbers Refer to Respondents--See Below)

Main Problems	Overlaps & Conflicts Among Regulations	Regulations That Do Enhance	Regulations that Do Not Enhance Safety, Or Work At Crosspurposes	Observations	Recommendations	Comments on Larger Study
					--Warning signals during crane operations --Area clearance and evacuation during helicopter landing and takeoff --Availability of gas masks --Availability of fire extinguishers --Area clearance during employment of radioactive and X-ray equipment --Prohibition of alcohol and non-prescription drugs --Warning signals for equipment malfunctions --Warning signals for pressure buildups.[19]	

Respondents

	Name	Association/Organization
1.	Mr. Walter W. Christy	Kullman, Lang, Inman & Bee Law Offices
2.	Mr. Robert C. Phillips	The Travelers Insurance Companies
3.	Mr. Michael Whitehead	State of Alaska, Office of the Governor
4.	Mr. S. J. Bellassai	Transcontinental Gas Pipe Line Corporation
5.	Mr. J. R. McGregor	Ocean Drilling and Exploration Company
6.	Mr. William T. Turner, Jr.	Texas Gas Transmission Corporation
7.	Mr. Lawrence J. Ogden Director, Construction & Operations	Interstate Natural Gas Association of America
8.	Mr. R. Todd Coyle Chairman, Committee on Navigation Improvements	North Atlantic Ports Association, Inc.
9.	Mr. John E. Whitman Manager of Operations - Offshore North American Production	Conoco, Inc.
10.	Mr. Charles A. Praznik Personnel/Safety Supervisor	Salen Offshore Drilling Company
11.	Mr. Donald G. Russel	Shell Oil Company
12.	Mr. L. G. Otteman	Shell Oil Company
13.	Mr. H. B. Barton Regulatory Affairs Manager Production Department	Exxon Company, USA
14.	Mr. Myron R. Elliot Manager Offshore Division	Sun Gas Company
15.	Mr. F. F. Syfan Chairman	Amoco Production Company
16.	Ms. Patricia L. Jerman Coordinator, Coastal Energy Impact Program	State of South Carolina, Office of Executive Policy and Programs
17.	Ms. Frances Beinecke	Natural Resources Defense Council, Inc.
18.	Mr. James R. Jay	Marine Drilling Company
19.	Mr. Ted Thorjussen Vice President	West Gulf Maritime Association
20.	Mr. George F. Brown Conservation Manager	Eastern Region, U.S. Geological Survey
21.		Occupational Safety and Health Administration

of the order that requires a 10,000 psi annular blowout preventer in certain regions (this provision was revised subsequent to the comments).

Several regulations were cited as being too complex or yielding little safety benefit. Examples included the mud reserve requirements and the failure inventory reporting system of the Geological Survey.

The majority of respondents thought there should be more thorough assessment of the consequences of regulations before they are implemented.

Finally, as a group, the respondents considered the study of OCS safety to be timely and important.

Review of the Geological Survey's Development of the Best Available and Safest Technologies Requirement and Program

In July 1980, the Geological Survey requested that the Marine Board, including the Panel on Best Available and Safest Technologies for Offshore Oil and Gas, review and provide comments on the document entitled "The Use of Best Available and Safest Technologies (BAST) During Oil and Gas Drilling and Producing Operations on the Outer Continental Shelf." This publication describes the programs and philosophy of the Geological Survey for implementing Section 21(b) of the OCS Lands Act Amendments of 1978, the BAST requirement.

This document was reviewed as requested. A digest of comments received is contained in Table B-2.

TABLE B-2

Comments on the Development of the USGS Best Available and Safest Technologies (BAST) Program

Definition of the BAST Requirement	Incorporation of the Requirement into the OCS Regulatory Program	Application of BAST on the OCS	Development of Information for Determining BAST	Organization and Procedures of the BAST Program	Other
The BAST program is very general. The danger of this type of regulation is that if a change in attitude of the agencies were to take place, the general regulations could be implemented in such a restrictive manner that productive work could be effectively halted.[6] More explicit definitions of terms is necessary.[1] "Best" is vague. To be best, a technology must not just be safe; it must be demonstrated to be exceedingly safe. The definition should be tied to accomplishment of all the statutory objectives, not just those of concerns in the section (Sec. 21).[1]	The USGS cites a long list of regulations and standards that are applicable to the BAST program. What in those regulations requires BAST? Examples: OCS Order 2: Requires appropriate technology, not BAST. OCS Order 5: What basis exists for concluding that conformance to standards, codes and practice equals BAST? OCS Order 7: Where in this order is BAST required? Where do the regulations applicable to exploration and development and production plans spell out the information requirements that will permit the regulator to determine whether BAST will be employed? Why shouldn't training, at least relative to BAST equipment, be covered?	Training of personnel is a serious problem. Personnel must be competent to handle extreme events. Clear lines of authority are needed. More on-platform drills may be needed to ensure proper emergency response.[5] An area for investigation under BAST is that of construction operations on site, such as crane control, scaffolding, fuel storage, rigging and slinging.[5]	The BAST program should concentrate on known deficiencies in existing technology, and evolving technologies for deep water and arctic areas. The adage "If it ain't broke, don't fix it" should guide the program. The BAST program should address existing conventional technologies only to the extent to which such technologies have demonstrated safety deficiencies.[4] The best data bank for the study of deficiencies in conventional technology is that which is derived from detailed investigations of serious accidents. Existing investigation efforts should be strengthened to this end. Conversely, the FIRS program is an example of a data program that will not be helpful in determining BAST.[4]	The USGS must maintain a good communications link with the industry if they are to stay effectively abreast of evolving technologies so that BAST is supportive.[4] Minutes and recommendations of OTAC meetings should be publicly available.[1] The bureaucratic structure (OTAC) for BAST must be critically reviewed to ensure that its size and scope are in tune with the needs.[4] One of the functions of the BAST unit is to ensure that USGS personnel are aware of the state-of-the-art as described in journals and at conferences. More effort than just reading journals will be required to accomplish this because much of what has been successfully reduced to practices has not been presented to the general public.[6]	The BAST program is of central importance to the entire OCS leasing program.[1] The BAST program should be implemented in a manner that will not require unjustified increase in unnecessary sophisticated technology and that will concentrate on discovering and correcting deficiencies. It should be an iterative process, gradually applied to cause the least disruption of OCS operations.[6] The BAST program does not adequately address the complexities of developing BAST. All technology developments are evolutionary processes. The BAST program, as presented, incurs a possible risk of implementing mandatory technological

Definition of the BAST Requirement	Incorporation of the Requirement into the OCS Regulatory Program	Application of BAST on the OCS	Development of Information for Determining BAST	Organization and Procedures of the BAST Program	Other
The definition of "best" includes that which is not necessarily the most expensive or sophisticated. This is a very good point and should be emphasized.[6] "Available" is interpreted to mean that the technology does not have to be in actual use. This could require the use of unproven technology in place of known and reliable equipment.[6] "Safest" should not be defined in terms of all the numerous and often competing interests in the statute. "Safest" should be demonstrated by thorough testing and use.[1] A major omission in the "technology" definition is the failure to clearly	The USGS conclusion that if specific equipment, procedures or systems are covered by standards or codes, then BAST is being applied, raises serious questions. Where is the analysis set out for public review and comment which demonstrates that the existing requirements in fact constitute BAST?[1] The verification program has worked well and has resulted in greater safety.[5] The problem of duplicative and conflicting regulations should be addressed through BAST.[6] Existing programs are adequate to ensure that BAST is implemented.[6]		FIRS may not produce information useful to determining BAST. Therefore, it is necessary to place more emphasis on accident investigation. In this area, it is essential that overlaps between USGS and USCG be eliminated.[6] FIRS data can be misapplied. Operating conditions determine whether equipment can or cannot be used in different offshore locations. A safety device showing poor reliability in one case could very well be experiencing outstanding performance on an industry average basis.[8] The FIRS appear to be an optimum approach for mediating an otherwise difficult problem of accepting (or rejecting) the	The organization and procedures for implementing BAST are excessive. There is a real threat that OTACs will feel compelled to develop recommendations to justify their existence. OTACs should meet on an as needed basis rather than once a month.[8, 3] Improvements in OCS technology have developed slowly. In view of this, the frequent meetings of the OTAC appear unjustified. OTACs should meet on an as-needed basis.[6]	requirements that will prove ultimately to be unworkable. The urgent tone implicit in a program requiring monthly meetings or regional OTAC teams and the complete revision of OCS orders on a semiannual basis connotes an intent to mandate rapid changes in OCS technology. To be workable and beneficial the program must include sustained periods of technology testing in the field before technologies are mandated.[4] The USGS BAST program as outlined should allow continued cooperation between the USGS and industry for the most effective developmemt of OCS resources.[6] The BAST program has a consistent and logical organization and content with respect to its intended purpose.[7]

TABLE B-2 (cont'd)

Comments on the Development of the USGS Best Available and Safest Technologies (BAST) Program

Definition of the BAST Requirement	Incorporation of the Requirement into the OCS Regulatory Program	Application of BAST on the OCS	Development of Information for Determining BAST	Organization and Procedures of the BAST Program	Other
interpret technology to include safety practices maintenance procedures, etc.[1] "Economic Feasibility" is not defined at all.[1] "Practicable" is nowhere defined and should be. The determination of whether a requirement is practicable should be made on an industry-wide basis, or with respect to classes of operations and should involve consideration of whether deployment of such technology can be afforded.[1] The definition of "significant effect of safety, health, or the environment" is left completely to the agency's discretion.[1] The definition of "incremental benefit vs. incremental costs" obfuscate more than it clarifies.			assertions of permit applicants, equipment vendors, and public interest advocates. However, the relative ease of the government's requiring the submission of the data must be tempered with the difficulty of data analysis and the drawing of conclusions.[7] In the R&D area, major effort needs to be directed to determing the projects that the government should support to be responsive to BAST.[6] It is most important that R&D activities be carefully developed in a complementary way with similar industry activities if these efforts are going to be effective in extending technologies and developing BAST.[4]		The existence of a program description document adds to the force and effect of BAST to the point that further specificity in regulation is not needed.[7] The BAST program has been made intelligible to even a non-engineer. The regulatory requirements for the use of BAST seem to be totally adequate.[2] There is an urgent need for a moratorium on new offshore requirements at least until the effect and impact of all the new revised and regulations can be thoroughly analyzed.[8]

Defintion of the BAST Requirement	Incorporation of the Requirement into the OCS Regulatory Program	Application of BAST on the OCS	Development of Information for Determining BAST	Organization Procedures of the BAST Program	Other
The assumption under the statute is that BAST should be employed unless the evidence clearly and overwhelmingly demonstrates otherwise.[1]					
The definition of the application of BAST is in error. BAST standards can and should apply to small individual elements of OCS operations; however, the standard should be set for the entire industry or a class of operations. Also, mitigation of human error by requiring deployment of fail-safe equipment should be a part of BAST.[1]					

Respondents

1. Sarah Chasis, Natural Resources Defense Council
2. John D. Costlow, Duke University Marine Laboratory
3. Floyd Garrot, Exxon Corporation
4. Ronald L. Geer, Shell Oil Company
5. Ben C. Gerwick, Jr., University of California, Berkeley
6. Griff C. Lee, McDermott, Inc.
7. George F. Mechlin, Westinghouse Electric Corporation
8. F. E. Syfan, Offshore Operators Committee

APPENDIX C

SOURCES OF DATA ON THE SAFETY OF OCS OPERATIONS

As described elsewhere in the report, the committee assembled information on OCS safety from individual accident records, automated data files, special studies, and other information sources. This Appendix describes the primary sources of incident and technical data. It also describes a Coast Guard-funded project to establish an automated OCS safety data system. Finally, comments are offered on designing a functional OCS data system.

Data Sources

Numerous written materials on OCS safety were accessed in the course of the study. The majority of these are listed in the "General References" section of this report. Many contain data and analysis on aspects of OCS safety. Also listed are thorough studies of OCS safety that have been conducted in Britain and Norway, which contain much information that is useful for comparison.[1, 2]

Other sources of OCS safety data, which were heavily relied upon in the course of the study, are the data banks of OCS accident and incident information compiled by federal agencies, private companies, and professional associations. Table C-1 provides a synopsis of these.

The committee did not find any unified system of tracking OCS activity either in the government or industry. While data files exist on facilities, equipment, and pipelines, the committee was forced to estimate the number of OCS workers. Furthermore, some of the tallied information on activities is inadequate. For instance, although the Geological Survey keeps detailed statistics on wells started, producing zones completed, dry holes, etc., no record is kept of wells completed. Nor is it possible without combing through individual records to determine the number of producing wells or to calculate total well-years of exposure.

The U.S. Geological Survey events file is the primary source of information on safety incidents such as blowouts, fires and explosions, spills, pipeline accidents, deaths, and injuries related to other incidents. It covers only the Gulf of Mexico operating area. However, this represents about 95 percent of all OCS activity. The most significant limitation in the use of the events file is its lack of detail on systems and equipment definition; the causes, consequences, and costs of operational failures; and corrective actions. Also, the accuracy of the information in the events file varies depending on the thoroughness, experience, and

TABLE C-1

Sources and Characteristics of OCS Safety Data

Source	Time Period Covered	Name and General Content	Remarks and Limitations
U.S. Geological Survey	1967 to mid 1979	USGS EVENTS FILE: All accidents report to USGS Gulf of Mexico Region after mid 1970 plus some events known to USGS from early 1967 to mid 1970.	1967-1975: Information limited due to development of reporting and recording system. Post 1975: Information much more complete and consistent. General: Covers only the Gulf of Mexico. Limited in content and consistency by variations in reporting and collecting data and summarizing data for insertion into USGS computer system. Inadequate depth of detail. Limited cause and effects information. Little information on corrective actions. Present USGS computer system is difficult to query except for obtaining complete print outs in mixed form (partially in summarized remarks). Original reports prior to about 1976 often difficult to locate due to changes in USGS-Metairie office file system.
U.S. Geological Survey	1967 to mid 1979	USGS ACCIDENT SUMMARY: Same basic content as USGS EVENTS FILE plus some additional data.	Basically same limitations as for USGS EVENTS FILE. Not entirely consistent with EVENTS FILE because of change in personnel who summarized original reports for the collections of data for the EVENTS FILE and ACCIDENT SUMMARIES. Consistency in general, however, is still good between reports.
U.S. Geological Survey	1971-1978	OCS OIL AND GAS BLOWOUTS, OPEN FILE REPORT 80-81. Blowout data extracted from EVENTS FILE.	Same limitations as EVENTS FILE.
U.S. Geological Survey	1953-1979	OUTER CONTINENTAL SHELF STATISTICS - 1980 ANNUAL REPORT. Large amounts of detailed information on oil and gas production, lease sales, revenues, values, and wells drilled each year.	Generally excellent data and apparently quite consistent. One minor limitation is that well abandonment each year are lumped in with failures and dryholes so that one cannot obtain numbers of active wells for each year.

TABLE C-1 (cont'd)

Sources and Characteristics of OCS Safety Data

Source	Time Period Covered	Name and General Content	Remarks and Limitations
U.S. Geological Survey	1975 - 1979	USGS STATISTICS ON FACILLTIES: Internal annual summary USGS-Metairie of numbers and types of production complexes in Gulf of Mexico OCS. Contains information on numbers of major and minor structures; status (producing, etc.); product; major equipment such as heliports, production equipment, compressors, etc., and unmanned, attended (one shift during daylight) or manned (24 hours coverage).	No information on numbers of wells, or degree of manning beyond the daylight shift or 24 hours coverage.
U.S. Geological Survey	Dec. 31, 1979	USGS PIPELINE STATISTICS: Computer printout of USGS-Metairie file on DOT and DOI pipelines. Information on number of units, length, substance carried, and status (abandoned, out of service, etc.)	No clear distinction between gathering lines and process piping but apparently the process piping is limited to instrument gas, air, etc.
U.S. Coast Guard	1976 - 1978	DRILL-FLOOR ACCIDENT FILE: Collection of 1950 "typical" personal-injury type accidents from files of 3 or 4 major drilling contractors. Includes types of accident and injury; severity; specific job position, training, tool, and body part injured; location on drill rig; and length of experience.	No breakdown available of year, percentage of accidents covered, population represented. No assurance that company data is "representative" selection since not all accident reports were analyzed. Comparison to other data set indicates selection was probably representative.
U.S. Coast Guard		CASUALTY FILE: Collection of vessel casualties, including about 60 accidents with mobile drilling units. Contains great detail on location, weather, cause, regulations violated (if any), license status of crew, etc.	Primary devoted to "marine" accidents. Lacks information on the status of MODU's (i.e., in transit, setting up, on station) at the time of the accident.
U.S. Coast Guard		COAST GUARD SPILL REPORTS: Annual collection of voluntary reports on "Polluting Incidents in and Around U.S. Waters." Contains information on source of spill by type of facility, type of equipment, personnel errors, etc.	Data from voluntary reports, probably incomplete. Although it includes breakdowns for "Offshore Production Facilities," there is no distinction made between State and Federal (OCS) waters.

TABLE C-1 (cont'd)

Sources and Characteristics of OCS Safety Data

Source	Time Period Covered	Name and General Content	Remarks and Limitations
U.S. Coast Guard		WORKPLACE SAFETY FILE: Comprehensive file on deaths and personal injuries on the OCS.	Currently, under development covers only the Gulf of Mexico. It will contain information from the OCS events file, drill floor accident file, "Charlie" reports, and also information from the Society of Exploration Geologists and, most important the Bureau of Labor Statistics.
Offshore Rig Data Services, Inc.	1970-1979	ORDS DRILL RIG FILE: Commercial collection of data on numbers of each type of drill rig in service each year and footage drilled in Gulf of Mexico, Pacific Coast, Atlantic Coast, and Alaska.	Not absolutely accurate since data were assembled from a variety of sources and the crew breakdowns were "typical" ones with no account taken to individual differences in operator practices.
International Association of Drilling Contractors	1970-1979	ANNUAL SAFETY REPORTS: Annual report of drilling accidents. Data submitted by member companies (90% of all offshore drillers). Data from up to 158 companies is included. Tallied by land, water, and outside U.S. shows personal injury frequency rate and manhours worked per year by company (identity shielded by a code number). Aggregates data by type of injury, body part effected, experience level of personnel. Also total fatalities.	Most accurate source of information on personal injuries during drilling. However, it does not differentiate OCS from all offshore waters. Little causal information. Also doesn't show job class of personnel.
Society of Exploration Geologist	1970-1977	ANNUAL SAFETY SUMMARY REPORT FOR 1978. Tabulation of man-hours worked and accident frequency rates. 1977 data contains some information on the causes of accidents. Data submitted by member companies. Probably includes the majority of exploration accidents.	Data is not very useful for OCS analysis because it does not differentiate OCS or even "offshore" from onshore.
Bureau of Labor Statistics	1976-1978	Drawn from information reported on the workmen's compensation form LS-202, which contains the employer's initial report of a lost time injury.	Most specific information on personal injuries. OCS injuries specially identified.

Source: Committee on Assessment of Safety of OCS Activities

technical qualifications of the personnel who collect the data and enter it into the computer. Another limitation on the use of the Geological Survey's events file is the way the information has been machine-stored. Changes in format occur from year to year. Furthermore, the system into which information has been entered is not readily queried other than at the gross level of the type of event, e.g., "list blowouts by year." This means that analysis of safety data, such as was undertaken in this study, must be made by hand or the data must be reentered into a different type of computer file.

The U.S. Coast Guard is building an automated workplace safety data file that will combine all the data available on the subject. However, existing coverage is confined to the Gulf of Mexico. While the existing files (Table C-1) are limited because of the difficulty of correlating from one data base to another, the end product, a unified data base, will facilitate the analysis of safety problems.

A Unified OCS Safety Data Base

The Coast Guard has recently initiated the development of a unified OCS safety data base. The purpose of the project is to enter all OCS safety data, including the information from all the data sources listed in Table C-1 (as well as other information), into sets of readily analyzable, cross-correlatable computerized files. Completion of this project will enable an OCS safety analyst to access the safety information by machine and to automatically correlate data at several levels. For example, instead of simply obtaining a list of blowouts, it will be possible to automatically obtain a list of blowouts that occurred during development drilling in which oil was spilled.

While the design of the system has proceeded smoothly, its implementation has been difficult because of the limitations of the existing data. Existing data are incomplete, by year, by topic, and in technical content. Thus the system will be weak on causal information, because little causal information has been collected on OCS safety incidents. Furthermore, existing data files vary in format and are not readily manipulated. To enter information into the new, flexible system, it is often necessary to return to the original record rather than to use the existing machine file on the event. Finally, because reporting requirements overlap, the information in the various data sources also overlaps. It is not readily possible to discern when the same safety event is included in more than one existing file without returning to the original accident record.

Characteristics of a Successful OCS Safety Data System

The Coast Guard project provides a good starting point for the design of a comprehensive OCS safety data system. The system would include a data base, as is being developed, and provisions for utilizing the data in the analysis of safety problems. Chapter IV of the report contains a discussion of the need to utilize safety data in the analysis of safety problems. Following are comments on needed improvements in existing OCS safety data and data management systems.

An effort needs to be made to increase the completeness of the data being entered into the Coast Guard's system. An ideal entry would define systems and equipment to at least three levels (system, component, part), clearly state the cause and effect sequence, and include causal information and information on corrective actions and their costs. The accuracy of the information would be improved if the task of entering safety information into an automated system were made the specific responsibility of a group of technically competent personnel who had a firm understanding of the uses to which safety data are put.

Since an important purpose of the analysis of safety problems is in preparing for the development of frontier areas, the system needs to cover all OCS operations, frontier areas as well as the Gulf of Mexico. The data entered into the system need to be uniform. Regardless of which agency collects the data, the data files need to cover the same geographic area and similar units of measure and descriptors should be used.

The automated data base needs to be capable of manipulating data internally in order to provide a variety of outputs to facilitate safety analysis. Useful system outputs would include textual descriptions of a complete file or a subset of events, such as single events, or all similar events in a given time period, by type of facility or type of operation; tabular data, such as numbers of events in a given time period or by type of facility, system, operation, or cause; and graphic displays of data, including frequency distributions, bar charts, curves, and so forth.

NOTES

1. Burgoyne, Dr. J. H., "Offshore Safety," Department of Energy, London, 1980.
2. "Safety Offshore," the Royal Norwegian Council for Scientific and Industrial Research, Norway, 1979.

APPENDIX D

OCS SAFETY REGULATIONS

A major hindrance to assessing the adequacy of OCS safety regulations is the fact that there is a great difference between the literal meaning of the text of legal requirements and the reality of their implementation at the regional level and in the field. Thus, while it was necessary in the study to compile a complete set of the federal regulations related to OCS safety, the assessment focused on the implementation of regulations and not simply on their textual content.

Regardless of the forms of OCS safety regulation--whether they are called statutes, regulations, orders, standards, or criteria--regulations are government requirements that demand compliance on the part of an OCS operator. Each federal agency has tailored its OCS safety regulatory program around the activities it is required to regulate and around the regulatory methods it has historically used. Each program has evolved differently. The following paragraphs discuss the role and relative importance of various types of regulations.

Statutes are Acts of Congress that establish government policy and assign duties and authorities to the executive agencies. Some statutes convey a general mandate to an executive agency and empower the agency to make ensuing detailed policy and technical decisions. An example of such a statute is the OCS Lands Act of 1953, which gave broad and general authority to the Department of the Interior and to the Coast Guard to regulate the safety of OCS oil and gas development. Although the 1978 Amendments to the act provided somewhat more specific directives, the majority of the provisions still convey mandates to agencies or are otherwise too general to be assessed as regulations. Contrasted to this type of statute, some laws establish highly specific requirements and charge an executive agency with their implementation. Much of the environmental regulations of the 1970's, including the Clean Water Act, are of this type. When statutes follow this form, their provisions are often germane to an assessment of regulations.

The most prevalent form of regulation is requirements that have been promulgated in the "Code of Federal Regulations" (CFR). Regulations appearing in the CFR travel through a process mandated by the Administrative Procedures Act. This Act requires that proposed regulations first be published by the authoring agency in the Federal Register to give the public an opportunity to comment on the provisions. After a comment period, the agency considers the comments and responds to them. Only then is a proposed rule made final and adopted.

CFR regulations are the primary vehicle that agencies use to translate general statutory guidance into specific programs. However, in the implementation of programs, it is often useful to develop and employ even more specific types of regulations. For example, the Geological Survey sets out the general requirements of its exploration, development, and production plans in CFR regulations. Yet it maintains a set of OCS Orders that set out specific operating requirements tailored to each geographic area. In considering the difference between the Geological Survey's use of CFR regulations, which are national in scope, and OCS Orders, which apply to specific regions, it should be noted that recent revisions of the OCS Orders have tended toward national uniformity and their promulgation has followed administrative procedures not unlike those used in promulgating CFR regulations.

The Bureau of Land Management often attaches clauses (lease stipulations) to its lease contracts that stipulate how various aspects of operations are to be conducted in the leased area. Such stipulations are as binding as any other regulation, and they often cover the same types of substantive matters treated in OCS Orders or other regulations. One little known fact about lease stipulations is that, since they are contract provisions, they can be changed at any time upon agreement of the contracting parties without public scrutiny.

Another type of regulation used by the Geological Survey is Notices to Lessees. Notices are one step down in formality from OCS Orders since they are not usually subject to public comment because they are published in the Federal Register. Notices usually comprise engineering or operational advisories on technical matters. Notices were not included in the compilation of safety regulations prepared in the course of this study. An even less formal mechanism used by the Geological Survey is the publication of Safety Alerts. Safety Alerts are informal advisories issued to operators to focus attention on unsafe conditions that have come to light as the result of an accident or for some other reason.

The Coast Guard issues Navigation and Vessel Inspection Circulars to enforce its CFR regulations. Circulars are informational bulletins that explain what equipment and procedures will constitute compliance with CFR regulations. Circulars, especially the one on mobile offshore drilling units, have been included in the regulatory data base.

Many regulatory programs are implemented by permits that are required by law or established in CFR regulations. Permits are important in the regulatory programs of the U.S. Army Corps of Engineers, the Department of the Interior, the Department of Transportation, and the Environmental Protection Agency (EPA). A unique feature of regulation-by-permit is that permits are applied for, reviewed, and issued in field offices. While the actions of the field offices in issuing permits must adhere to the controlling regulations, in actuality each office develops its own case history regarding what is acceptable for permit issuance and compliance.

Because OCS permits are such an important regulatory tool, it is not possible to assess the adequacy of OCS regulations without gaining an understanding of how permit programs are administered.

Some of the EPA's CFR regulations call for the establishment of standards--the concentration of oil in produced water that is discharged, for example. The standards that are in effect must be adhered to in order to obtain and comply with the appropriate permits. The setting of standards in these instances is the product of scientific research and economic and environmental analysis. The standard is then enforced through a permit system. Both of these are forms of regulations.

Another kind of standard is the consensus standard. Consensus standards are engineering statements of accepted safe practices or materials in a technical area, such as "well control." Consensus standards are usually developed under the auspices of professional technical associations that seek to involve all who have an interest in a standard, in its development. Many government regulations obtain a necessary technical component by incorporating a consensus standard by reference. Indeed, the need to have a regulation in a given technical area is often the impetus behind developing a consensus standard in the area. A virtue of this form of regulation is that standards can be changed to keep pace with technology without having to revise an entire regulation.

Establishing the Regulatory Data Base

The regulations that affect OCS safety were identified by the committee with the assistance of the regulatory agencies. In October 1979, all OCS regulatory agencies were requested to furnish a list of regulations that could possibly relate to the objectives of the study, as stated in Section 21(a) of the OCS Lands Act Amendments. The committee edited the federal agencies' suggested regulations, based on the committee's definition of regulations and their forms and on the continuing identification of problems for analysis. This revised set of regulations was sent back to the federal agencies in May 1980 for their review and comment. Finally, the committee reviewed this second set of federal agency comments and compiled a "dictionary" of federal regulations that affect the safety of OCS Oil and gas activities. Table D-1 presents the contents of this dictionary of safety regulations in summary form.

To facilitate the analysis of regulations, it was necessary to summarize the content of the regulations and to classify their applicability. Accordingly, a worksheet was prepared for each OCS safety regulation. Figure D-1 is an example of a regulation worksheet.

TABLE D-1

Regulations That Affect The Safety Of OCS Oil And Gas Activity

U.S. Geological Survey	30 (Mineral Resources) CFR 250 - Oil and Gas and Sulphur Operations in the Outer Continental Shelf (in part).
	30 CFR 251 - Geological and Geophysical Explorations of the Outer Continental Shelf (in entirety).
	Gulf of Mexico OCS Order No. 6--Completion of Oil and Gas Wells (in entirety).
	Gulf of Mexico OCS Order No. 9--Oil and Gas Pipelines (in entirety).
	Pacific Area OCS Order No. 6--Procedure for Completion of Oil and Gas Wells (in entirety).
	Pacific Area OCS Order No. 9--Approval Procedure for Pipelines (in entirety).
	OCS Order No. 1--Identification of Wells, Platforms, Structures, Mobile Drilling Units and Subsea Objects.
	OCS Order No. 2--Drilling Operations (in entirety).
	OCS Order No. 3--Plugging and Abandonment of Wells (in part).
	OCS Order No. 5--Production Safety System (in entirety).
	OCS Order No. 7--Pollution Prevention and Control (in entirety).
	OCS Order No. 8--Platforms and Structures (in entirety).

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	Safety Requirements for Drilling Operations in a Hydrogen Sulfide Environment," (standard), 1978.
	Training and Qualifications of Personnel in Well Control Equipment and Techniques for Drilling on Offshore Locations (standard), 1977.
U.S. Coast Guard	33 (Navigation and Navigable Waters) CFR Subchapter C, (Aids to Navigation), Part 67--Aids to Navigation on Artificial Islands and Fixed Structures (in part).
	33 (Navigation and Navigable Water), CFR Subchapter I, (Anchorages).
	33 CFR Subchapter N (Artificial Islands and Fixed Structures on the Outer Continental Shelf), Part 140--General Provisions.
	33 CFR Subchapter N, Part 142--Inspections.
	33 CFR Subchapter N, Part 143--Construction and Arrangement (in part).
	33 CFR Subchapter N, Part 144--Lifesaving Appliances (in entirety).
	33 CFR Subchapter N, Part 145--Firefighting Equipment (in entirety).
	33 CFR Subchapter N, Part 146--Operations (in entirety).
	33 CFR Subchapter N, Part 147--Safety Zones (in entirety).
	33 CFR Subchapter O (Pollution), Part 153--Control of Pollution by Oil and Hazardous Substances, Discharge Removal (in part).

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	46 (Shipping) CFR Subchapter F (Marine Engineering), Part 54 0--Pressure Vessels (in part).
	46 CFR Subchapter F, Part 56--Piping Systems and Appurtenances (in part).
	46 CFR Subchapter F, Part 58--Main and Auxiliary Machinery and Related Systems (in part).
	46 CFR Subchapter I-A (Mobile Offshore Drilling Units (MODU's)), Part 107--Inspection and Certification (in part).
	46 CFR Subchapter I-A, Part 109--Operations (in part).
	46 CFR Subchapter J (Electrical Engineering), Part III--Electrical System, General Requirements (in part).
	46 CFR Subchapter J, Part 112--Emergency Lighting and Power System (in part).
	46 CFR Subchapter J, Part 113--Communications and Alarm Systems and Equipment (in part).
Department of Transportation	49 (Transportation) CFR 190 - Pipeline Inspection.
	49 CFR 191 - Transportation of Natural and Other Gas by Pipeline: Reports of Leaks (in part).
	49 CFR 192 - Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards (in part).
	49 CFR 195 -Transportation of Liquids by Pipeline (in part).
Environmental Protection Agency	40 (Protection of Environment) CFR 110-Discharge of Oil (in part).

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	40 CFR 112 - Oil Pollution Prevention (in part).
	40 CFR 125 - National Pollution Discharge Elimination System (in part).
	40 CFR 151 (proposed) - Hazardous Substances Pollution Prevention from NPDES Permitted Facilities (in part)
	40 CFR 220-230 - Ocean Dumping Regulations (in part).
	40 CFR 435.10-12 - Effluent Limitation Guidelines for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category (in part).
Army Corps of Engineers	33 (Navigation and Navigable Waters) CFR 209.135 Shipping Safety Fairways and Anchorage Areas, Gulf of Mexico (in part).
	33 CFR 209.138 - Shipping Safety Training in the Pacific Ocean at Port Hueneme, California (in part).
	33 CFR 209.138a - To Authorize Exploratory Drilling in the Gulf of Gulf of Santa Catalina, California (in part).
	33 CFR 322.3(b) - Activities Requiring Permits, Outer Continental Shelf (in part).
	33 CFR 322.5(f) - Special Policies, Outer Continental Shelf (in part).
Bureau of Land Management	43 (Public Lands: Interior) CFR 340 - Grants of Pipeline Rights-of-Way on the OCS (in part).
	Lease Stipulations, as follows:

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	Atlantic - Nos. 2, 3, 4, 5, 6 Gulf - Nos. 2, 3, 4, 5, 6, 9
	Pacific - Nos. 4, 5, 6, 7, 8, 9, 10 Alaska - Nos. 2, 4, 5, 6, 7
Council on Environmental Quality	40 (Protection of Environment) CFR Part 1510 - National Oil and Hazardous Substances Pollution Contingency Plan.
U.S. Congress	P.L. 95-372, Outer Continental Shelf Lands Act (in part).
	33 USC 466 et. seq., Clean Water Act (in part).
	STANDARDS
American Bureau of Shipping	Rules for Building and Classing Mobile Offshore Drillings Units.
American National Standards Institute	B31.3 - Piping.
	ANSI/ASME SPPE-1-1977 - Quality Assurance and Certification of Safety and Pollution Prevention Equipment Used in Offshore Oil and Gas Operation.
	ANSI/ASME SPPE-2-1977 - Accreditation of Testing Laboratories for Safety and Pollution Prevention Equipment Used in Offshore Oil and Gas Operations.
American Petroleum Institute	Spec 2C - Offshore Cranes.
	Spec. 14A - Subsurface-Safety Valves.
	Spec. 14D - Wellhead Surface Safety Valves for Offshore Service.
	Bulletin T-5 - Employee Motivation Programs for Safety and Prevention of Pollution in Offshore Operations.

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	RP T-1 - Recommended Practice for Orientation Program for Personnel Going Offshore for the First Time.
	RP T-2 - Recommended Practice for Qualification Programs for Offshore Production Personnel Who Work with Anti-Pollution Safety Devices.
	RP 2D - Recommended Practice for Operation and Maintenance of Offshore Cranes.
American Petroleum Institute	RP500B - Classification of Areas of Electrical Installations at Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms, 1973.
	RP53 - Blowout Prevention Equipment Systems, 1978.
	RP14G - Fire Prevention and Control on Open Type Offshore Production Facilities, 1978.
	RP14F - Design and Installation of Electrical Systems for Offshore Production Platforms, 1978.
	RP14E - Design and Installation of Offshore Production Piping Systems, 1975.
	RP 14C - Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms, 1978.
	RP13B - Standard Procedure for Testing Drilling Fluids, 1978.
National Fire Protection Association	Automatic Fire Detectors, 1978.
	Cutting and Welding Processes, 1977.

TABLE D-1 (cont'd)

Regulations That Affect The Safety Of OCS Oil And Gas Activity

	Purged and Pressurized Enclosures for Electrical Equipment, 1974.
	Aircraft Fuel Servicing, 1975.
	National Electrical Code, 1978.
Institute of Electrical and Electronics Engineers	Recommended Practice for Electric Installations on Shipboard, 1977.

Source: Committee on Assessment of Safety of OCS Activities

REGULATION WORKSHEET

MAJOR AREA OF CONCERN/Subarea/specific subject:
WELL CONTROL/General
FIRE AND EXPLOSION/General
INSTALLATION LOSS/General
WORKPLACE SAFETY/General
OPERATIONAL DISCHARGES/General

Agency: U.S. Geological Survey
Form: CFR
Number & Title: Sec. 250.46, Safe and Workmanlike Operations
Codified location: Title 30 Mineral Resources; Part 250 - Oil and Gas and Sulfur Operations in the OCS
Authority: 43 USC 1334, 1335
Source: 34 FR 13547, Aug. 22, 1969; 44 FR 61886, Oct. 26, 1979
Applies to: OCS oil/gas operations
Summary: Require the lessee to operate in manner consistent with the health and safety of all persons, and with the protection of the environment.
Other std/reg referenced:
Directed toward:
Purpose: To promote safe and pollution free operations on the OCS
Enforcement mechanism (inspection, report, plan, etc.): Through field investigations
Comment: These rather general regulations form the basis for more detailed OCS operating orders

Source: Committee on Assessment of Safety of OCS Activities

FIGURE D-1

APPENDIX E

PERSPECTIVES ON OCS OPERATIONS AND SAFETY

To assess the adequacy of technologies and regulations to provide for OCS safety, it is necessary to understand how safety issues figure in the technical and policy context in which they arise. For example, industry and public interest groups purport to have specific interests in the achievement of OCS safety. A clear understanding of their respective positions is necessary in order to assess the adequacy of technologies and regulations. Each viewpoint provides a different set of terms by which to judge adequacy. Recognizing that in the last analysis the assessment of adequacy must be a judgement, the committee attempted to make balanced determinations of adequacy by taking all points of view into account.

This appendix presents the various points of view that must be considered in judging the adequacy of OCS safety in order for the judgement to be in some sense balanced. The sources for the points of view are the individual committee members who hold those views. The perspectives are those that these individuals presented and defended to the committee. Each point of view is not subscribed to by the committee as a whole. The intent is that, taken as a whole and not individually, the perspectives represent a balanced approach to the judgement of adequacy.

Industry Interests

The views of industry were presented to the Committee by O. J. Shirley of the Shell Oil Company. To this end, he compiled two background papers for the committee; one on industry's view of OCS regulation and one on the cost to industry of OCS regulation.[1, 2] These papers are summarized in this section.

Any attempt to describe a good regulatory process for a free, industrialized society is bound to stir debate, if for no other reason than recognizing that such a "model" may be somewhat idealized considering the political, emotional and sometimes irrational environment in which regulations are developed. All the same, and despite the infinite variables, trying to describe the elements of a model regulatory process can provide a useful yardstick or point of reference for those who accept the arguments presented, and who are routinely interested in trying to constructively assess the effect of regulation on an industry.

If it is accepted that the industrial elements of a society, like private citizenry, must be regulated for the benefit of society as a whole, then it can be reasonably argued that a desirable degree of regulation is one which avoids the extremes of too much or too little regulation, and protects the interest of society as a whole while causing the least constraint on industrial productivity. Further, if the object of a free society is to maintain a high degree of personal and industrial freedom, it follows that the regulatory regime in that society should be the minimum required to protect society as a whole. Or said another way, no regulation should exist unless that regulation serves to benefit some significant element of our society.

A number of key tenets can be used to determine whether a beneficial and useful regulation can be developed. Among these tenets are the following:

- The regulation should satisfy an identified need.
- The regulation should have a well defined objective and purpose.
- The actions demanded by regulation should be technically feasible.
- The benefits of a regulation should be predictable.
- Regulatory benefits should exceed regulatory costs.
- Regulatory compliance and enforcement procedures should be straightforward.
- Regulations should be performance oriented.
- Similar activities should be similarly regulated.
- Regulatory actions must maintain perspective with reality.
- Penalities should be commensurate with the nature of the regulatory infraction and should be directed toward the primary offender.

Finally, recognition must be given to the limitations in accomplishments to be obtained by the regulatory process.

The offshore oil and gas industry is now governed by voluminous regulations from multiple agencies with overlapping jurisdictions. The regulatory network covers activities from "conception to grave," is time consuming and costly to both industry and government and is producing results of questionable benefit. Many regulations tend to be oriented toward technology (how to do and what to do) rather than results to be obtained (performance) and discourage innovation. Many regulations infringe on business judgments incumbent to OCS activities and demand precise scheduling of activities that are fraught with uncertainty and which require flexibility to adjust objectives based on progressively accumulated knowledge.

Penalty provisions are severe and provide both civil and criminal remedies for <u>any</u> violation or false information, however minor, which can be construed to be "knowing and willful."

Increasing demands are now being made to furnish the government with proprietary interpretative data which is the heart of competition for OCS leases and the culmination of the exploration effort and skill of a company.

Compared to a reasonable model such as developed above, regulations governing oil and gas extraction on the Outer Continental Shelf are clearly excessive, produce little quantitative benefit to society, and serve to impede the development of badly needed domestic energy supplies.[3] Regulations for the OCS have been developed in isolation without consideration of the interrelationship of impacts created by these regulatory activities, other societal activities, and natural events in the marine environment. If the United States is to expeditiously develop the critically important oil and gas resources of the OCS, the regulatory structure governing oil and gas activities must be radically improved. Such improvements can only be obtained in an objective manner by centralizing regulatory responsibility and by subjecting all regulatory requirements to a quantitative cost-benefit analysis. Much of the needed reform could be accomplished administratively; however some legislative changes also seem necessary.

From an industry perspective the regulatory complex imposed on OCS operations is confusing, lacks definitive purpose, is costly and produces little, if any, quantifiable benefit to society. In the context of other industrial activities the regulations imposed on the OCS industry appear punitive rather than constructive. Further, it seems that the OCS industry has been subjected to microscopic examination in isolation from the real world in an attempt to correct by regulation each minute flaw without regard to the relative importance of the flaw compared to natural occurrences, other societal or industrial activities and risks routinely accepted by society. In any case, with few exceptions, it is difficult to discern any beneficial effect of present OCS regulations toward improving the energy supply of this nation.

In the absence of regulatory reforms and strongly affirmative administration policies toward domestic energy development, the vitality of industry and the energies of government are sapped by often meaningless bureaucratic exercises which produce nothing for our society. In the meantime development of OCS oil and gas resources is being delayed incrementally, lease sale by lease sale, well by well, to an accumulated total loss of potential oil and gas production which may profoundly affect the economic health of this nation.

Some Environmental Concerns in Offshore Oil Development

Environmental views were presented and defended before the committee by Dr. Michael E. Bender, an environmental scientist, and Sarah Chasis and Douglas Foy, two environmental lawyers. The points of view of Dr. Bender and Ms. Chasis are elaborated on in background papers accompanying this report.

Few environmental subjects have stirred more public and scientific controversy than appraisals of the potential ecological effects of oil spill or oil-related developments. Although ecological changes resulting from offshore oil development can be brought about by a variety of activities, the demonstration of effects resulting from specific activities is usually more easily accomplished than determining the specific causes and effects. With regard to the oil industry, the determination of causal relationships is especially complicated since so many different activities are involved. This is especially true with respect to the determination of the actual causes of effects resulting from spilled oil or chronic discharges since so many different compounds are involved. In the course of this study, recent literature on the fates and effects of petroleum and drilling fluids on the marine environment was reviewed by different scientists, with different viewpoints. These appear in the volume of background papers accompanying this report.

Petroleum operations can alter the offshore environment in at least three ways.

- Modifications to the environment can result from structural alterations necessary for drilling, production, and transmission of a product. Typically, these alterations accompany such activities as the emplacement or removal of offshore structures, disposal of mud and cuttings, refuse disposal, and setting of anchors. These operations often have such environmental effects as local increases in turbidity and seafloor disturbances. These effects are usually short-lived, except of course for those related to the actual physical presence of platforms and pipelines.

- Deliberate or accidental discharges of petroleum, drilling muds, or formation waters into the marine environment can cause acute environmental impacts. For example, discharge of drilling muds into the marine environment can physically smother benthic organisms. Although acute effects tend to be of short duration, they can, as is the case in damage to bird populations, have longer-term implications.

- The long-term presence in the environment of even small amounts of petroleum, drilling muds, or formation waters can trigger chronic effects. A chronic effect may result from toxic compounds in drilling muds, which, after building up in the environment for many months, attain a level of contamination that hinders biological activity in an area.

Of these three modes in which offshore activity can alter the marine environment, the one that has attracted the most scientific and public attention is acute effects, especially sudden, cataclysmic contamination of the marine environment by petroleum. The context in which acute effects are usually considered is the threat of ecological disaster resulting from accidental petroleum spills. In point of fact, in certain cases (e.g, the Santa Barbara blowout of 1969) oil pollution has reached the beaches and caused acute damage to sea life and birds. However, in other instances, such as the IXTOC blowout off Mexico, little short-term damage has been detected after substantial accidental introductions of petroleum into the marine environment.[4]

Despite the attention paid to acute effects, the chronic effects associated with OCS activity may well be as or more serious. Without arguing the relative importance of acute vs. chronic effects, it is necessary for all to understand that the introduction of petroleum and associated chemicals into the oceans is a continuing threat to the viability of marine ecosystems. While concentrations of crude petroleum and other chemicals on the order of parts per million are needed to kill most adult marine animals in laboratory studies, long-term exposure to concentrations of petroleum hydrocarbons and other chemicals in the parts-per-billion range disrupt behavior patterns of certain marine animals. Very little is known about these long-term or chronic effects of chemical exposure as they relate to continued survival of marine species.

Crude petroleum and other chemicals are composed of hundreds of different individual components. Some of these components are readily measured. Others can be quantified only by the most advanced analytical techniques, and some cannot yet be measured. Petroleum and other chemical compounds are metabolized by the enzymes of fish and other marine species. After exposure, their tissues contain traces of the original chemicals as well as a variety of metabolites. Only a few of the metabolites have been identified so far, and their effects on marine animals are largely unknown. Moreover, spilled petroleum is continually undergoing chemical change ("weathering") in the ocean and the effects of these changed compounds on marine biota are also largely unknown.

The issue of chronic effects was raised in litigation surrounding the sale of OCS leases on Georges Bank (lease sale 42) in 1979. Commenters on the draft environmental statement on the 1979 lease sale pointed out that the document had not addressed the environmental effects of chronic discharges of oil even though it clearly stated that perhaps as much as 96 percent of the total amount of oil released would be released in nonaccidental, chronic discharges. Some scientists even suggested that chronic releases could cause much more damage to the fisheries than accidental spills because the routine discharges of oil, in formation waters that have been processed for instance, tend to be highly enriched in the most toxic fraction.

The message for decision-makers is that, while structural alterations of the environment and the acute effects of spills certainly deserve to be monitored and studied, the chronic environmental effects of offshore development may be just as, if not more, serious. Furthermore, chronic effects tend to be somewhat more subtle and therefore more difficult to gain a scientific understanding of or to mitigate.

The Interplay Between Technology and Regulations: A Look at the Blowout Preventer

Phillip S. Sizer of the Otis Engineering Company focused the committee's attention on the interrelationship between technological development and government regulations. Technological development and government regulations interact in a number of interesting ways. A plethora of detailed, equipment-specific regulations can freeze technological development while performance standards can be used to force technological development in socially desirable directions. The government also has the option of investing directly in the development of needed technologies. In promoting OCS safety, the challenge before the government is to use its powers creatively and constructively to continue to provide a climate for technical development that will maintain adequate levels of safety.

In this connection, a reasonable person might wonder about the situation that prevails today and the state of affairs in the past. In partial answer to this, it is instructive to take a historical look at the development, use, and regulation of one important piece of safety technology: the blowout preventer.

A blowout preventer is a set of remotely operated valves located on top of a well in order to prevent the escape of pressure either in the annular space between the wellbore and the drill pipe or in an open hole during drilling, completion, and workover operations. A ram preventer uses rams to seal off pressure on a hole with or without pipe. An annular preventer, usually installed above the rams, forms a seal in the annular space between the pipe and wellbore or, if no pipe is present, in the wellbore. For effective well control, the seal provided by the blowout preventer must counterbalance the pressure encountered in the well.

The first patent on a blowout preventer was awarded nearly a century ago, in 1882.[5] Designed for use with the cable tool technology that prevailed at the time, the device employed a screw-operated gate valve to cut the cable and shut off the vertical bore of the well. The valve also diverted the flow so that runaway wells could be brought under control.

Since 1882, more than 13,000 patents have been awarded on improvements to blowout preventer systems. Landmarks in the development of the technology include the invention of the ram-type blowout preventer in 1903, pressure-operated rams in 1928, pressure-fed rams (in which the ram is held in place by the well pressure itself) in 1935, and the self-feeding ram (in which an elastomer is forced through the ram face onto the pipe to create a tight seal), also in 1935. More recently, a subsurface safety valve has been developed to shut off a well in the event that the wellhead is carried away.

In the early days, in the nineteenth century oil fields, blowout preventers were not needed to control the mild downhole pressures encountered in the shallow wells that usually were drilled. By the early 1900's, however, oil men became interested in drilling deeper wells. To increase its depth capabilities, the industry began to shift from cable-tool technology to more sophisticated rotary drilling techniques. In cable-tool drilling, the hole is drilled by dropping a sharply pointed bit on the bottom of the hole. The bit is attached to a cable, and the cable is picked up and dropped, over and over. No drilling fluid is required. In rotary drilling, a hole is drilled by a rotating bit to which downward force is applied. The bit is fastened to and rotated by the drill stem, made of pipe, which provides a passageway through which drilling fluid is circulated. The fluid is required in rotary drilling to flush cuttings from the bit, lubricate and seal the well, and to maintain control of the pressure in the well. In rotary drilling, the wellbore becomes a hydraulic column. Muds and other liquids are pumped through the well to flush drill cuttings from the bit and to carry them to the surface. Since in rotary drilling the well is full of fluid at all times, it is necessary to maintain well control by controlling the fluid in the well. Although blowout preventers were originally invented simply to control the picturesque but unprofitable "gushers" of the nineteenth century, the technology received a major boost, and really came into common use, with the advent of rotary drilling and the consequent technical necessity of maintaining well control at all times. In other words, once rotary drilling came into common use the blowout preventers also became general practice with the oil industry because they were needed to handle the higher pressures that were just then being commonly encountered at the new, deeper depths and also to assist in the control of the hydraulic column in rotary-drilled wells.

Thus by the 1940's, at the onset of the offshore drilling industry, a mature blowout prevention technology had been developed in concert with rotary drilling technology. Furthermore, the use of blowout preventers was accepted practice throughout the oil industry. Therefore, as the industry moved offshore, blowout preventers were designed into drilling systems for the same safety and economic reasons that dictated their use onshore.

When, shortly after passage of the OCS Lands Act in 1953, the government first issued regulations concerning OCS operations, the use of blowout preventers was included as a general requirement.[6] This had the simple effect of confirming accepted practice. The general requirement was reaffirmed in the initial OCS orders, which were developed in the late 1950's. The orders were subsequently revised in 1967, 1975, and 1979. Although each revision has stated the blowout preventer requirement in greater detail, the revisions have generally had the effect of confirming accepted industry practice. The 1975 revision, for example, incorporated by reference the American Petroleum Institute (API) standard RP 53. Prepared by industry, this standard details recommended practice regarding the use of blowout preventers offshore.

This 30-year history of the regulation of the use of blowout preventers can be described in systematic terms. Without government intervention, industry has historically developed technologies and established accepted operating practices, which have been adhered to by OCS operators. Government requirements in this regard have simply mandated accepted operating practices. This has served the purpose of administratively establishing a basic level of safety to which all operators must adhere. The specific benefits that accrue from having a regulation that requires the already-accepted general practice are:

- Establishment of a safety floor to which all operators must adhere.
- The government gains the ability to inspect offshore operations to ensure that the safety floor is maintained at all times and to enforce adherence to the safety floor if that should ever be necessary.

In this system, industry has been free to develop its own design and operating requirements, while government has played an administrative role in ensuring that all operators adhere to accepted practices.

In recent years this balanced approach to OCS regulation, in which industry and government were in some sense technological and administrative partners in OCS regulation, has tipped in favor of a larger role for government and a smaller role for industry.

The trend toward more substantive government involvement in the development of OCS operating practices was given a boost by the OCS Lands Act Amendments of 1978 (P.L. 95-372), which requires that the government ensure "On all new drilling and production operations, and wherever practicable on existing operations, the use of the Best Available and Safest Technologies (that are considered to be) economically feasible." This is interpreted meaning that, among many other things, the government should have some independent capability to make substantive engineering design decisions in order to identify BAST and to require it.

It need hardly be pointed out that the possibility of more substantive involvement of the government in regulating engineering design, over and above its long-accepted administrative regulatory role, is causing consternation in some quarters of the oil industry. There is some concern that the government could become overzealous and impose unthought-out or costly regulations. A more objective statement of the situation is that the government is, for the first time, capable of mandating performance standards to force technological development (or at least utilization) in certain instances.

Human Factors Aspects of OCS Safety

Dr. Lawrence Zeitlin, a human factors expert, elaborated on the human aspects of safety for the committee.

Accident data on the offshore oil and gas industry are strikingly similar to that of the maritime and construction industries. Accidents in each of these industries can be placed into either of two distinct categories: individual and personal accidents or system failures.

Individual and personal accidents involve a worker's interaction with hardware or equipment. Human performance here is predictable--it can be predicted that a certain number of people will be hurt over a given period of time. Furthermore, adverse environmental conditions--long shifts, darkness, excessive heat, cold, or noise--will stress human performance. The most common type of individual or personal accident in these industries is contusions and abrasions to extremities. Despite explosive growth in government safety regulations, the rate of occurrence of these types of incidents has not significantly changed in more than 20 years. The second most common type of injury is the sprained back. The rates for this injury are similarly constant. These examples seem to indicate that individual and personal accidents are not a regulatory problem. These incidents persist because a worker becomes tired, inattentive, or irrational at a particular point in time. One reason that these incidents seem to defy control is because readily available solutions, such as training and safety consciousness programs, occasionally are either not consistently applied (in the case of some marginal companies) or not accepted on the part of workers who, for whatever reason, are not sufficiently motivated to act safely. Crane safety is an example. Although the safety of cranes has been extensively studied and the entire crane, including its controls, has been designed to promote safety, crane operators continue to deliberately exhibit "cowboy" tendencies by taking unreasonable risks to show prowess.

Systems failures are, by contrast, unpredictable. They result from events that were unthought of or unplanned for. If the regulatory scheme in this regard appears to be inadequate, it is due to the common preconception that nothing can happen that was not thought of ahead of time, in a risk assessment or other planning mode. A tragic example of this attitude is evident in the capsizing of the ALEXANDER KIELLAND hotel platform in the North Sea, in 1980. The pentagonal platform had been designed to a two-compartment standard, equivalent to a passenger ship, i.e., she was designed to be stable even in the event that two compartments in a leg were flooded. However, the loss of an entire leg exceeded this design condition and the capsizing was the result.

In considering OCS safety from a human factors standpoint, it is necessary to toss aside certain false assumptions that prevail, i.e, that human performance is unpredictable, that human life cannot be qualified (i.e., have a dollar value assigned to it), and that reasonable persons will not do stupid things. Actually, the obverse of each of these assumptions is true.

Some International Concerns About Offshore Safety

Myron Nordquist, an international and natural resources lawyer, briefed the committee on the international regulatory regime relative to OCS oil and gas operations.

The international legal regime governing oil and gas exploitation activities on the OCS, including safety regulation, is derived from the international customary law doctrine of the OCS and the 1958 Convention of the Continental Shelf (CCS).[7] In addition, the Informal Composite Negotiating Text (ICNT), produced by the Third United Nations Conference on the Law of the Sea, contains provisions pertinent to the safety regulation of offshore installations.[8] While the ICNT, as its title implies, is still informal and nonbinding, it represents an emerging consensus of national opinions developed over a decade of international negotiations. Accordingly, the provisions of the ICNT relevant to this study provide significant evidence of binding customary law.

In addition to the legal arrangements governing offshore mineral development operations, there are important technological issues that bear directly on the safety of offshore activities. The international forum most concerned with resolving such technical issues is the International Maritime Organization, formerly the InterGovernmental Maritime Consultative Organization (IMCO).

Notwithstanding the considerable body of international law applicable to offshore development, coastal nations are the source of the primary legal regimes governing offshore development activity. The U.S. legal regime, in particular, has been compiled and described as a part of this study. It is instructive to compare the U.S. legal regime with those of other countries with extensive offshore developement activity, such as the United Kingdom and Norway.

The legal regimes for offshore safety of the U.S., U.K., and Norway are all compatible with the applicable international rules. The consequences of this are twofold. First, the existence of international rules creates certain standard practices applicable to all adhering coastal nations. Second, certain unresolved problems inherent in the international law carry over to the coastal nation legal regimes.

One of these problem areas concerns the establishment of realistic safety zones around offshore installations. The Convention of Continental Shelf (CSC) authorizes coastal countries to establish safety zones of 500 meters around offshore installations. Under the terms of the ICNT, safety zones may be larger than 500 meters if the larger zone is in accordance with recommended practices of international organizations. Currently, coastal country laws, including U.S. laws, authorize safety zones of 500 meters, as provided for by the Conventional of Continental Shelf. However, offshore developers consider the 500-meter rule to be entirely inappropriate for today's technologies. One reason is that many large modern vessels cannot heave to or even significantly alter their course in 500 meters. Another reason that the rule is considered inadequate is that the underwater cables of some of the larger offshore installations extend to 1,000 meters or more. In addition, safety zones cannot be established that might impinge on established navigation routes. In other words, under international law, the interests of unimpeded navigation can be construed to take precedence over the safety of offshore structures. Thus, the international rules that apply to safety zones should be adapted to comport with modern offshore technologies and safety concerns.

The major problem with regard to the international regime governing the safety of offshore operations is the ambiguity over the extent of coastal nation authority to establish and enforce safety regulations against foreign vessels, particularly in safety zones, and the potential conflicts between flag country and coastal country jurisdiction. Coastal nation regulations based on the rules and standards established by IMCO or set out in international conventions will help ensure their international acceptability. Nevertheless, the problem of enforceability against nonmembers of IMCO or nonparties to these conventions remains. Further, the uncertain legal status of mobile offshore rigs and similar structures presents additional opportunities for conflict.

The Social Acceptability of Risk*

Mrs. Hyla Napadensky, a risk assessment expert, discussed risk concepts with the committee.

> The main consequences of the scientific revolution beginning with Galileo were not only the development of technology but also the divorce between the system of values and the system of knowledge, which had hitherto been assumed to be inseparable."[9]

Any judgment as to the adequacy of OCS safety must inevitably involve a prior judgment as to whether the existing safety situation, either real as evidenced by factual data or potential as otherwise discerned, is acceptable.

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*In discussing risk, it is useful to define several terms. A hazard is a real or potential condition or set of circumstances that can cause or lead to injury or death, or damage to property, or the environment. A hazard analysis identifies and characterizes the latent hazards within a system. Risk is the probability of an undesired event occurring and the magnitude of its consequences. The product of probability and consequences corresponds to the expected value of the loss. A risk analysis comprises all efforts to obtain quantitative measure of the risk. The total risk of a system is the aggregation of all identified risks within the system. Risk assessment is the process of obtaining risk estimates and evaluating the risks against some reference. Risk management comprises risk assessment and all efforts (activities) to keep the actual risk within acceptable limits.

When the question of risk acceptability is addressed, a given risk is generally compared with other societal risks. For example, comparisons may be made with voluntary risks such as motor vehicle accidents (probability of a fatality per person exposed); controllable risks, such as fires in homes; or involuntary risks, such as natural disasters. In these comparisons, it is important to recognize that voluntary risks are accepted at a higher level than involuntary risks. Comparing risks only helps to give a "feel" for the magnitude of the risk involved; comparisons should not be used to imply acceptability.

Some risk assessors advocate that the acceptable risk for a new technology should be the same level of safety associated with ongoing activities having similar benefits to society.[10] There are several pitfalls in this approach. First, it assumes that what was considered acceptable in the past will be considered acceptable in the future. Second, it is based on the assumption that all benefits to society can be quantified and compared. Third, its premise is that all risks associated with a new technology are predictable.

There are at least four different approaches to evaluating future risks.[11]

- <u>Real Risk</u>. This will be determined by future circumstances when they develop fully.
- <u>Statistical Risk</u>. This is based on currently available data, typically as measured actuarially for statistical purposes.
- <u>Predicted Risk</u>. An analytical prediction derived from system models structured from historical studies.
- <u>Perceived Risk</u>. This is the degree of safety--or lack of it--as intuitively perceived by individuals.

Predicted risk is the outcome of risk assessment studies. Where the real risk is known, it has been shown that the perceived risk rarely is the same.[12] If the reference risk--the risk that society is currently exposed to--is misperceived, the magnitude of the new risk cannot be assessed reliably. An additional complicating factor is that the individual's perception of risk depends upon that person's role in society.

There are a number of aspects to evaluating the social acceptability of risk. The risk should be compared with that of similar activities or with some other standard. The risk should also be evaluated in light of the associated benefits and costs to society, the risks, and the costs and benefits of alternative courses of action. Psychological, social, political, and legal considerations must also be taken into account.

In the case of human and structural safety on the OCS, it is feasible to evaluate the acceptability of the risks involved. It is possible to determine all the factors needed for an evaluation, as identified in the previous paragraph. All inputs are predictable and quantifiable, including the costs associated with human life and personal injuries. Risks for activities of comparable type and scale, such as the U.K. chemical industry, have already been determined and their acceptability has been evaluated.[13] The feasibility of evaluating the acceptability of the risk associated with human and structural safety on the OCS is enhanced by the fact that the risks are semivoluntarily accepted, i.e., the people who assume the risks are also the people involved in the activity.

Evaluating the acceptability of the risks attendant to environmental safety on the OCS may not be feasible at the present time, because the factors needed to perform the evaluation are not readily quantifiable in the area of the environmental effects of discharges. This is because there is currently no agreement as to the site-specific effects of discharges.

Assuming that the risks are quantifiable, difficulties will still be encountered with calculating the benefits of courses of action, because the perception of benefits is highly dependent on the perspective of the analyst both in terms of the factors considered to be benefits and the value placed on the benefits. Even if all perspectives were applied to the benefit analysis and all factors were included, the value or magnitude of the benefits might not be readily quantifiable. For example, how can the benefit of the reduced dependence by the U.S. on foreign oil be quantified? The perception and quantification of this benefit is based largely on political forecasting, which is an imprecise endeavor.

Difficulties are also encountered in calculating the costs associated with engineering or management measures to reduce discharges. Similarly, it is hard to evaluate alternatives, since they may run the gamut from alternate methods of OCS operation to alternate sources of energy.

Even though there are many uncertainties and problems in measuring risks, benefits, and costs in the area of environmental safety, considerable insight can be gained from attempts to quantify or estimate qualitatively these parameters.

It is frequently argued that the acceptability of a certain level of risk should be a political or social decision and should not be left to the scientist. However, the scientist can provide guidance to the policymaker in balancing the quantifiable or predictable with those factors that are not quantifiable, in order to make the best possible judgement. Hesitating to evaluate the acceptability of risks on the OCS until uncertainty is eliminated may mean forgoing the benefits (however crudely measured) of OCS activities.

Achieving a Balanced Approach

A continuing frustration for the committee in this study has been the desire to have a "yardstick" with which to measure OCS safety. The reality is that there are no "yardsticks" or simple quantitative measures to use in assessing the adequacy of technologies and regulation to provide for OCS safety. The best that anyone, including the committee, can do under the circumstances is to gain a full understanding of all perspectives on OCS safety and to ensure that, in analyzing the situation, all viewpoints are acknowledged, considered, and kept in balance.

NOTES

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4. *Technical Report on the Drilling and Accident of IXTOC Well No. 1: The Environmental Impact and Preliminary Conclusions.* Mexican Petroleum Institute, August, 1979.
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APPENDIX F

BACKGROUND PAPERS PREPARED FOR THE USE OF THE COMMITTEE

A number of background papers prepared in the course of the study explore issues or contain significant analysis not available elsewhere. These have been printed separately. Following is the table of contents of this volume.

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ASSESSMENTS OF OCS TECHNOLOGIES AND SYSTEMS

Drill Rig Accidents
by Stearns H. Whitney

Survey of Lost-Time Occupational Injuries Occuring on Conoco Operated Properties in OCS Waters
by John Whitman

Crane Safety in OCS Operations
by Lawrence R. Zeitlin

Development of Fixed-Leg Platform Technology
by Griff C. Lee

Hurricane Losses
by Griff C. Lee