INSPECTION OF OFFSHORE OIL AND GAS PLATFORMS AND RISERS

A Report Prepared by the
Committee on Offshore Energy
Technology of the Marine Board
Assembly of Engineering
National Research Council

NATIONAL ACADEMY OF SCIENCES
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NOTICE

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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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Marine Board
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PREFACE

Studies conducted since 1971 by the U.S. Geological Survey, the General Accounting Office, the President's Council on Environmental Quality, the Congress' Office of Technology Assessment, and the National Research Council's Marine Board have addressed the safety of oil and gas operations on the Outer Continental Shelf (OCS). One of the most recent studies, conducted by a panel of the Marine Board, reviewed the practices for verifying the structural adequacy of new, fixed offshore oil and gas platforms and recommended the establishment of a third-party verification procedure by the U.S. Geological Survey (USGS) of the Department of Interior. The report of this study is Verification of Fixed Offshore Oil and Gas Platforms, issued in 1977.

The Marine Board has a long standing concern in matters affecting the safety of OCS oil and gas operations and adequacy of the technical base to support such operations. These matters have been addressed repeatedly in a number of Marine Board meetings and in several reports of its panels. As a result of these concerns and in response to requests by the USGS and the Division of Fossil Fuel Extraction of the Department of Energy, the Marine Board organized the Committee on Offshore Energy Technology in the fall of 1977 to evaluate the technology base to support:

(i) efficient and economic exploration and production of energy resources from beneath the ocean, and

(ii) standards and procedures the government could exercise to fulfill its statutory responsibilities for conserving vital resources, protecting the environment, and safeguarding human life.

During discussions between the USGS and the Marine Board, it became clear that the USGS needed advice in devising a program to carry out its mandated responsibilities for the structural safety of fixed, steel-constructed oil and gas drilling and production platforms on the Outer Continental

Shelf. Accordingly, the committee undertook an assessment of the requirements and methods for the in situ inspection and monitoring of such structures.

This report is based on the committee's review and evaluation. It concerns inspection procedures that could take place after the platforms have been installed on the OCS and after they have been verified for structural soundness by the USGS and found to meet the applicable specifications and performance criteria. Because of the close relationship of the verification and post-installation procedures, the committee has found that many of the conclusions and recommendations for management functions and personnel experience in the Marine Board's 1977 report on verification, prepared by a different group of experts, closely parallel what is considered appropriate and useful for the inspection effort.

The committee was concerned with major steel-constructed drilling and production platforms that are fixed to the sea bottom, as well as pipeline risers that are mounted to the platform. It did not address concrete gravity oil and gas platforms such as the ones now being installed in the North Sea, because none of these structures has yet to be erected in the offshore sites of the U.S. In this study, the committee also did not consider drilling and production equipment and piping.

Contributors to the study are listed at the end of this report. In particular, the committee acknowledges the assistance of G. P. Smedley, Head, Offshore Services Group, Lloyd's Register of Shipping, London, and Nils Nørdenstrom, Vice President, Det norske Veritas, Oslo, Norway. Mr. Smedley and Dr. Nordenstrom participated in discussions of the committee and provided detailed information about inspection procedures and management operations in effect for North Sea oil and gas production platforms.

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INTRODUCTION

Oil and natural gas from beneath the oceans off the U.S. help to lessen the nation's dependence on imports of these fuels. This offshore region provided 13 percent of the nation's domestic gas in 1978. Since the 1930's, the principal source of energy from the ocean has been the Gulf of Mexico, in water less than 125 meters (410 feet) deep. In recent years production has been extended to other areas, as major reserves have been discovered off Southern California and in the Cook Inlet of Alaska.

Currently, some 2,400 production platforms are operating in what the American Petroleum Institute refers to as "federal waters"--that is, beyond the coastal zones on the Outer Continental Shelf (OCS). These range in size, complexity, and function from small, unmanned well jackets to huge platforms like Exxon's Hondo in the Santa Barbara Channel off California and the Cognac platform in the Gulf of Mexico. Hondo is in water that is 259 meters deep (850 feet) and Cognac is in water 310 meters deep (1,050 feet). Rising from the floor of the Gulf a total of 385 meters (1,290 feet), it is taller than the Empire State Building.

The typical platform of the late 1940's stood in only 6 meters (19.5 feet) of water and weighed 1,091 metric tons (1,200 tons). By 1967, the size of the platforms had increased to 100 meters (328 feet) and 5,918 metric tons (6,510 tons). Today, platforms can be erected in water some 300 meters deep (about 1,000-1,200 feet) and weigh more than 47,000 metric tons (about 52,000 tons). (See Figure 1)

A platform in 100 meters (328 feet) of water in the Gulf of Mexico can cost $10-$15 million, depending on the number of wells being drilled and facilities on board. Cognac, by contrast, cost $265 million. By the time it was fully equipped and ready to operate, with some 500 safety devices to guard against spills, blowouts, and other accidents, Cognac represented an $800 million investment that will begin producing oil in the fall of 1979.

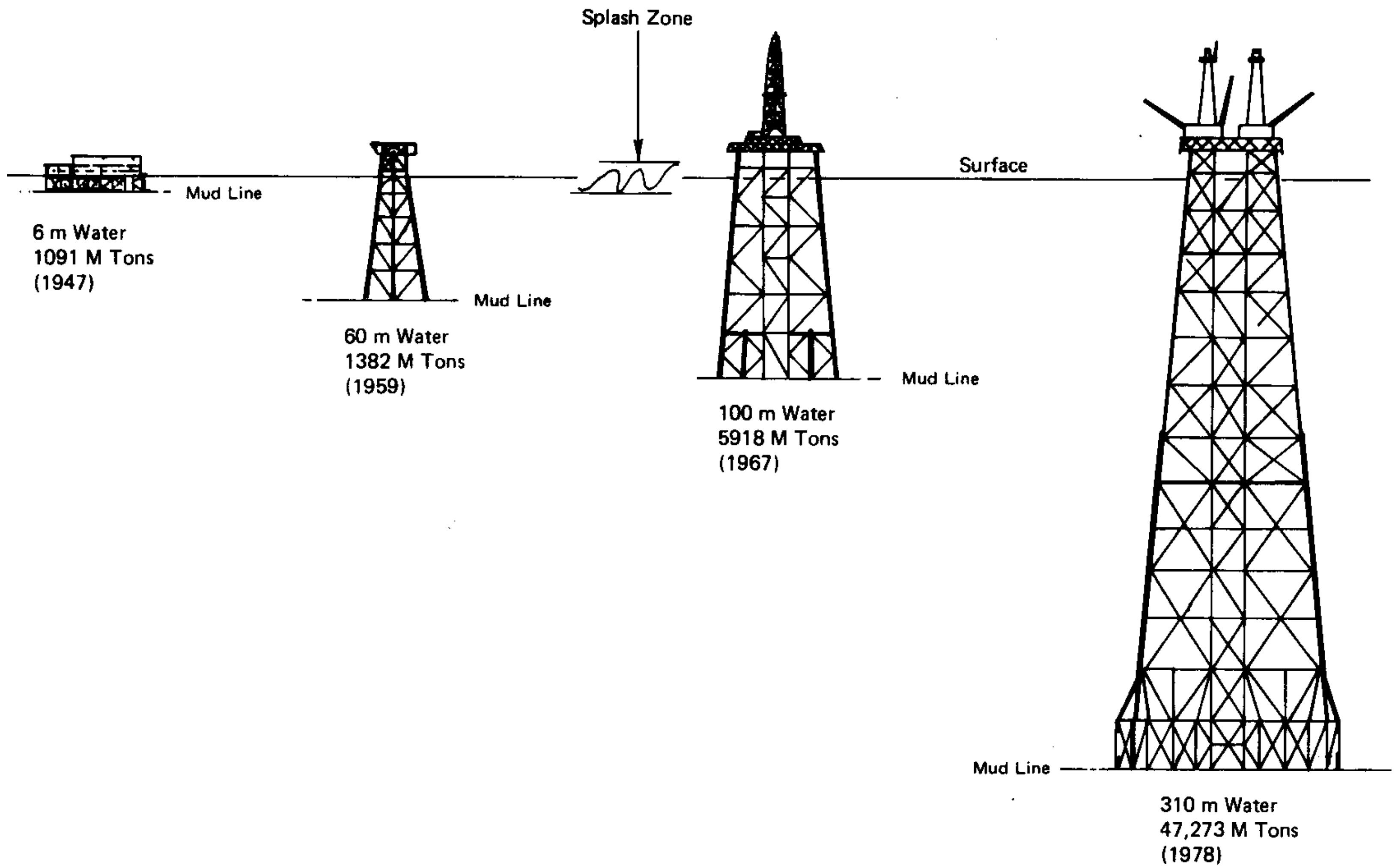


Figure 1: Examples of Offshore Steel Platforms

The safety of such oil and gas operations on the OCS is a primary responsibility of the U.S. Geological Survey (USGS). In its publication, "Policies, Practices and Responsibilities for Safety and Environmental Protection in Oil and Gas Operations on the Outer Continental Shelf,"1/ the USGS has described its responsibilities, which are mandated by the U.S. Congress in the OCS Lands Act of 1953 (43 USC 1331-1343) as amended. Accordingly, the USGS is required to:

- Protect against losses to human life and property, injuries to personnel, damages to the environment, and waste of natural resources by means of an organized and systematic approach to the preleasing and leasing of potential or known oil and gas sites on the OCS.
- Establish requirements for safe drilling and production operations on the OCS.
- Ensure that the oil and gas industry complies with regulations, safe practices, and environmental safeguards through the development and enforcement of stringent requirements.
- Maintain an R&D capability for improving the functions it is required to do.

A number of other federal agencies also have responsibilities for safety on the OCS.

The U.S. Coast Guard, under the same Outer Continental Shelf Lands Act (43 USC 1333), promulgates and enforces:

- Safety of life and property on offshore structures (equipment for construction, layout, lifesaving and fire fighting, and operations on offshore structures) and proper maintenance of equipment to ensure its appropriate operation when needed.
- Inspection and verification of commercial vessels sailing under the U.S. flag that engage in OCS operations, including mobile offshore drilling units; also licensing of marine personnel crews.
- Prevention, control, and cleanup of discharges of oil and other hazardous substances from facilities engaged in OCS activities.

- Safety of human and vehicular diving operations, submersibles, and underwater (subsea) structures; regulations governing commercial diving are under preparation.2/

The Office of Pipeline Safety of the Department of Transportation has jurisdiction for gathering lines and transmission pipeline offshore and onshore. Pipelines of an oil or gas producing facility are under the jurisdiction of the USGS from the platform to the flange connecting to the gathering lines. The scope of responsibility is described by a Memorandum of Understanding (MOU) between the Departments of Transportation and the Interior, but the agreement fails to define a number of other types of pipelines such as transmission pipelines mounted on and crossing over fixed offshore platforms.3/

The Occupational Safety and Health Administration (OSHA) of the Department of Labor claims jurisdiction, along with the USCG, over offshore worker safety. OSHA receives reports of all accidents involving human fatalities and injuries to five or more employees who require hospitalization. The agency is also concerned with the development of regulations for the diving industry. Thus, diving operations relating to inspecting platforms come under OSHA.4/

The U.S. Environmental Protection Agency (EPA) is generally responsible for pollution control and waste disposal in waters of the territorial sea, the contiguous zone, and the high seas.

The National Oceanic and Atmospheric Administration (NOAA) houses the Office of Coastal Zone Management, which administers the coastal zone programs of the states as directed by the Coastal Zone Management Act of 1972 as amended (76 USC 1451-1464).

Still other departments and agencies of the federal government have responsibilities for the safety of OCS operations. To reconcile a framework that is often confused, conflicting, and fragmented, the agencies have resorted to issuing MOU's. This procedure has helped to clarify differing interpretations of legislation, regulations, and policy as well as problems that may be caused by overlapping jurisdictions. Additionally, the coastal states are increasingly involved in the approval process for offshore activities and some have established their own regulatory standards for coastal waters.

Most offshore oil and gas technology has been derived from years of experience in designing, fabricating, installing, and operating platforms in the Gulf of Mexico. This know-how, coupled with the experience and knowledge that has been accumulating as platforms are built in such harsh environments as the North Sea, is being used to design the platforms that will be constructed off Southern California and in the Gulf of Alaska, as well as in the Atlantic and Arctic Oceans as oil and gas reserves are discovered there. In these areas, storm, seismic, and geological conditions are more severe than they are in the Gulf of Mexico and impose additional considerations for the safety of operating personnel and the preservation of the environment.

When a panel of the Marine Board of the National Research Council examined the casualties involving offshore oil and gas platforms for the years between 1947 and 1975 in the Gulf of Mexico, it found that the record was "exceptionally good."5/ To be precise, of some 3,000 structures erected in the Gulf during this period, storms destroyed only 26 and partially damaged another 11. "While oil spills have resulted from storms or from such other causes as collisions, fires, blowouts, or storage tank ruptures," the panel reported, "no significant spills have been attributed by the U.S. Geological Survey and the U.S. Coast Guard to failures of the platform structures."

It is clear, therefore, that no system to verify and inspect the offshore platforms would have been able to prevent their damage from storms, collisions, or fires. Indeed, as the earlier Marine Board panel has rightly observed, no procedure "could guarantee that a fixed offshore oil and gas production platform will be safe or secure at all times for operating personnel, that it will withstand the effects of all storms, collisions, or other accidents of nature or man, and that it will preserve the environment." What a verification and inspection program does is provide a practical way of providing credible assurance to the public and the various governments (at local, state, and national levels) that all reasonable precautions have been taken, based on the best applicable technical and environmental knowledge available, to ensure the integrity of the offshore structure.

PLATFORM INSPECTION

The purpose of an inspection for fixed offshore oil and gas platforms is to identify any structural flaws, degradation, or changes that would require remedial measures to safeguard human life, conserve the resources, and protect the natural environment. While the USGS has the statutory authority to require inspection of offshore platforms under the Outer Continental Shelf Lands Act of 1973, as amended in 1978, a formal inspection program has not been established.

Some degree of inspection has always been practiced by the major oil and gas companies in order to identify maintenance needed and to assure the safety of operating personnel. Cost considerations motivate the platform owners and operators to minimize maintenance for offshore structures. Repair costs are high in offshore operations and are particularly high for the submerged part of the structure, where even minor repairs require the use of divers or remote operations. However, as the Offshore Operators Committee explained, in its statement submitted for this study:

> The most important consideration by far in achieving safe and reliable long-term operations in the offshore environment is proper design and construction of platform and facilities...The experienced offshore operator knows that he cannot rely on in-place inspections to assure structural integrity. He should so design the structure, the pipeline risers, the cathodic protection system, the coating system and the platform protection devices (e.g., barge bumpers, riser protectors, etc.) to prevent structural degradation and damage over the platform life.6/

Inspection of Onshore Steel Structures and Ships

The committee found, in considering an inspection program for fixed offshore oil and gas platforms, that with few exceptions fixed onshore steel structures, including skyscrapers, are not legally subject to inspection after construction. Once the onshore structure is built and approved in conformance with the applicable building code, the proprietor is solely responsible for its condition. Should a code violation be alleged, for example, as a result of changes or deterioration, the local agency responsible for code enforcement will make an inspection for evidence of the violation. If the violation is substantiated, the owner may be subject to legal action.

Exceptions to this rubric include highway bridges built with federal funds. Such bridges are subject to inspection every two years by a registered professional engineer, with other qualifications unspecified. A related exception is a vehicle code requirement in California, under which a state agency determines the safe load capacity for bridges at the request of the responsible local agency.

Thus, in the absence of legal requirements for the inspection of most land-based structures, economic considerations become a major factor for inspection and maintenance. Among the economic considerations are the owner's liability in the event of personal injury or property damage arising from structural failures, the insurer's and underwriter's costs for protection against liability and loss, and the losses incurred when production and utilization are interrupted. In recent years, the courts have imposed heavy penalties and large awards in liability actions, thereby increasing the significance of economic considerations in planning inspection and maintenance programs.

The legal requirements for the inspection of such nonstructural onshore fixtures as boilers, elevators, and fire escapes have resulted largely from public reaction to disasters caused by the failure of this type of equipment. Bridge failures, railroad accidents, and earthen dam collapses have also precipitated legal requirements for inspection.

Ships, aircraft, trucks, buses, and automobiles are subject to legal and other requirements for inspection during their construction and service. By their nature, these vehicles pose hazards to human safety, as well as financial liability to owners, operators, investors, insurers, and users. In addition, environmental considerations are causing new inspection requirements. Such factors may also ultimately influence the inspection requirements for offshore oil and gas platforms and their pipelines and moorings.

Inspection and maintenance of ships, or other mobile marine structures, are required, at least in part, because of their continuous exposure to wear and tear. However, they may be drydocked, or at least be brought into shallow and sheltered water for inspection and repair, in contrast to fixed, offshore steel structures.

Platform Description

For general descriptive purposes, fixed offshore oil and gas platforms are considered to consist of three sections: (i) the above-water portion that supports the deck and drilling and production equipment, (ii) the splash zone, and (iii) the underwater or submerged part.

Above the water the platform is exposed to possible damage from operating activities, action of the wind and spray, and, in some areas, ice. Under storm conditions, a portion of the platform framing is also exposed to wave forces. Durable protective coatings require occasional maintenance or replacement. Structural members are designed to accommodate normal operational loads for the life of the platform and to withstand severe storms. Operational accidents such as ship collisions with the platforms may make it necessary to have an inspection or lead to repairs. Above the water the platform requires routine maintenance, but it is easily inspected and maintenance needs are readily identified.

The splash zone of the platform is the part that interacts with the surface of the water. It is exposed to the corrosive action of the sea as well as to electrolytic activity and corrosion. Subject to constant wave action and possible damage from boats, this part of the platform is more difficult to inspect. Special protective coatings and added steel thickness are used in this region to protect the structure from waves. Occasional maintenance of the protective coatings is necessary. Structural members in the splash zone are designed to withstand wave impacts throughout the expected operational life of the platform. Inspection and repairs may be necessary if the effects of the wave environment have been underestimated in the design of the platform.

The submerged part of the structure is below the splash zone. Its inspection and repair is significantly affected by water depth and diver limitations. This part of the structure is normally in a benign environment with respect to boat damage and other factors that might result in repairs or lead to the need for inspection. Structural members are designed to safely carry loads created by extreme storms or earthquakes, in addition to loads from deck equipment and operational activities. Under normal operating conditions, this section of the platform is subject to relatively light loads, considering the structural capability of the platform. Only extreme environmental events such as severe storms, seismic activity, bottom slumps, and serious accidents may impose loads that might overstress and damage the submerged structure.

Cumulative high-cycle loading in severe operating environments may cause fatigue to structural joints or the submerged structure. Under current design practices, adequate fatigue resistance is provided for the structure's service life. Exceptions may occur when the severity of an operating environment is underestimated or when extension of technology requires materials or practices for which little experience exists.

The seawater is corrosive to structural steel, and cathodic protection systems are used to protect against damage or deterioration of the submerged portion of the platform. Therefore, continuing effective performance of the cathodic protection system is essential for maintaining structural integrity.

Loading Conditions

An offshore platform must support the loads imposed by its own weight, by equipment for drilling and production operations, and by environmental conditions. Accidental loadings, sometimes treated separately in design rules and practices for offshore platforms, are considered to be either operational or environmental in this discussion.

Operational Loads

Platforms are designed to carry out a specific, well-defined function. Thus, the operations, the related equipment, and the loads caused by these operations need to be carefully defined and the structure designed accordingly to accommodate all the prospective loads. Operational loads may change if plans for the development and operation of the oil field are revised. The revised plans could require additional or new equipment, making it necessary to reappraise the platform's capability to carry the new operating loads safely. The revision in operating loads does not affect the inspection requirements unless the integrity of structure at the new operating levels is in question.

Offshore oil operations involve heavy equipment which carries heavy loads and transmits them to the platform. Although structural members are of adequate size for normal operation of the equipment, accidents can damage the structure so that inspection and repair are needed. The inspection not only indicates the nature and magnitude of the repair required, but also whether the loads were potentially damaging to parts of the platform other than the locally damaged area. Objects that fall from the deck may damage the bracing or even the main members of the section below the surface.

Normal and abnormal marine operations, such as the docking of supply vessels, may necessitate inspection of the platform, although most platform fenders absorb the impact of such vessels. Accidental landings could cause damage directly to the structural members. Structural protection is generally adequate, provided that fenders are properly maintained. To ensure this protection, inspection and maintenance of fenders are required.

Environmental Effects

Environmental effects fall into the following categories: (i) particular events such as severe storms or earthquakes whose possible singular occurrence fix an important design loading condition, and (ii) relatively frequent events that have a cumulative or, perhaps, continuous effect on platform design requirements. The second type of event includes frequent waves and ice-induced forces in harsh environments that make demands for fatigue resistance on the design of the platform.

Inspection requirements differ for each of the environmental conditions. Should an extreme but rare environmental event occur in the course of platform operation, due consideration must be given to its effect on the integrity of the structure. Accordingly, inspections for damage should be carried out as appropriate.

Uncertainties about the precise magnitude of severe events has little effect on inspection needs. However, knowledge of exposure to severe events, coupled with inspection results, should provide enough information to improve the level of confidence in design adequacy and limit needs for future inspections.

Environmental effects that occur frequently, and that therefore may be referred to as operational conditions, have a different bearing on design and inspection than the serious but rare event. Here the design and operating issues are the identification of (i) all environmental events that bear on the design, (ii) adequate information about the frequency and magnitude of the events, and (iii) technology required to design, fabricate, and operate platforms so that they safely resist cumulative effects. The need for inspection relates, then, to the level of success in dealing with the three design and operating issues. Inspections related to operational conditions are not necessary for the operation of a specific platform when (i) there are adequate environmental data on which the design can be based and (ii) reliable operation over a long period or other suitable verification demonstrates the platform's capability for maintenance-free operation. By contrast, inspections may be essential when there are (i) sparse or incomplete environmental data at the time of design that could lead to the omission of a significant design factor or to the underestimation of the magnitude of a recognized design condition and (ii) requirements to operate in areas where the technology or the environmental information may not be sufficient to attain the expected performance or where reliability has not been verified. In the latter case, inspection may be necessary to indicate whether or not all significant design conditions have been identified and expected structural performance has been achieved. Environmental monitoring, in the case of sparse data, could reduce the need for inspection by resolving any uncertainties as to expected conditions.

Inspection Criteria

The committee used two basic criteria in evaluating the options for inspection:

1. The proposed inspection is essential to maintaining the integrity of the structure in service.

2. The data obtained from the inspection are sufficient to detect need for repairs or remedial action.

Thus, inspection serves to identify the maintenance or repair programs that may be appropriate to preserve a structure's load capacity, operational utility, and structural safety, thereby meeting the fundamental objectives of the owners and the government.

The inspection can relate a structure's actual condition to its design capacity and normal capability, but the inspection itself cannot provide a measure of absolute load capacity. The criteria are intended to take into account those portions of a platform that may be subject to routine maintenance or may be relatively susceptible to accidental damage, as well as those portions that never require maintenance under normal conditions. They provide a rationale for inspection, yet limit it to the essential purpose--that is, to make sure, within acceptable limitations, that the platform will help to safeguard operating personnel and conserve resources and that it will not harm the natural environment.

No mathematical formula can be applied to determine whether or not an inspection program is needed or even if one is adequate. In an effort to determine the needs and sufficiency of an inspection program, the committee formulated the following guidelines.

Inspections are needed as a result of:

- overloads and impairment caused by accidents, storms, or other environmental events;
- damage and degradation caused by corrosion, fatigue, fouling, and everyday wear and tear; and
- factors that could not be resolved during the verification process, such as the unanticipated consequences of the use of the newest technology and the lack of sufficient environmental data.

Inspections are not needed for parts of a platform that are designed to operate with little or no maintenance, provided that:

- sufficient prior experience and quality control measures exist to assure that design expectations (which are part of the verification procedure) are met, and
- the structure is not subjected to conditions more severe than those anticipated by the design.

An inspection procedure is redundant and is not needed if it provides more information than required for recognizing structural degradation or if it is not critical for determining remedial action. While no inspection program can guarantee that all defects or degradations can be detected in the structure, it must provide sufficient information for the implementation of routine maintenance programs. In addition it must indicate whether or not special or extraordinary remedial or restorative measures are needed.

The scope of methodology of an inspection program will also be affected by such considerations as:

- the safety of personnel and the protection of the environment;
- the adequacy of environmental monitoring to verify that design loadings have not been exceeded;
- cost-benefit relationship of the inspection program;
- the adequacy and credibility of inspection and support services;
- the amount of time required to complete an inspection under normal circumstances and under storm conditions;
- priority of inspection procedures; and
- the availability of the technology for a credible inspection procedure.

In theory, a comprehensive cost-benefit analysis could be used to judge the worthiness of an inspection program, provided that values can be assigned to human lives and to environmental impacts. Such an analysis would not be credible at present and any judgment of economic consequences must be, of necessity, somewhat subjective and incomplete. Moreover, definitive acceptance criteria are not available for deciding on the necessity for unusual or extraordinary repairs when flaws or cracks are discovered by inspection. Such criteria will require development for each specific platform. The decision to make repairs, therefore, depends on considerations other than the inspection data and is an example of the type of action that would fall into the Failure Reporting and Analysis function of the inspection management system, described in a later section of this report.

Strategies for Inspection

Two basic strategies for inspecting fixed offshore oil and gas platforms were considered by the committee. One of these strategies would require inspection at fixed intervals of time, and the second would require inspection when a problem arises or after the occurrence of a specific event.

A consideration of the characteristics of production platforms described earlier indicates a clear need to mix these two basic strategies in any inspection program. Some portions of a platform clearly require inspection at periodic time intervals. Performance of the cathodic protection system, for example, is critical, and its periodic monitoring is appropriate. Periodic inspection is also appropriate for the above-water part of the structure and the splash zone where maintenance needs are expected and exposure to accidental loads is probable.

On the other hand, any and all portions of a structure could require inspection after, for example, the occurrence of a specific event, such as a severe storm or earthquake, bottom slump, or a ship collision, or the development of new technical information that could raise a question as to the continuing adequacy of the structural integrity of the platform. Therefore, the committee concludes that inspection of offshore platforms should be carried out both periodically, including monitoring of the cathodic protection system, and whenever a major environmental incident or accident occurs.

The committee has considered four categories of inspection:

1. Annual, visual inspection of the splash zone and above-water parts of the platform, supplemented by additional inspection after it has been exposed to, say, a severe storm or an accident.

2. General visual inspection by divers or remote TV of the submerged part of the platform and the contiguous ocean bottom when needed.

3. Visual inspection by divers or remote TV of specific, cleaned regions of suspected damage to the submerged part of the platform, possibly supplemented by nondestructive testing.

4. Periodic inspection of a cleaned, preselected number of joints of the submerged structure, supplemented by nondestructive testing if this is judged necessary.

The basic criteria listed earlier provide the basis for judging the merits of the four categories of inspection, which are described in greater detail below. The categories are distinguished primarily by the portion of the structure involved and the level of inspection detail required. For completeness, performance monitoring of the corrosion protection system should be included, because the committee judged it to be an essential part of any inspection and maintenance program.

Category 1 attempts to satisfy the need for both major types of inspection after an established period and after a potentially damaging event. The inspection is to be made visually over the splash zone and above-water parts of the platform. These sections are particularly vulnerable to operational accidents and sea and weather forces. Moreover, because of the constant use of these sections, routine maintenance is necessary. Damage or degradation of these sections is evidenced by (i) deterioration of protective coatings, (ii) deformation or other gross evidence of accidental or environmental overloading, and (iii) fatigue cracks caused by environmental or other loads unaccounted for in the design.

Coating deterioration and deformation above the water are readily apparent by visual inspection, as is evidence of gross overload. However, minute cracks such as an incipient fatigue crack possibly might not be detected in a visual inspection and would remain undetected until they increased to detectable size. Cracks of this type are extremely rare in the Gulf of Mexico, where experience with offshore platforms since the 1940's has been incorporated into their design and fabrication. Design and verification practice should ensure that fatigue design technology and Gulf of Mexico experience are extended to other geographical areas. However, in those cases where questions of the design, fabrication, or loads above the water surface cannot be resolved, physical inspection may be the final fallback position. In such cases, visual inspection for fatigue damage is adequate if there is sufficient redundant strength in a joint containing a visible fatigue crack or enough redundancy in the adjacent structural framing to assure the platform's integrity until the flaw can be detected and repaired.

Category 2 inspections are made by divers or remote TV (i) if the Category 1 inspections indicate possible damage to the submerged structure, (ii) if available environmental information is deficient or if there has been an extension of technology for which there is little related experience, (iii) after an accident that may possibly have damaged the underwater portion of the structure, and (iv) to detect scour or bottom erosion. In cases ii, iii and iv, the need for Category 2 derives from questions raised in the verification process. In such an instance, Category 2 inspection should be made at least twice, with an interval of about five years between each inspection. Continued inspection should be contingent upon review by the government establishing the need for prolonged observation.

There are three considerations relating to the sufficiency of data obtained by this category of inspection. First, visual observation will reveal evidence of substantial overloading from severe environmental events or accidents by the deformation of a member or joint, the presence of debris, or the changes in the ocean bottom adjacent to the platform.

The second relates to cumulative fatigue loading. No practical means are presently available for measuring how long a structural joint can withstand certain repetitive loadings before it cracks. Visual inspection for cracks or fractures is the recognized practice on all marine structures. As noted, Category 1 visual inspection for fatigue damage is considered adequate if there is enough redundancy in the structure to maintain safety until a flaw is detectable and can be repaired if necessary. Third, visual inspection is also sufficient for detecting excessive fouling and scour, and for revealing general evidence of any unexpected structural change. In most situations, a visual inspection should reveal or detect deformed joints, buckling members, or twisting that would provide a warning of unsafe conditions and signal the need to initiate more detailed work. If questions remain as to the adequacy of the structure after a Category 2 inspection, Category 3 inspections should be initiated. Given the back-up by Category 3, Category 2 inspection should be sufficient for structures typically designed and built for redundancy.

Category 3 inspections concentrate on the part of the structure that has been identified by the Category 2 visual inspection as needing a more detailed examination. Such inspections, performed by diver or remote TV, call for the part to be cleaned as needed beforehand in order to determine the nature and extent of repairs or to resolve any questions raised by the previous Category 2 inspection. Information such as crack length, propagation rate, or crack termination may be essential to a decision on repairs and should be collected. To facilitate the examination, nondestructive testing may be added as appropriate. This category of inspection should identify the need for corrective action and provide the information for design of the remedial measures.

Category 4 includes periodic, detailed visual inspections of a number of designated joints of the submerged structure and, if deemed necessary, nondestructive testing of the joints.

This inspection procedure is responsive to British and Norwegian practices and requirements for construction and inspection of offshore oil and gas platforms in the North Sea.7, 8/ The committee questions the value of the additional data to be derived from this inspection in view of the costs for the large number of divers and services required to perform it. the limitations on the ability to conduct the inspection caused by adverse weather, and the certainty of data based on a limited capability to examine the part and its properties under adequate scientific and technical conditions. An application for Category 4 inspection could arise, however, if new environmental or technical information led to identifying a possible deficiency in specific joints of a platform.*

Corrosion Protection Monitoring

Adequate corrosion protection to prevent undue loss of structural steel in the submerged part of a platform is essential for preserving the integrity of the structure. The performance of the cathodic protection system for typical platforms can be monitored by measuring the electrical potential between the platform and a suitable reference electrode suspended in the water at various depths and from designated locations of the deck. Typical installations for cathodic protection systems are platforms with geometry, electrode distributions, and attachments such as pipelines that fall within the established guidelines for the design of the system. For these installations, no unusual "hot spots" occur with localized potentials significantly different from the potential over a substantial region of the structure. Hence, an overall general traverse is sufficient to establish that the protection is adequate. Recommended practices for the design of corrosion control systems have been published.9/

The committee recognizes that platform framing geometries or other special situations could present unusually difficult problems for cathodic protection design. Such situations should be considered as exceptions, and a special monitoring program set up to provide back-up inspection measurements. In normal practice, measurements for electropotentials taken once a year have proved adequate in monitoring the capability of the protection system. The committee recognizes the need for more frequent surveillance of the operation of impressed current systems to avoid lapses of protection during periods when the supply of current is inadequate. During such periods, corrosion can occur very rapidly. The inspection intervals set out above are predicated on the use of anodes, with performance established through operational experience or appropriate tests. The use of a reliable structural attachment for the anodes should be standard.

*After the completion of the committee's study and while this report was being written, Jack Boller, Executive Director of the Marine Board, was informed by officials of Det norske Veritas that the Norwegian organization was modifying its requirements for this type of inspection as a result of the operational experience and the excessive cost.

Inspection Capability

Status

Inspection practices around the world and present-day technology for performing inspection have been extensively documented in three reports. Underwater Inspection/Testing/Monitoring of Offshore Structures 10/ describes all actual or potential underwater inspection requirements (national and international) for fixed concrete and steel structures promulgated by the governments of offshore oil and gas producing countries. It assesses the state of the art in underwater nondestructive testing, as well as of the monitoring and inspection of offshore structures, and evaluates the capability of servicing personnel and hardware producers to meet the inspection requirements. It also establishes priorities of specific tasks for technology development that need to be undertaken to satisfy current and future requirements. In the second report, Offshore Installations: Guidance on Design and Construction,11/ the United Kingdom's Department of Energy explains the procedure for certifying that fixed and mobile offshore installations are fit for their purposes in accordance with legal requirements. The third report, Rules for the Design, Construction, and Inspection of Offshore Structures,12/ sets forth guidelines for inspection by Det norske Veritas. The committee frequently consulted these documents in its consideration of inspection capabilities.

The rules applicable to North Sea platforms require annual surveys, during which a cumulative fraction of joints is cleaned and given detailed visual inspection, supplemented by nondestructive testing if required. In practice the limitations on the survey are too great to achieve what is required by the rules. These limitations include diver capabilities, diving hazards, and necessary instrumentation, as well as the sheer number of joints to be inspected. Nondestructive testing is being used to a limited extent in the North Sea, especially where possible defects have been indicated by visual inspection or where joints are deemed particularly critical. However, present-day technical capability is limited by the lack of quality control standards in application. Instrument calibration to repeatable standards and personnel qualifications are key issues, along with recording and audit techniques for the inspection procedure.

In contrast to North Sea practices, the types of inspection judged to be sufficient for U.S. offshore structures rely primarily on visual inspection, supplemented, if necessary, by detailed visual inspection requiring cleaning. Nondestructive testing is a supplementary inspection carried out as needed and related to a specific need.

The current technical capability is also limited by a lack of noncontact inspection methods. Developments are underway, but no reliable results have been achieved thus far. Such methods include vibration measurement and analysis and remote acoustic detection of crack propagation. Other monitoring concepts may be directed at detecting loads that exceed the design criteria, critical changes in the platform response characteristics, and specific structural failures. In the future, engineers may be able to compensate for the limitations of inspection capability in the initial design of the structure.

Inspection Needs vs. Data Required

A series of matrices were prepared by the committee to illustrate the general relationships of data needed to appraise the condition of fixed steel offshore platforms, the available inspection technology, and the means of delivering the technology to the inspection site.

The first matrix (Table I) relates the data required in terms of measurable physical properties to inspection operations directed at the three sections of the platform: the structure above the water, the splash zone, and the submerged structure. The matrix depicts elements of the inspection that cover all the significant sources of failure of the structure. Some elements may be supplemental, to be implemented in case a primary technique reveals an anomaly. The structure may be examined periodically or examination may follow an accident, storms, or seismic activity that exceeds the design limits of the structure. Definition of the event that leads to inspection requires a companion activity for monitoring environmental factors and platform response characteristics and for logging accidents.

The second matrix (Table II) relates the data requirements to means for acquiring the data. The means are in various degrees of development, ranging from shelf hardware to R&D projects. Their utility above water and in the splash zone is generally adequate, but in the submerged zone it is reasonably satisfactory only to depths in which divers can function. Utility decreases as depths increase.

The third matrix (Table III) relates the inspection techniques to various means by which they can be brought to the site. It also indicates whether or not the technique, together with its delivery system, is presently available (X); existing but requiring adaptation to the marine environment (O); or currently only an R&D project (R).

Table I: Inspection Needs vs. Data Required for Steel Structures

Inspection Type	Inspection Needs \ Physical Properties	General Structural Integrity	Structural Deformation	Joint Separation	Joint Cracking	Corrosion Protection System Integrity	Corrosion Potential Measurements	Corrosion Thickness Measurement	Fouling	Scour	Nature and Location of Debris	Vibration	Tilt
GENERAL PERIODIC INSPECTION	**Above Water**												
	Existence of Corrosion					X		X					
	General Deterioration and Cracking		X	X	X			X					X
	Structural Distress	X	X	X	X								X
	Splash Zone												
	Corrosion					X	X	X					
	General Deterioration		X	X	X		X	X	X				
	Structural Deformation	X	X	X	X							X	
	Thickness Gauging							X					
	Weld Zones in Detail		X		X			X					
	Excessive Fouling								X				
	Submerged Zone												
	Member Missing	X										X	
	Structural Deformation	X	X	X	X							X	
	Excessive Scour									X	X		
	Corrosion-Protection System					X	X	X					
	Thickness Gauging							X					
	Weld Zones in Detail		X		X			X					
	Excessive Fouling								X				
	Presence of Debris										X		
	Repairs and Modifications		X	X	X	X	X	X					
EVENT-ORIENTED INSPECTION*	**Above Water**												
	General Structural Integrity	X	X	X	X	X							X
	Splash Zone												
	General Structural Integrity	X	X	X	X	X	X						
	Submerged Zone												
	General and Local Structural Integrity	X	X	X	X	X	X	X		X	X		X
	Corrosion Inspection Where Suspected						X	X					

*Requirements are the same for event-determined and periodic inspections.

Table II: Data Required vs. Sensors for Steel Structures

Applicable Sensors	General Structural Integrity	Structural Deformation	Joint Separation	Joint Cracking	Corrosion Protection System Integrity	Corrosion Potential Measurements	Corrosion Thickness Measurement	Fouling	Scour	Nature and Location of Debris	Vibration Signature	Tilt
Eye	X	X	X	X	X		X	X	X	X		X
Television	X	X	X	X	X		X	X	X	X		
Film Camera	X	X	X	X	X		X	X	X	X		
Optical Scan	X	X	X		X			X	X	X		
Acoustic Scan	X	X							X	X		
Ultrasonic Thickness							X					
Radiographic				X								
Magnetic Particle				X								
Corrosion Potential					X	X						
Profile Gauge		X					X					
Straight Edge		X					X					
Accelerometers											X	
Ultrasonic Flaw Detection		X	X									
Platform Tilt and Level Gauge												X
Eddy Current				X								
NOTE: Cleaning is required for certain measurements:												
(a) Brush			X	X			X	X				
(b) Chipper			X	X			X	X				
(c) Water Jet			X	X			X	X				

Table III: Sensors vs. Transporters

SENSOR \ TRANSPORTER	SUBMERSIBLES					STRUCTURAL MOUNT	
		Tethered		Untethered			
	Divers	Manned*	Unmanned	Manned	Unmanned	Permanent	Temporary
Eye	X	X		X			
Television	X	X	X	X		O	O
Camera	X	X	X	X	R		O
Optical Scan	R	R	R	R	R		
Acoustic Scan	X	X	X	X	R		O
Ultrasonic Thickness	X	O	O	O	R		O
Radiographic	X	O	R	O	R		
Magnetic Particle	X	O	R	O	R		
Corrosion Potential	X	X	X	X	R	X	X
Profile Gauge	X	O	R	O	R		
Straight Edge	X	X	O	X	R		
Accelerometer						X	X
Ultrasonic Flaw	X	O	R	O	R		
Platform Tilt and Level Gauge							X
Eddy Current	O						
NOTE: Some sensors require preliminary cleaning:							
(a) Brush	X	O	R	O	R		
(b) Chipper	X	O	R	O	R		
(c) Water Jet	X	O	R	O	R		

SENSOR
X = Existing System
O = State-of-Art
R = R&D

*Without diver lockout, but includes one atmosphere diving suit.

The matrices show general relationships for possible combinations of need and technology. It is helpful to identify the specific needs that are directly related to inspection categories 1, 2, and 3. Category 1 inspections performed after severe environmental loading require some means for determining the occurrence. This may be derived from instrumentation that is installed on-board or based on local information from shore stations where hurricane tracks are closely monitored. However, the occurrence of other events related to bottom dynamics must be inferred from crew observation, platform tilt, or other response measurements such as acceleration. All accidents should be recorded.

Visual techniques for divers or submersibles in Category 2 inspections underwater are established capabilities identified on the matrices, particularly Table III. Category 3 inspections underwater are also primarily visual, but require detailed or close-up observation. Cleaning is a necessity for which the diver capability is established, though difficult. At greater depths, or in environments beyond acceptable diver limits, submersibles are deficient in cleaning capability, as indicated in Table III. For Category 3 inspections, using nondestructive testing, the disparity between diver and submersible capabilities is apparent in the table. Standards and qualifications for this level of inspection are not established.

System Capabilities

Underwater Inspection/Testing/Monitoring of Offshore Structures, mentioned above, contains an assessment of the inspection technology with respect to platforms. Offshore Pipeline Safety Practices 13/ prepared for the Office of Pipeline Safety of the Department of Transportation, assesses inspection technology for pipelines, and a report of the Harry Diamond Laboratories of the U.S. Army Materiel Development and Readiness Command 14/ describes sensors with respect to general OCS pollution and safety control. The committee has found these reports helpful in its evaluation of system capabilities.

The following amplifies Tables II and III and suggests the research and development effort that may be required.

Visual inspection underwater can be accomplished by divers, television, movies or still cameras. Acoustic imaging of adequate resolution and laser optical scanning (down to 125 meters) are in varying stages of development. Some of the deficiencies of visual inspection that are caused by diver disorientation or use of underqualified inspectors can be surmounted with closed circuit TV monitored by a trained observer on deck. While detailed or close visual inspection is not limited by sensor technology, the cleaning process poses a constraint on this procedure. General visual surveys are also limited by illumination backscatter at short ranges.

Nondestructive testing techniques for ultrasonic thickness and flaw detection and magnetic-particle inspection have been adopted by various users and are commercially available. Dye penetrant and eddy-current techniques for crack detection have not been adopted, but radiographic methods have been tried in dry habitats on such simple shapes as pipes. For limited application as a supplemental technique to Category 3 inspections, ultrasonics and magnetic-particle inspections are sufficient when performed by qualified divers.

High-pressure water jetting is a favored cleaning technique because there is no surface peening, but the technique is slow and cumbersome. Cleaning is critical to effective detailed underwater inspection.

Table III shows three ways of bringing and applying the sensors and cleaners to the site: divers, various types of submersibles, and structure-mounted sensors. The latter may range from strain gauges to TV cameras, but they, or their wiring, tend to have short lives underwater compared to the longevity of the structures. Thus, the committee concludes that, as indicated by Table III, human divers are the only reliable means of bringing the sensors to the site of inspection.

Inspection Research & Development

The new fixed offshore oil and gas platforms are large and are being installed in deeper waters. Greater numbers of divers, who require extensive time and extensive support services, will be needed to perform appropriate inspection. However, greater water depths and diving hazards are making conventional procedures for inspection no longer acceptable to operators or regulators. Consequently, remote control vehicles (RCV) are coming into use or being planned for the future. Complete RCV systems which include cleaning that would be useful in depths beyond diver capabilities are not available. It is necessary, therefore, that the capabilities of RCV's and submersibles (including one atmosphere diving suit), be extended to include at least a cleaning capability for large platforms functioning at great depths.

Suggested R&D

Table IV is a suggested list of specific subjects for R&D that will lead to increasing inspection capability, productivity, and quality. Priorities are not indicated in the table because inspection R&D must be considered in relation to R&D needs in other areas of offshore oil and gas technology.

However, the committee recognized that technology for inspection underwater is advancing rapidly and that many of the limitations that it identified are likely to be overcome in a few years.

Table IV: R&D Needed to Support OCS Inspection and Monitoring

R&D AREA	REPRESENTATIVE R&D TOPICS
Cleaning	Cleaning: Adapt the present Navy Work Systems Package for deep cleaning operations for commercial application by divers and submersibles.
Remote Sensing Devices	Television: Investigate the use of fiber optics cables and transmission and signal processing techniques to meet the bandwith requirements of remote underwater TV transmission for inspection purposes.
	Optical Scan: Develop a systems concept to exploit laboratory developments in rapid total scanning (laser mapping) of underwater structures.
	Acoustic Scan: Exploit acoustic imaging technology to cope with regimes of high turbidity and consequent limited visibility.
	Ultrasonic Thickness Gauge: Develop an instrument designed specifically for underwater use.
	Radiographic: Adapt existing instruments for use in unmanned submersibles. Eliminate radiation hazard to observers.
	Magnetic Particle Inspection (MPI): Develop MPI systems for tethered and untethered submersibles; extend depth capability beyond present 100 m limit.
	Corrosion Potential Meters: Package for use in unmanned submersibles.
	Sub-Bottom Profilers: Experiment to determine profilers' applicability for use in inspection of buried man-made structures such as platform foundations.
	Profile Gauge: Package for use with remote controlled vehicles.
	Accelerometers (Dynamic Analysis): Pursue and develop this technology.
	Ultrasonic Flaw Detection: Develop computer-aided processors for *in situ* or real time interpretation.
Inspection Vehicles	Divers: Extend depth capability of commercially available saturated diving services. Adapt fiber optics to diver-carried data tethers to improve safety, to obtain greater transmission bandwith and immunity from electromagnetic interference.
	One-atmosphere Diving Suits (ADS): Improve tactile response of ADS, improve manipulators and include snap-on-tool capability; improve operator response in reduced visibility conditions.
	Manned Submersibles: Develop lightweight, expendable fiber optics links for communication and data transmission including observing underwater inspection from the surface.
	Unmanned Tethered Submersibles: Develop lightweight cables for fiber optics and power transmission (high data-rate feedback). Develop "intelligent" vehicles with minimum of operator feedback control required.
	Unmanned Untethered Submersibles: This embryonic technology area should be supported and systems development encouraged.
Pipeline Inspection and Monitoring	Develop devices for the measurement of internal corrosion in underwater platform risers.
	Develop leak detection flow meters.

INSPECTION MANAGEMENT

The management of an inspection program under the aegis of the USGS should integrate with and transfer smoothly from the verification process, particularly because the USGS has the jurisdiction for both activities. The engineering disciplines used for reviewing and approving inspection are essentially the same as they are for verification. It may happen that questions or reservations raised by the design verification process may influence or be reflected in the inspection requirements at a specific site. Conversely, inspection requirements will influence the design, and the management process should provide a conduit for information interchange.

In Verification of Fixed Offshore Oil and Gas Platforms, the Marine Board's panel devised a matrix of options for the performance of verification functions. Table V, prepared by the committee, is similar to the matrix for verification but has been modified to cover the functions and responsibilities appropriate to inspection.

Functions and Responsibilities

The functions in Table V marked by asterisks and identified as "approve plan," "provide appeal route," "failure reporting and analysis," "post-inspection and repair review," and "audit implementation" are considered to be primarily USGS responsibilities. The remaining functions are "prepare plan," "check plan," "implement plan," and "monitor implementation." The management options for these functions need to be balanced against the considerations of credibility, accountability, and cost.

As with any program, the effectiveness and the impact of implementing the inspection program are dependent upon the personnel performing it. The management of this program needs to be coordinated with the management of the verification program, as the two are very much interdependent.

The operator is best qualified to prepare the plan according to government guidelines because the industry will

Table V: Inspection Functions

FUNCTION	MANAGEMENT RESPONSIBILITY
Prepare Plan	Industry
Check Plan	USGS/Contractor **
Approve Plan*	USGS
Provide Appeal Route*	USGS
Implement Plan	Approved Inspection Agent
Monitor Implementation	USGS/Contractor
Failure Reporting Analysis*	USGS
Post Inspection and Repair Review*	Review Board***
Audit Implementation*	USGS

* Functions considered to be government responsibilities.

** USGS/Contractor means: USGS personnel undertake part of the function and may use contractors to assist for selected-definable portions, or contractor undertakes entire function.

*** Detached, high-level group, appointed to review post-inspection and repair after major structural failures.

design, fabricate, install, and maintain the platform. Also, because the structure is likely to be owned and operated by one company, it is in the best interests of both the government and the industry that accountability rests with the owner-operator.

Although the USGS has the alternative of reviewing the plan for technical and administrative adequacy by its own staff or by an independent contractor, this committee urges the USGS to develop and maintain a stong in-house technical management team with oversight for the performance of OCS inspection. Even so, the USGS may want to engage contractors for assistance in checking the plan. To assure credibility and accountability, contractors in the "check plan" function should not be drawn from the commercial organizations involved in the inspection of the specific structure.

Plan preparation, checking, and approval may become cumbersome and redundant if the process for the large number of Gulf of Mexico platforms is not addressed in some special way. Of more than 2,400 oil and gas rigs operating in the Gulf, about 1,000 of these can be characterized as production platforms.15/ Even 1,000 production platforms can overload the inspection management process.

Nevertheless, the problem may not be critical because there have been few platform failures and no loss of lives resulting from platform failures. Furthermore, the many years of experience is reflected in the constant upgrading of design standards.16/ Finally, because the self-inspection practices of the owner-operators generally correspond to Categories 1, 2 and 3, it appears to the committee that the considerations for inspection plan development and approval could proceed with a minimum of difficulty, provided that the appropriate administrative procedures are simplified for the Gulf of Mexico.

While the USGS's own approval of the plan is required to maintain credibility and accountability, the provision of an effective appeal procedure is considered essential for settling disagreements encountered both in the inspection plan review and in the implementation of the plan. Disagreements will be unavoidable on occasion because of the advancing nature of the engineering involved, the interpretation of the data, and the lag in modifying codes, regulations, and standards that need to catch up with the technical advancements.

Implementation

If the implement plan function is performed by the USGS, a large staff is likely to be necessary, and scheduling the government personnel to inspect could impose considerable unwanted delays. This function can be carried out, however, by industry, using qualified inspection agents approved by the USGS. The owner-operator's choice of inspection agents should be submitted in the inspection plan for USGS approval.

To be qualified as an independent inspection agent, the organization or personnel selected should not have corporate affiliation with the owner-operator; nor should the agent be allowed to inspect any of the components which it or a corporate affiliate has designed, fabricated, or installed, or any function which it or a corporate affiliate has performed for the platform to be inspected. Inspection personnel may be independent consultants or may be drawn from the industry or sources such as consulting firms, offshore engineering and inspection firms, and classification societies. Inspection reports prepared by such agents need to be submitted to the USGS and the operating companies.

A well-trained, knowledgeable USGS staff will be necessary to monitor the implementation function ("monitor implementation"). By using contractors, the size of the USGS staff may be kept to a minimum. Even so, the USGS will need to spot check the entire implementation program.

Reporting and analysis of problems and failures to platform structures should deal with repairs and modifications made following the planned periodic or event-dependent inspections. The reporting can be implemented using the present USGS-industry reporting system for safety devices. The post-inspection and repair review functions should occur only following major structural failures or other critical and possibly damaging events. The review should be conducted by an independent, high-level review board to provide the necessary credibility in the identification of probable cause.

The auditing function will assure the USGS that the agents are conducting the inspection procedure in compliance with the inspection plan. Spot checks may be required in which inspection techniques and inspection records are carefully examined and authenticated.

Effecting Transition

The elements of a transition to the establishment of a working inspection system are treated briefly in the remainder of this section and illustrated in Table VI. Similar steps for the verification transition period were structured by the Marine Board's Panel on Verification Guidelines for Offshore Structures. In fact, the inspection plan development and approval process is so closely tied to the verification procedure that the former must follow the latter in timing. Without the verification process, a site-specific and performance-oriented inspection plan would have no practical basis.

Fixed platforms in the Gulf of Mexico are exceptions because their performance may be inferred informally from the historical record of platforms designed for the region. It is therefore necessary that the evolution of inspection documentation account for the disparity between possible inspection plans for existing platforms, platforms now being designed and installed, and future platforms whose design and installation will come under verification guidelines.

A policy document is essential to bridge the disparity. Natural environmental conditions and platform structural characteristics vary from region to region. In addition, the various USGS field offices may have dissimilar technical and administrative expertise. Thus, a policy document may be the most pervasive assurance of even-handed management and operation.

In the discussion on Functions and Implementation, the committee noted the need to obtain contract support as an immediate source of knowledgeable personnel, subject, of course, to the avoidance and the appearance of avoidance of conflicts of interest. Assured support eliminates the dangers inherent in hasty recruiting of inspectors and allows for a changing balance of expertise as the work progresses and evolves.

Documentation is a particularly difficult process. To avoid the documentation of nonessentials, the verification process should identify the likely problems, which invariably affect the perceived needs of the inspection. Accordingly, inspection rules during the transition period should be restricted to known, definable problems.

The qualifications for inspecting agents should match the inspection requirements, but the qualifications need to be flexible enough or allow for changes as inspection requirements alter. It is important to avoid rigidity and overqualification of prospective agents, which would impose unnecessary restrictions and limitations on recruitment. Take the

Table VI

Transition from Verification to an Established Inspection System

STEPS	DESCRIPTION/REASON
Verification	The certification of design, fabrication and installation. The verification process identifies inspection needs--e.g., design load limits which may be exceeded.
Board of Consultants	Authoritative expertise drawn from government, industry, and academia. These authorities make the initial judgments essential to policy and technical limits, subject to final authority of USGS.
Policy Statement	Top management definition of intent, scope, authority, and priority relative to operations, management, and engineering. This is essential to the united approach to which industry can respond.
Documentation	Specific definitions of inspection classes, practices, standards, and procedures. These are the rules applying to phases of transition to established inspection. The problems to be avoided are variability in the rules, which may whipsaw the industry and excessive codification, which tends to stifle performance incentives.
Qualifications	Specific definition for inspection agents. Delineation of standards and motivation to qualify agents is essential to competitive cost and data quality.
Internal Operations	USGS must recruit and train personnel in the engineering disciplines for plan review, approval, and monitoring. A nucleus of highly qualified professionals is required to develop and implement these and other matters.

case, for example, that inspectors must possess diving capabilities and support, but later it may turn out that other methods of inspection are used that make diving unnecessary.

The growth and capability of the USGS staff are dependent on such nontechnical constraints as national budgets and hiring ceilings. Moreover, USGS organizational options will have an impact, such as field locations and grade. For these and other reasons, the committee considers it prudent that the transition period be heavily dependent on outside contractors rather than internal staff.

PLATFORM RISERS

The risers considered in this report are the vertical section of the production pipelines that are supported on the platform and rise from the seafloor to the platform. Usually flexible, they are used to protect the oil and gas pipeline from the well to facilities above the ocean surface. They are sometimes called platform or pipeline risers. Excluded from this report is the piping associated with the platform production processing equipment. Such other risers as well strings, conductor pipes, and casing are covered by existing regulations, and therefore are not properly part of this report.

Riser Integrity

The hazards associated with submerged pipelines have been extensively documented in a report for the Office of Pipeline Safety.17/ Some of the information in this discussion is derived from that report, including Table VII, which lists possible hazards and their damage potential and probability. Not all of the hazards bear on platform risers--anchor dragging, for example, or fishing and dredging. The estimates found in the table for extensive and moderate damage apply only to Gulf of Mexico platforms. For northern latitudes the degree of damage increases because of added thermal effects, ice, abrasion and chafing, along with the increased probability that these factors will occur. Potential hazards are specific to the site and region.

The design, fabrication, and installation history of the pipeline is critical for assuring the integrity of the installed pipeline. Factors enumerated in Table VIII, taken from a report for the Office of Pipeline Safety, are appropriate for platform riser inspection. To these must be added the design factors. Loadings and other design conditions are derived from factors such as:

- Boundary effects (plant and platform movement)

Table VII

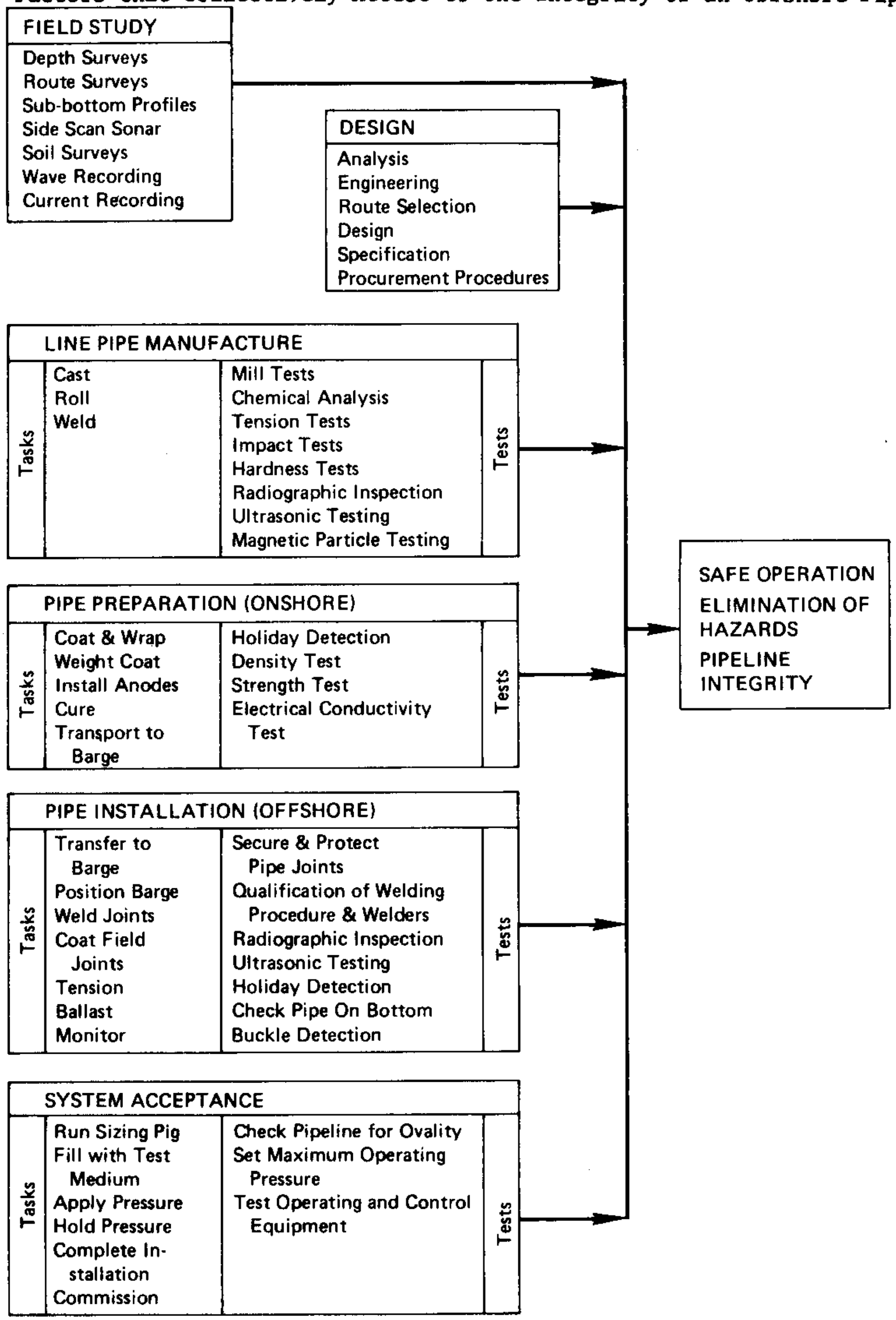
Determination of Relative Severity of Potential Hazards

POTENTIAL HAZARD	DAMAGE POTENTIAL			PROBABILITY OF OCCURRENCE		
	Extensive	Moderate	Minor	Most Probable	Expected Occurrence	Least Probable
External Corrosion	O			O		
Water Depth, Waves, Currents, Tide and Surge, Wind } Sea State Exceeding Design		O				O
Marine Fouling			O			O
Thermal Effects and Ice			O			O
Abrasion and Chafing			O			O
Hurricanes	O					O
Severe Storms	O					O
Earthquakes	O					O
Soil Transport			O		O	
Erosion			O		O	
Bottom Phenomena			O		O	
Ship and Barge Accidents	O			O		
Anchor Dragging	O			O		
Fishing	O					O
Dredging		O				O
Debris Discharge		O				O
Dropped Objects		O			O	
Operator Errors			O		O	
Equipment Inadequacies	O				O	
Equipment Malfunction	O				O	
Vandalism	O					O
Sabotage	O					O
Internal Corrosion	O				O	
Explosion	O					O
Fire	O					O
Unnoticed Damage During Construction		O			O	
Material Deficiencies		O				O
Poor Quality Control		O				O
Design Deficiencies			O			O

Adapted from: Offshore Pipeline Facility Safety Practices. Vol. I. Report No. DOT/MTB/OPSO-77/13. Prepared for U.S. Dept. of Transportation

Table VIII

Factors that Collectively Attest to the Integrity of an Offshore Pipeline



SOURCE: Offshore Pipeline Facility Safety Practices. Vol. I. Report No. DOT/MTB/OPSO-77/13. Prepared for U.S. Dept. of Transportation

- Operational and source pressures
- Operational temperatures and thermal stress
- Other environmental forces
- Weight stresses
- Riser contents
- Internal and external corrosion

Problems to be avoided under these conditions include:

- Loss of cathodic protection
- Deformation, excessive yield
- Buckling
- Brittle failure
- Fatigue failure
- Coating, loss or damage
- Stability against loss of support

Current design practice is based on a growing body of experience and is sufficiently related to performance to allow changes in design methods, materials, fabrication, and operations practices. Where design questions arise, back-up inspection is possible, as it is with platform structures.

Inspection

A number of recommendations have been made for the inspection of submarine pipelines in the "Third Report of the Marine Board Review Committee on the Safety of Outer Continental Shelf Operations."18/ Of these, the following are particularly applicable to the subject at hand:

Inspection should require that any submarine oil or gas line have:

a) a leakage rate below a stated level;

b) a high reliability factor against the probability of leakage for a specific period based on the best technology available.

The report encourages the development of leak detection and corrosion measurement sensors. While these recommendations remain desirable, the developments cited in the report have not yet produced desired results. In the meantime, visual identification of leaks remains one of the most reliable methods for detection.

The inspection process for pipelines may be discussed in terms of the above-water and underwater zones, as has been done for Category 1 and Category 2 inspection of the platform structure. The above-water and the splash zones of the pipeline are more or less continuously under visual observation. Coating damage and damage to the protective structure are subject to routine maintenance. External corrosion is easily detected. Internal corrosion and erosion may be checked by thickness measuring techniques such as ultrasound. Removable sections make it possible to take direct measurements. However, corrosion and erosion are likely to be problems only under certain conditions of fluid velocity, composition, temperature, and pressure. As previously noted, if special conditions are encountered in design, site-specific inspections should be agreed upon in the planning and approval process. This is essential because of the range of environments, the fluid character, plant and platform life, and the extent to which design objectives reflect inspection and maintenance efficiency.

The condition of the riser support and its attachments can be ascertained by visual inspection. If the riser is enclosed in a support J-tube or casing, the condition of the J-tube or casing is subject to visual inspection. Displacement from relative motion of the platform and the bottom is observable, as well as local damage, loss of coating, or extreme corrosion. Significant leaks may be visible.

The need for underwater inspection of pipeline risers is keyed to circumstances similar to those for the structure--(i) such events as accidents, bottom scour, or earthquakes which could cause damage or (ii) evidence from the above-water inspection of internal corrosion which could also exist below water.

The accompanying matrix, Table IX, prepared by the committee, is a tabulation of sensors versus data that may be needed for inspection purposes. The information was derived from the report prepared for the Office of Pipeline Safety, the report of the Harry Diamond Laboratories, and various trade publications.19, 20/

Table IX: Pipeline Inspection Data Needed

SENSORS \ DATA	Buckling	Displacement*	Strength	Cladding	Coating	Cathodic Protection	Erosion	Leaks	Corrosion
Eye	X	X		X	X		X	X	
Television	X	X		X	X		X	X	
Film Camera	X	X		X	X		X	X	
Acoustic Scan		X							
Coupon or Section							O		O
Pressure			X					X	
Flow Meter								R	
Ultrasonic Flaw			O	O	O		O		O
Magnetic Anomaly			O	O			O		O
Corrosion Potential						X			
Fluorimeter								X	

SENSORS
X = Existing System
O = State-of-the-Art
R = R&D

*Supports and unsupported spans.

Technical capabilities are severely limited for underwater inspection of the risers and for detailed measurements such as internal corrosion or erosion, except when the radius of the bends is sufficiently large and the diameter of the riser is at least 15 to 20 cm to accept instrumented pigs.* The routing of the riser or pipeline within J-tubes or casings or within protective fenders makes external access almost impossible. If access is possible, detailed nondestructive testing for thickness measurements is as difficult to perform for risers as for underwater structures. Unless the riser is sufficiently large for instrumented pigging, or the riser can be shut down for pressure testing, leak detection is the only alternative. It is apparent that inspection should be a consideration where practicable in the design of future risers.

Leaks resulting from internal corrosion may be detected by visual observation, video systems and photographs, or fluorimeter. Optical techniques, using TV, movie, and still cameras, are subject to diver and submersible limitations. Flow measurement devices for the various kinds of fluids carried by risers are not sufficiently accurate for use as leak detectors.

* A package of instruments that can be inserted into the pipeline, propelled the length of the pipeline, and retrieved.

CONCLUSIONS

Platforms

The purpose of inspection of a fixed oil or gas production platform on the OCS is to identify any structural flaws, degradation, and deficiencies in order to ensure that it presents a minimum risk to the operating personnel, the natural environment, and the owner-operator, and that the condition of the platform has not been significantly altered by its age, its operation, accidents, and environmental forces. Inspection is not intended to gather engineering and scientific information, however valuable this may be, or to answer questions relative to hypothetical failure modes. The inspection process can, however, supplement the verification process in instances when not enough information and experience have been accumulated to fully identify design needs.

The quality of environmental information and the performance of the technology as appraised and reviewed in the verification procedure makes inspection an issue specific to the site.

Monitoring the corrosion protection system to prevent undue loss of structural steel from the submerged part of the platform is essential for preserving structural integrity.

The committee finds today's technology adequate for Category 1 and Category 2 inspections. Category 3 underwater inspection, however, is currently limited by cleaning capabilities and by the observational range of the human diver and remote television. When cleaning and detailed inspection are necessary, human productivity underwater is quite low. Divers are limited in their underwater performance by the depths they can work in for prolonged periods for physical and psychological reasons, by the dangers of the sea, and by the rigid standards and qualifications imposed. Remote television is currently adequate to meet many of the demands of observational inspection, though remote vehicle transport for cleaning equipment is not available at present. Where divers and submersibles are involved, the system is subject to the vagaries of weather. Monitoring systems are under development, but none has been proven for general use.

Category 4 inspection suffers the same limitations as those of Category 3, except that the demands on the system are greater.

The committee recognizes that of the 2,400 production platforms in the Gulf of Mexico, about 1,000 are considered of major size, with an excellent record of structural adequacy. Based on the record achieved so far for such platforms, the industry has shown a consistent high level of performance. Improvements to fixed oil and gas production platforms have been obtained through incremental stages as commercial firms have drilled more intensively at greater depths of the OCS and as costs for designing, building, and operating the platforms have risen. Accordingly, special consideration is appropriate to minimize the planning, approval, and implementation of an inspection program for these structures.

Because inspection needs to supplement the verification procedures, it should be coordinated with a verification program. Specific functions inherent to an inspection program are the logical and practical responsibility of the USGS, private industry, and others. For example, the preparation and execution of inspection plans are an industrial responsibility, while approval, appeal, failure analysis, and audit are the responsibility of the USGS, and post-inspection and repair review are functions for an independent review board. The inspection program, however, would be largely dependent on highly competent technical and managerial personnel within the USGS.

Although no R&D is required for inspections in categories 1 and 2, it is necessary to raise the productivity of Category 3 inspections, which require R&D for perfecting cleaning subsystems, advancing nondestructive testing instrumentation subsystems, and improving diver performance and submersible systems. Additional criteria are needed for subsequent inspection when the need for unusual or extraordinary repairs is discovered by inspection.

Platform Risers

Risers may affect platform safety and add new problems to underwater inspection because of internal pressure, internal corrosion, and in some cases inaccessibility. Above the water and in the splash zone, the same inspection approach applies to risers as to the platform. This includes the periodic monitoring of the cathodic protection of the riser. The technical capability for taking measurements underwater for internal corrosion and erosion is limited, except when the diameter of the riser is large enough (15 to 20 cm) and the radii of bends is sufficiently large to accept instrumented pigs.

RECOMMENDATIONS

The Committee's recommendations to the USGS for implementing a post-installation inspection program for fixed steel offshore platforms are:

Platforms:

- Adopt and implement an inspection program, including monitoring of the corrosion protection system and using the concept of inspection categories 1, 2, and 3, for platforms. The program should include the basis for determining events that precipitate Category 2 and 3 inspections.
- Develop procedures and standards for acceptance of remedial actions carried out in response to the results of an inspection.
- Require that inspection plans be specific to the site, the platform design, and the installation history of the platform. While such plans should cover the newer oil and gas production areas such as the OCS of the North Atlantic and off Southern California, as well as the Gulf of Alaska, simplified procedures should be put into effect for the Gulf of Mexico.
- Coordinate the management of the inspection program with the verification program.
- Recruit the necessary professional staff to manage an inspection program.
- Assure R&D programs to support inspection systems.

Platform Risers

- Implement a visual inspection program above the water and in the splash zone of platforms concurrent with the inspection procedure.

- Implement an underwater visual inspection of risers concurrent with underwater platform inspection. The inspection should examine coatings, attachments, protective structure, displacements, and evidence of leaks. If necessary, supplemental inspection for internal corrosion or erosion may be required. Cathodic protection measurements are necessary at least on an annual basis.

- Initiate and sponsor R&D for internal corrosion and erosion measurements in risers.

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APPENDIX

CONTRIBUTORS TO THE STUDY

R. Frank Busby
Busby Associates

Felix Dyhrkopp
U.S. Geological Survey

Floyd Garrot
Offshore Operator's Committee

Richard Krahl
U.S. Geological Survey

Eugene Mitchell
Consulting Engineer (Diving and Salvage)

Nils Nordenstrøm
Det norske Veritas

William Radlinski
U.S. Geological Survey

S. Sigmund
National Oceanic and Atmospheric Administration

G. P. Smedley
Lloyd's Registry of Ships (London, England)

Howard R. Talkington
Naval Ocean Systems Center

W. C. Walsh
Lockheed Missiles and Space Co.

Tom Wartelle
J. Ray McDermott and Co., Inc.

William Whitmore
Lockheed Missiles and Space Co.