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APPLICABILITY OF NASA CONTRACT QUALITY MANAGEMENT AND FAILURE MODE EFFECT ANALYSIS PROCEDURES TO THE USGS OUTER CONTINENTAL SHELF OIL AND GAS LEASE MANAGEMENT PROGRAM

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16. Abstract

This report illustrates an approach that might be used for determining the applicability of NASA management techniques to benefit almost any type of down-to-earth enterprise.

It describes a study made by a small team of Marshall Space Flight Center experts at the request of the U. S. Geological Survey to determine the following:

1. The practicality of adopting NASA contractual quality management techniques to the U. S. Geological Survey Outer Continental Shelf lease management functions
2. The applicability of Failure Mode Effects Analysis to the drilling, production, and delivery systems in use offshore
3. The impact on industrial offshore operations and onshore management operations required to apply recommended NASA techniques
4. The probable changes required in laws or regulations in order to implement recommendations.

The report identifies several management activities that have been applied to space programs and recommends their institution for improved management of offshore and onshore oil and gas operations.

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FOREWORD

By William A. Radlinski, Acting Director
U. S. Geological Survey

This report, prepared for the Geological Survey by a team of NASA experts, examines the feasibility of applying to offshore oil and gas operations advanced engineering techniques designed to increase the reliability of safety and antipollution equipment.

As an outgrowth of earlier informal discussions, Geological Survey, in May 1971, requested NASA's Mississippi Test Facility to propose a plan by which the applicability of NASA procedures for quality control and hazard analysis to offshore oil and gas operations might be determined. With the cooperation of the George C. Marshall Space Flight Center and the Office of Manned Space Flight, a study plan was developed and approved in July 1971 and a team of NASA personnel assembled to carry out this study for Geological Survey during the period from mid-August to mid-October 1971. This report is the result.

While quality control and hazard analysis procedures are not unique to the aerospace industry, techniques to assure the functional reliability of complex hardware systems were brought to a state of high perfection by NASA in its space program. On the federally-managed Outer Continental Shelf in the Gulf of Mexico, there are now over 1800 drilling and production platforms each of which has intricate electrical, mechanical, and hydraulic systems which must function reliably if accidents and pollution incidents are to be avoided. Through the cooperation of NASA and of industries operating on the Outer Continental Shelf, it has been possible for technical experts from NASA's staff to study firsthand offshore oil and gas facilities and operations. These experienced engineers and technicians present in this report their preliminary recommendations for action by the Federal Government and the oil industry to provide greater assurance that offshore energy resources can be produced with reasonable safety and protection from pollution of the marine and coastal environment.

Actions that the team recommend to be taken by Government and industry include:

1. Systematic evaluation of equipment failures to prevent recurrence

2. A research and development program for equipment and procedures improvement

3. Refined equipment specifications for safety and pollution prevention

4. Safety and antipollution training and motivation of oil and gas platform personnel to reduce human error.

This study and report are part of a continuing effort by the Geological Survey to explore all avenues offering potential for improving safety and avoiding pollution associated with offshore oil and gas operations. It appears from the preliminary analysis that the report offers constructive recommendations concerning the problems that have been associated with the recent serious events on the Outer Continental Shelf, and it is intended that action on them be taken promptly.

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APPLICABILITY OF NASA CONTRACT QUALITY MANAGEMENT AND FAILURE MODE EFFECT ANALYSIS PROCEDURES TO THE USGS OUTER CONTINENTAL SHELF OIL AND GAS LEASE MANAGEMENT PROGRAM

I. INTRODUCTION

With a view toward improving safety and pollution prevention and in accordance with an agreement between the Director, U. S. Geological Survey (USGS) and NASA's George C. Marshall Space Flight Center (MSFC), a team consisting of NASA personnel and a USGS representative conducted a study of offshore drilling and production operations during the period August 16 through October 8, 1971. Specifically, the study was to determine:

1. The practicality of adopting NASA contractual quality management (quality control) techniques to the USGS/Outer Continental Shelf (OCS) lease management functions

2. The applicability of Failure Mode and Effect Analysis (FMEA) to the drilling, production, and delivery systems in use offshore

3. The impact on industrial offshore operations and onshore management operations required to carry out a full-scale investigation and systems design for either quality control or FMEA programs

4. The probable changes in law or regulation required for either the full-scale investigation or implementation of either program to offshore operations.

The team was composed of Morris K. Dyer, MSFC/Huntsville, chairman; Dewey G. Little, MSFC/Mississippi Test Facility, alternate chairman; Earl G. Hoard, MSFC/Huntsville, member (FMEA); Rayford Campbell, MSFC/Michoud Assembly Facility (quality control); and Alfred C. Taylor, MSFC/Michoud Assembly Facility (quality control). The USGS liaison was Elmo G. Hubble, district engineer, Lafayette District No. 2, Gulf Coast Region. Lyle C. Curran, MSFC Quality and Reliability Assurance Laboratory; and Louis Fabian, MSFC Astronautics Laboratory, served as consultants to the team.

II. STUDY APPROACH

To achieve these objectives, it was necessary that the team become acquainted with the USGS organization and lease management methods at the national, regional, and district levels, as well as the constraints, if any, imposed by law or regulation that might affect implementation of either quality control or FMEA procedures. The team also became familiar with the technical, inspection, or other related requirements placed by USGS or other governmental agencies on offshore oil and gas operators and the industry management attitudes and procedures in general and specifically as pertain to quality control and design analysis. Finally, the team familiarized itself with the nature of offshore operations.

To accomplish these objectives the team had meeting in Washington, D. C., with the Department of Interior, USGS, Bureau of Mines, and Department of Transportation, Office of Pipeline Safety. In New Orleans, Louisiana, it met with the USGS Gulf Coast Region Office and the OCS Operators Committee (subcommittee on OCS Orders). Further, it visited a major operator's district office, an independent operator/drilling contractor, and a company providing inspection/testing services on the OCS for several operators. Team representatives also met with the U. S. Coast Guard, Office of Marine Inspections, 8th District, and attended OCS lease sale hearings conducted September 8 and 9, 1971.

Additionally, the team visited the USGS District Office of Gulf Coast Region, Lafayette, Louisiana; Louisiana State Department of Conservation, Baton Rouge, Louisiana; a major fabricator of platforms for use in offshore drilling and producing operations; and a major operator's area office in Morgan City, Louisiana. In Houston, Texas, it inspected a manufacturer of subsurface safety valves and other critical equipment used on the OCS as well as a major operator's facility, where tests on safety and other equipment used on the OCS were being performed, and the production research headquarters of a major operator. The team spent several days on production platforms and drilling rigs in the Gulf of Mexico.

During each of the above meetings, the team members had detailed discussions with responsible personnel and viewed operations. They also examined hardware when appropriate, and they reviewed problems that have caused or could cause accidents and/or pollution. The team also concerned itself with documentation, when available. In order that the applicability of the NASA contract quality management and FMEA approach could be assessed, the discussions and reviews concentrated on:

1. Public laws
2. Government regulations and enforcement
3. Government and industry specifications
4. Equipment and methods research activity
5. Management, organization, and planning
6. Engineering design, documentation, and analysis
7. Procurement
8. Manufacturing
9. Drilling and production
10. Inspection and test
11. Problem/failure causes, reporting and analysis
12. Training
13. Information exchange
14. Written procedures
15. Maintenance
16. Motivation of personnel for safe and pollution-free operations.

At all times, the personnel visited were cooperative, spoke openly and frankly, and provided the team with documentation requested.

III. GENERAL OBSERVATIONS

A. Current Quality Control Status in OCS Operations

From the beginning of the study, it became apparent to the team that there was an absence of formal quality control organizations and procedures. In neither government nor industry was an organizational element or an individual designated as "quality control." This fact added a new dimension to the study as it became necessary to examine all facets of the industry to determine whether any of the functions normally performed by quality control/reliability organizations were being carried out by other organizational elements. The examination was thorough, and many hours were devoted to covering the full range of quality control and systems design elements. With certain very limited exceptions, inspection is the only quality control activity to emerge during the study as an element universally utilized. The operators generally do not perform inspections on the OCS, even those required by USGS, but very informally employ third party or contract personnel for this effort. Operators do inspect, with their own or contract personnel, major work such as platform fabrication or pipeline (flow line) laying, while such work is in progress.

Most purchases of equipment for use offshore are by catalog or to American Petroleum Institute (API) specifications, American Society of Mechanical Engineers (ASME) codes, etc. In these cases, no inspection requirement is placed nor inspection performed at the manufacturer's plant upon receipt. Platform manufacturers and some equipment manufacturers do employ inspection as a tool to improve quality rather than because of its requirement by the Government.

Formal, regularly-scheduled inspection of equipment on the OCS is primarily limited to those safety and antipollution items required by OCS Orders No. 8 and 9 and appears to have been instituted because of those requirements. Little or no use is being made of the records generated as a result of these inspections for problem prevention purposes, either by the operators or USGS.

In summary, the lack of identifiable quality control organizational elements, primary reliance on inspection, and widespread objection to written procedures or record-keeping indicates a significant lag in quality control and reliability technology in OCS operations. The need for improved equipment and methods for offshore operations is recognized; however, the

need for and use of quality and reliability techniques as aids to effecting this needed improvement is not yet generally appreciated by industry. Figure 1 shows the complexity of organization and interfaces of a representative oil and gas company performing drilling and production operations on the OCS. Quality control techniques can be used to help improve total operations.

B. Progress in Achieving Safe and Pollution-Free Operations on the OCS

In its study, the team found that significant progress has been made in the past 2 years toward achieving safe and pollution-free drilling and production operations on the OCS. As meetings were held with offshore industry representatives and their operations were viewed, it became evident that the good business and good citizenship reasons for safe and pollution-free operations are recognized and that sincere attempts are being made to achieve this, often at significant cost.

There is no doubt, however, that invoking Federal regulations through the lease instrument (particularly in the detail specified in OCS Orders) as well as the knowledge that the USGS has enforcement resources and authority, has provided some necessary guidance to industry and much of the incentive for industry to expend the time and funds for improvement.

C. Basic Problems Associated with Safety and Antipollution Aspects of OCS Operations

Although, the OCS petroleum industry has responded in a responsible manner to the Government's requirements for safety and prevention of pollution; many failures or malfunctions of safety and antipollution equipment are occurring. Human error is contributing significantly to the relatively few serious accidents and pollution incidents that do occur. There is considerable evidence of a "production first" philosophy in the OCS operations in the Gulf which is delaying problem resolution. The organization structure and the allocation of minimal funds for other than production activities are indications of this attitude. Additional progress toward the goals of safety and pollution-free environments is the responsibility of management, which must recognize the need for and provide specific resources to better cope with hazardous operations and to reduce human errors and equipment malfunctions.

The hazards associated with oil and gas operations are well recognized. The basic ingredients of fire (fuel, oxidizer, and ignition source) are continually present. The majority of equipment and procedures to protect

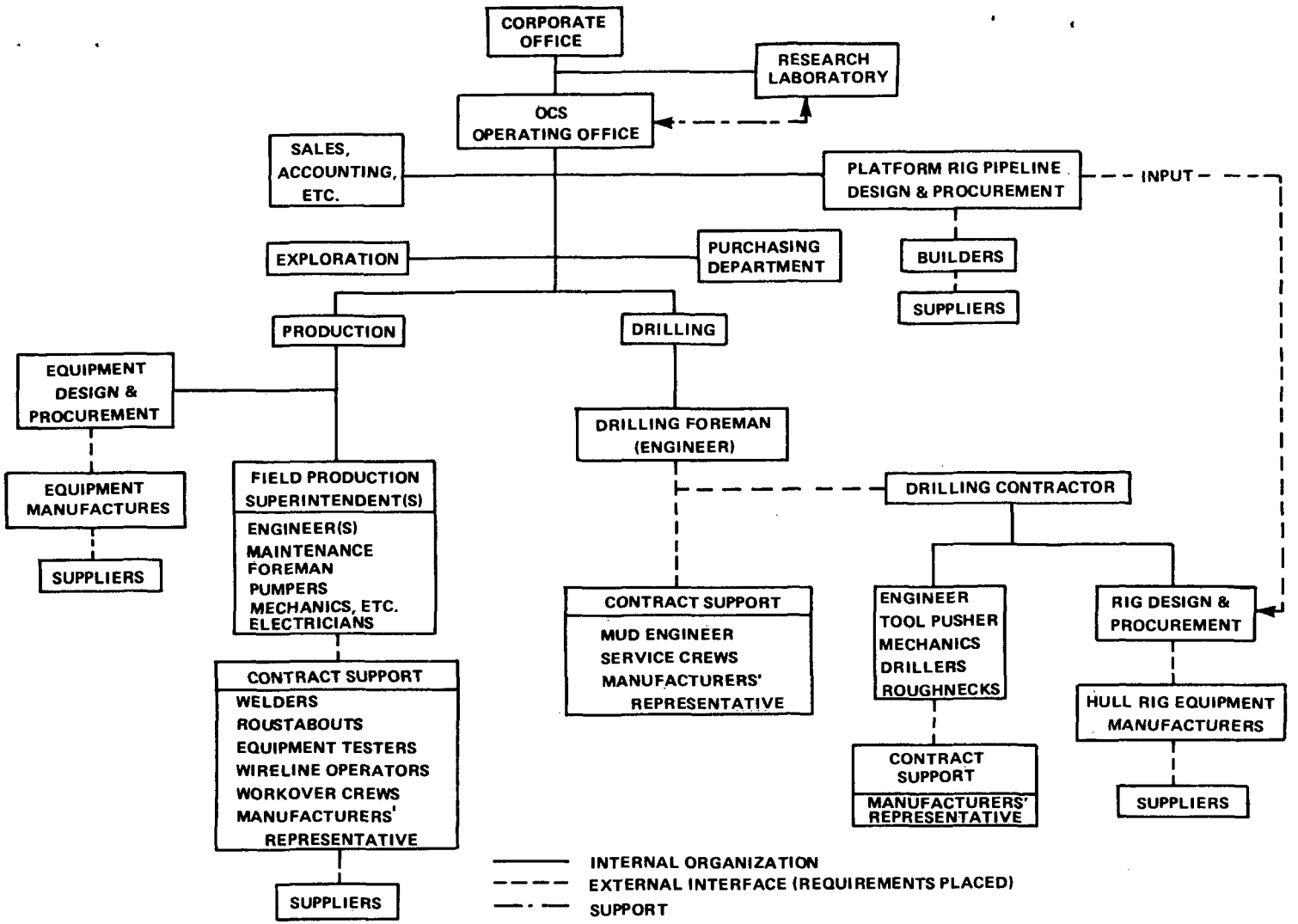

Figure 1. Representative oil and gas company organization and interface for OCS operation.

against the hazards, however, has been developed on a reaction basis. A more effective method is an analytical effort to recognize problems in advance. Corrective action for the more serious problems may include design changes, warning systems, backup systems, or a plan for alternate operations.

Problems peculiar to oil and gas wells, such as sand production, inefficient subsurface safety equipment, and equipment problems associated with corrosive atmosphere, have plagued the industry from the beginning. These can only remain serious problems, however, because of insufficient research and development efforts.

The solution of these problems will require some additional or redirected resources, the allocation of which must be made based upon a cost-effectiveness approach. Implementation of the recommendations of this study group can assist in demonstrating to management that the resources allocated can result in at least a reduction in probability of catastrophic loss and pollution and more on-line production time through improved equipment.

IV. CONCLUSIONS

The following discussions and conclusions relate to the basic study objectives set forth in Section I. The recommendations contained in Section V are based upon these conclusions.

A. Applicability of NASA Contract Quality Management Techniques

The NASA contractual quality management approach basically places technical, quality, and reliability management program requirements with aerospace companies through the contract instrument. With these is placed the responsibility for demonstrating, through plans, procedures, and records that technical requirements are being met. It also includes the evaluation of company plans and procedures and the systematic monitoring of the company program to ensure that plans and procedures are being followed and that technical requirements are being met. This often includes certain inspections or tests by Government personnel after completion by company personnel.

A key feature of the NASA approach is tailoring requirements and procedures to the nature and complexity of the hardware and operations

involved. On very complex space systems, the full range of requirements is applied, whereas only certain of these are applied on less critical, less complex systems. Even within these requirements, procedures developed for compliance are tailored as much as possible to the individual situation. Every attempt is made to achieve the necessary degree of control in the most cost-effective manner.

The team concludes that the basic NASA contractual quality management technique is applicable to OCS lease management. It is, in fact, currently being implemented when the Department of the Interior lease is considered as the equivalent of the NASA contract.

The OCS operators are now obligated to comply with certain requirements (i. e., Federal regulations as detailed by OCS Orders), which include, in some cases, the development of operational plans and the generation of records. Also, USGS is evaluating certain operator plans upon submittal, as well as implementing a system to monitor compliance with lease-imposed requirements.

While the basic approach applies, the team further concludes that the majority of NASA quality system requirements are not applicable to OCS operations because the systems and operations observed, even though critical-to-safe and pollution-free operations in many individual cases, are not of sufficient complexity to warrant the broad range of requirements. Also, the documented technical requirement base (e. g., equipment specifications) over which quality system requirements are placed has not been sufficiently developed. Furthermore, the industry operates so informally that the procedures necessary to demonstrate even elementary quality system compliance do not exist (nor are they needed to the extent employed in the aerospace industry).

Some subelements of the following requirements [as contained in NASA Handbook NHB 5300.4 (1B), "Quality Program Provisions for Aeronautical and Space System Contractors" (Bibliography, Item 47)] could easily be tailored to OCS operations and applied through revision of or development of new OCS Orders. These are:

1. Training and certification of personnel [par. 1B202, NHB 5300.4 (1B)]

2. Quality Information [par. 1B203, NHB 5300.4(1B)]

3. Retrieval of records [par. 1B405, NHB 5300.4(1B)]

4. Inspection and test performance [par. 1B705, NHB 5300.4(1B)]

5. Inspection and test records and data [par. 1B706, NHB 5300.4 (1B)]

6. Remedial and preventive action [par. 1B802, NHB 5300.4(1B)]

7. Calibration controls [par. 1B905, NHB 5300.4(1B)]

The applicability of other requirements may become appropriate as the results accrue from these seven items and as equipment used on the OCS becomes more sophisticated.

B. Applicability of FMEA to the Drilling, Production, and Delivery Systems in Use Offshore

Two of the design analysis techniques used by NASA as an aid to determining critical equipment and identifying potential problems are: (1) Failure Mode Effects Analysis (FMEA) and (2) Hazard Analysis (HA). Recommendation No. 4 describes these in general terms, as well as other points pertaining to this conclusion. Although the study request only mentioned FMEA, preliminary review of documentation for systems utilized on the OCS and the nature of OCS operations indicated that HA may also be a valuable technique. Both techniques, therefore, were considered by the study team. It was concluded that

1. Hazards analysis rather than FMEA could be an appropriate tool for identification of problem areas in systems and methods currently used in OCS operations

2. More documented control over the design of critical systems and equipment used on the OCS must be achieved before HA can be fully utilized

3. Initiation of industry use of HA should be through a USGS requirement. (See Recommendation No. 5.)

4. The USGS Regional Office has the authority and if provided with the necessary staffing and tools (engineering documentation, HA methods) could provide an effective control over the reliability of the critical systems developed for OCS use.

C. The Extent, Character, and Nature of Access to Industry Production Operations Offshore, and Management Operations Onshore, Required to Carry Out a Full-Scale Investigation and Systems Design for Quality Management or FMEA Programs

The access to production operations offshore and management operations onshore that are necessary for full-scale investigation and systems design of both quality management or FMEA programs would be essentially the same that the team achieved during this study. As previously mentioned, the spirit of cooperation received by this team was outstanding. It is felt that this was a result of the excellent relationship enjoyed between the USGS Gulf Coast Region and the offshore operators, which the team feels has been brought about not only by mutual recognition of need and mutual respect, but by the tact and diligence exhibited by the regional supervisor, Mr. Robert Evans, and his staff. With this relationship, it is felt that access could again be gained to industry through the Gulf Coast Region office for a full-scale investigation.

It is concluded, however, that full-scale investigations of either quality management or FMEA areas to develop overall programs are neither required nor desirable. This conclusion is reached since it is felt that the feasibility study has identified certain basic needs which must be met before overall programs could be meaningfully devised. Action now should be implementation of the individual recommendations contained in Section V, coupled with formal and continuing encouragement of industry to investigate and apply as appropriate the full range of quality control, reliability (including FMEA), and HA techniques available.

If, after consideration of the above conclusion, USGS still desires to conduct a complete investigation and system design for FMEA/HA, a recommended next step would be selecting a typical offshore operation and performing a specimen analysis. The operation to analyze could be either a drilling or production operation. The production operation chosen should include a platform-to-platform flow (pipe) line operation with the ancillary equipment necessary for safety and control of the line. This arrangement would negate the necessity for providing a separate delivery system study, since the platform-to-platform flow line appears to have essentially the same characteristics. An analysis of this type would require a group of engineering personnel familiar with platform mechanical and electrical systems and a specialist on analysis techniques. The analysis would probably require several weeks because engineering documentation and operating procedures would

probably have to be generated by the group, in addition to the time required for the analysis. Experience data of this type could also be of assistance in implementing FMEA or HA.

D. Probable Changes in Law or Regulation Required for Full-Scale Investigation or Implementation of Quality Management or FMEA Programs

The OCS Act, lease provisions, and regulations were studied to determine probable changes required to permit full-scale quality management or FMEA investigations and to implement programs. In addition, other acts, such as the Federal Coal Mine Health and Safety Act of 1969 and the Natural Gas Pipeline Safety Act of 1968 were reviewed, as well as legislation proposed on September 30, 1970, by Congressman Charles M. Teague, California, concerning control and prevention of further pollution by oil discharges from Federal lands off the coast of California (Bibliography, Item 18).

It is concluded that no changes are required in the OCS Act, lease, or regulations to conduct detailed quality management or FMEA studies, nor to implement applicable features of either program. Implementation of applicable quality or FMEA/HA requirements can be effected through OCS Orders.

Implementation of study Recommendation No. 2 concerning information exchange will require an interpretation from the Justice Department regarding possible conflict with antitrust laws if the decision is to attempt to have industry serve as its own focal point. If the Department of Interior decides to serve as the focal point, a change in the OCS Act may be necessary to provide for this.

Implementation of study Recommendation No. 3 concerning research and development may require a change in the OCS Act in order to clearly give the Department of Interior the authority to conduct research and development on safety and antipollution equipment for OCS use. As a comparison, Section 13 of the Natural Gas Pipeline Safety Act specifies that the Secretary of Transportation shall conduct research and development, testing, and training to carry out provisions of the Act.

E. Adequacy and Scope of OCS Orders

The study team was asked to assess the general adequacy and scope of the OCS Orders from the standpoint of safety and prevention of pollution. The order program was also assessed from the view point of the guidance provided industry and its acceptance.

The team concludes that the OCS Order program as structured is moving in the right direction and that it is providing essential guidance to industry, which is being accepted as "law" by industry. The technique of using a subcommittee of the OCS Operators Committee to help develop orders is excellent in that it gives industry the opportunity to provide technical expertise and assess impact during development, thereby reducing the possibility of developing impractical or impossible requirements. It is essential that these orders continue to be developed for the most part at the regional level and that they be tailored as necessary for individual regional conditions. However, standardization of requirements among regions, where practical, is desirable.

The study indicates the need for additional or revised orders in the following areas: metering control, temperature controls on fired vessels, flame arresters, engineering documentation, training and certification of personnel inspecting USGS required safety/antipollution devices, standardization of forms, and failure reporting.

V. RECOMMENDATIONS

The following recommendations are made for consideration by the Director, USGS. Implementation by the USGS could provide industry with improved methods of preventing and resolving offshore equipment and personnel problems, and thereby reduce the probability of accident, pollution, or loss of production. Implementation could also provide the USGS with improved methods of determining the need, placing in effect, and maintaining OCS Orders, as well as improving methods of ensuring compliance with lease provisions.

In arriving at these recommendations, every effort was made to consider in practical terms the past history and nature of OCS operations, the actual needs, the impact of recommendations upon industry and USGS, and implementation means.

A. USGS/Operations

1. Failure-Reporting and Corrective-Action System. A basic tool for all reliability and quality control activities is a closed-loop, failure-reporting and corrective-action program. Failure-reporting involves tabulating the occurrence of incidents, problems, failures, and out-of-specification conditions. Corrective action begins with investigation and engineering

analysis of each reported problem or failure, followed, where appropriate, by laboratory analysis of failed hardware. The investigations and conclusions should be documented to provide a basis for remedial action, listings for repetitive failure searches (maintainability), and applicability to similar parts for other applications. Corrective action includes appropriate measures to prevent recurrence of the failure through redesign, stricter test/inspection standards, improved procedures, etc. The loop is closed only when steps to prevent recurrence have been checked to insure their effectiveness. Without a tool of this type to focus management attention on problem areas, it is doubtful that any real progress can be made toward improvement of equipment or procedures.

Observed conditions for offshore operations is a policy of replacement upon failure with no more than visual observation of failed items and without any type of record being made for the failure. Occasional exceptions were noted at the initiative of individual field engineers maintaining an informal record for particular problems. Equipment suppliers appear to place more emphasis on reporting failures. Malfunction reports are completed for returned hardware for management review and action.

In many cases, especially those involving hardware failures, a requirement for failure analysis should be passed on to the supplier. Even if this is not done, however, implementation of the recommendation set forth below will require the operator to work more closely with the supplier in terms of equipment/procedure interface to achieve a real corrective action rather than a simple replacement of equipment.

It is therefore recommended that USGS lay the groundwork for the type of activity, described above, in the drilling and production phase of the oil industry by requiring monthly summaries from each operator of failure causes and corrective action taken for all safety equipment specified by OCS Orders. All accidents and oil spills should follow similar procedures. For the procedure to be effective, its object should be recurrence prevention, with emphasis placed on the determination of causes, preventive action, and follow-up.

This recommendation, if adopted, will have a significant impact, primarily because of the change in policy made necessary by the majority of offshore operators. The statement is often made by offshore people that the only real test of equipment is to place it in service in the Gulf.

Whether this is a valid assumption or not, the data from this test should be utilized to maximum advantage. The basic philosophy to be followed is that every failure has a cause, every cause can be understood, and every failure can be corrected or alternate procedures provided.

2. Information Exchange. Even though no intercompany failure reporting and corrective action systems exist, individual operators know their overall problems with safety equipment and methods. There is no formal method now, however, for the rapid and positive exchange of this information on an industry-wide basis, so that problems experienced by one operator can possibly be avoided by others, thus reducing the risk of accident or pollution and that major or recurring problems that require research and development effort for resolution can be quickly identified. Information exchange is primarily through word of mouth, professional meetings, and technical journals. This method is at best uncertain. Development of the system outlined in Recommendation No. 1 (Failure-Reporting and Corrective-Action System) by each operator can help provide the basis for action within the company but does not fill the intercompany information exchange need. Industry representatives state that they desire to exchange this information more formally but fear that to do so would be in violation of antitrust laws.

That industry recognizes the need for this is evidenced by the following quote from the New Orleans newspaper, The Times-Picayune, attributed to an oil company executive while the study was being made.

> "Could all phases of the drilling industry, including operating company research and engineering, combine their know-how to solve the total problem, new system, rather than incremental improvement to the many pieces of the problem?"

The answer should be a resounding yes to this question, as the rapid exchange of information has been one of the keys to the successes achieved in the space program.

It is recommended that the USGS investigate the legal question of a possible antitrust law violation regarding formal exchange of hardware and method problem information within the oil and gas industry. If a favorable ruling is obtained, USGS should encourage and participate in the development and operation of the system.

As an alternative, USGS could become the focal point for this information and disseminate it to all concerned parties.

3. Research and Development. A concerted research and development program should be initiated as soon as possible for improvement of safety and antipollution equipment and development of methods of detecting potential equipment or material failures. Individual companies within the oil and gas industry have research and development programs that are devoted primarily to improving production capability in the increasingly adverse conditions that new discoveries are imposing. Based upon problems experienced within the companies, some individual effort to improve safety and antipollution equipment and methods is included. However many problem areas in the latter category remain unresolved. A few of these, pointed out to the study group, are metal fatigue in down-hole tabular goods, mud control devices and methods, automatic monitoring equipment, and sand erosion detectors. (See Recommendation No. 7, Wearout Prevention.)

The individual research and development efforts are improving individual situations. However, redundant efforts are being undertaken in some cases, while no known efforts are being applied nor is progress being made in others.

The focal point necessary to identify the total research and development needs and to bring concerted effort to bear in meeting these needs is missing. Since the industry is competitive, with each company primarily expending its resources to resolve its own problems, it appears that this research and development focal point should be a body separated from the competition, such as USGS.

It is recommended that USGS establish a method to determine needs and conduct or direct the research, testing and development necessary to improve equipment and methods for an increasingly safe and pollution-free operation on the OCS. (Note: Implementation of Recommendations No. 1 and 2 can aid greatly in determining needs.)

One product of this effort would be the development of technical data for inclusion in Government approved standards and specifications. (See Recommendation No. 4, Standards/Specifications Development and Use.)

An alternate recommendation is that USGS work with the industry in establishing an organization such as the API to serve as the research and development focal point, with all companies contributing toward resolution of problems.

4. Standards/Specifications Development and Use. The need exists for USGS to establish and require approved (USGS) standards/specifications for safety and antipollution devices in OCS operations. The petroleum industry and USGS rely on standards/specifications developed by API, ASTM, ASME, ABS, and others, as a minimum requirement in the manufacturing of equipment. The API, consisting of professional engineers representing their respective companies, appoints local task groups to formulate standards/specifications according to need. Standards/specifications have been written for tubular goods, wellhead equipment, production tanks, and other items. Safety and antipollution equipment, such as subsurface safety valves, blowout preventers, pressure/temperature sensors, and fluid-level controls, however, is being used on the OCS for which no standards/specifications are available. Much of the equipment now operating on offshore rigs and platforms was basically designed for onshore use and environment.

In reviewing a selected number of available standards/specifications and during discussions with operators and equipment manufacturing personnel, the need became evident for the development of new and, in some cases, more meaningful standards/specifications. Industry personnel stated on several occasions that while much good work has been done in developing existing specifications, many are written in general terms and in some instances are not adequate. The quality of equipment is a concern in the oil industry and especially to operators on the OCS, yet none of the specifications reviewed contained the requirement that companies manufacturing products to the specifications have even a basic quality control system. The assurance of reliable service in any product depends on its ability to meet certain properties. This requires the establishment of grade, type, and size classification to improve quality and provide interchangeability. Methods of testing to determine adequate properties and performance quality are also necessary. The development of a sound quality control system by the manufacturer could give purchasers reasonable assurance that these requirements have been met and that they have purchased reliable products.

Existing technical data, where available and adequate, should be utilized in developing standard/specification provisions. When sufficient technical data are not available, they should be generated by industry and/or Government research. (See Recommendation No. 1, Failure-Reporting and Corrective-Action System.)

The USGS should take the lead in ensuring the rapid development and use of adequate standards/specifications for all safety and antipollution equipment to be used on the OCS. The study team, therefore, makes the following recommendations.

a. That USGS seek API cooperation in establishing a committee to function under USGS guidance for the purpose of determining specific needs and to write, review, and approve standards/specifications for safety and antipollution equipment. The committee must function under the guidance of USGS.

b. That specifications developed by the committee contain requirements for a basic quality control system and, where equipment is to be used in a deleterious environment, an environmental test program. The committee should use as a quality system guideline, the quality control provisions of the Bureau of Mines specification covering fuses for trailing cables used in coal mines and in NASA Publication NPC 200-3, "Inspection System Provisions for Suppliers of Space Materials, Parts, Components and Services." (See Bibliography, Items 13 and 54).

c. That the USGS, through OCS Orders, require the use of approved standards/specifications.

As an alternate recommendation, if the USGS cannot obtain API participation, it is recommended that USGS establish a committee, comprised of appropriate members from the industry, for the purpose of developing these standards/specifications for equipment and methods used in OCS operations.

5. FMEA/HA. The feasibility of incorporating FMEA techniques into the lease management program, OCS, oil, and gas operations began with an attempt to define the need for this type of activity. Discussions with USGS personnel at each level, concerned with oil and gas operations, reveal a universal concern with the reliability of the equipment operating in the Gulf of Mexico. Staff members of the Oil and Gas Operations Branch expressed concern with the varying amount of control exercised by offshore operators over their equipment. Regional office members stated that while other considerations have occupied most of their attention in the past, more activity directed toward design review was planned for the future. District personnel offered the opinion that the present OCS Orders do, in fact, have room for additional coverage for such items as temperature controls for fired vessels, flame and spark arresters, and inspection of sand-producing well systems.

These observations, coupled with personal contact with offshore operators and service companies, indicate little organized control over attempts to upgrade the quality of hardware before installation. This gives rise to the recommendations that follow.

The team recommends that USGS request identification of operations and equipment critical to safety of personnel and pollution prevention. Data to complete this Critical Items List could be derived from two sources. One, from compilation of accident history and problem/failure reports, is the topic of another recommendation. The second source could result from analysis of the systems utilized to perform a given function. Two types of design/system analysis most commonly used in industry today are the FMEA and the HA.

Hazard analysis is a broad term covering a spectrum of analytical tools used to predict where safety problems may exist. Most of the analysis starts with a hazard or undesired event and works back through the operations to trace equipment failures and operational or procedural errors that may have led to the hazard. This procedure is usually accomplished by diagraming the process in the form of a tree, with causative paths as branches (or roots since work goes from undesired events to progressively lower levels). Hence, the name of the most commonly used diagraming method is fault tree (See Example, Fig. 2, page 28.)

The "top down" approach utilized in HA is directly opposed to the FMEA. The FMEA begins with a known failure mode of a low-level element within a system and proceeds to evaluate the effect of this failure mode upon successively higher levels of assembly until the ultimate effect upon a stated objective (mission success, personnel safety) is determined. A brief example of the technique is included on pages 25 through 27 (Table 1). The two types of analyses yield comparable results if common ground rules and similar considerations are used for both approaches. At present HA is considered more applicable to offshore operation than FMEA for the following reasons.

a. Accident history is one in which operator error is the greater contributor.

b. The HA "top down" method would be more adaptable to yielding intelligent data than the FMEA "bottom up" approach when low-level hardware is not well identified.

c. The simplicity of the systems, at the present time, does not require FMEA to assure complete coverage.

d. The HA is considered more easily explainable to personnel unfamiliar with design analysis.

The petroleum (drilling and production) industry is not presently organized and staffed to perform systems analysis, and a requirement for such would impact the industry significantly. This conclusion is based upon the following considerations.

a. Any analytical technique is dependent upon up-to-date and complete engineering documentation which is not available for the equipment in the Gulf.

b. Personnel trained for this type of activity are not available. The industry as a whole appears to operate without a formal quality control or reliability organizational element. Engineering personnel familiar with offshore operations could readily adapt to these techniques, but formal training would be required.

c. Management appears to be highly production-orientated and a considerable reevaluation of safety and antipollution needs is necessary to effect positive controls.

Therefore, the study team recommends a step approach as follows.

a. The USGS Gulf Coast Regional Office should be authorized to implement the proposed design review group.

b. The region should require submission from offshore operators a list of critical operations to be performed during drilling at time of permit request. List of critical systems should also be obtained at the time of well completion, and appropriate reviews conducted with the operator.

c. The requirement for submission of complete HA should be phased into system starting with new work, with time limits on existing wells.

d. The analysis group should work with operators to eliminate (reduce) hazardous operations by recommending redesign of hardware or operations.

e. Inspection criteria should be revised to include any additional critical equipment identified by HA.

The trend of the industry seems to be toward more complex systems because of deeper water operations, more safety equipment, and more sophisticated automatic control systems. This fact, plus incorporation of above steps, should tend to influence oil companies toward a more favorable atmosphere for acceptance of incorporating FMEA and HA techniques.

6. Engineering Documentation. OCS Orders have resulted in submission of certain minimal documentation to describe surface safety systems. This appears to be the only attempt to document a platform system. While some operators are beginning to see the usefulness of more complete engineering description, the prevailing control over equipment identification and description is minimal.

It is recommended that USGS require that certain minimum engineering documentation be available at the operator's lowest level onshore engineering office. This recommendation is made in pursuit of the preceding recommendation and others contained in this report, as well as the USGS stated objectives of reviewing process equipment designs more closely. The following list is recommended as minimum requirements.

a. Structural layout and details

b. Piping runs

c. Schematic diagrams (mechanical and electrical)

d. Engineering parts list (complete to valve and power supply level, including part number, name, and manufacturer)

e. Specifications for all actively functioning components.

(The list may be modified by experience of USGS or needs that developed at a later date.)

7. Wearout Prevention. Preventive maintenance appears to be used for preventing corrosion of platform structural members, i. e., periodic replacement of anodes in cathodic systems, sand blasting and painting operations, etc. However, as previously stated, a replacement upon failure policy for process equipment seems to prevail. Production equipment is designed to remain in service for the life of the well and generally does for wells operating under optimum conditions. There are insufficient records to analyze replacement frequency or yearly replacement costs for random failures.

The USGS personnel advance the opinion that inspection frequency, controlled by OCS Orders, is sufficient to rectify hazards associated with failure of safety equipment with the exception of wells producing sand. Some research toward developing a reliable sand detector is being made. One promising type examined was a wearout probe which could be attached to a signal or a shut-in system. To accelerate a solution to this problem, the following action is recommended.

a. Development of a reliable sand erosion probe under USGS sponsorship (including a specification)

b. USGS revision of OCS No. 8 specifying method of implementation of sand erosion probe

c. Requirement for rigorous test and inspection (x-ray/sonic) of wells upon sand detection.

At a later date when data on failed equipment are available, an evaluation of the necessary inspection frequency and/or periodic replacement of selected safety equipment should be undertaken.

8. Training and Certification. One of the basic quality management techniques used by NASA to ensure that companies meet contractual provisions, with minimum governmental monitoring, is the requirement for them to train and to certify, as trained, personnel performing critical manufacturing or inspection/test functions. This technique is being applied to a limited extent in some areas of oil industry support operations such as the certification of welders employed in the manufacture of offshore platforms.

This technique could be applied by USGS to ensure that OCS operators improve their performance in meeting the requirements of OCS Orders No. 8 and 9, pertaining to inspection and maintenance of safety and antipollution equipment. Better performance in this area by operators can reduce the risk of accident and pollution and reduce the amount of monitoring by USGS.

Most of the testing on the OCS of equipment required by USGS is now performed by personnel of some 27 small companies. Operators contract for these services on a very informal basis and require neither evidence of personnel qualification nor standardization of test techniques. It is recognized that most of this equipment is relatively simple, as are test procedures; however, some minimum skill is required.

It is recommended that USGS require, through revision or addition of OCS Orders that:

a. Operators develop methods to ensure that company or contract personnel performing inspection and test of safety or antipollution equipment are properly trained in USGS requirements, the equipment functions, test methods, etc., before performing these services and that training is periodically updated as equipment is modified or new types of equipment are utilized. Operator or outside-source certification of personnel following demonstration of skill should be required.

b. Operators provide USGS with a description of the methods to be employed in accomplishing the above and that these methods be approved in advance by USGS.

It is also recommended that USGS witness some test performance and check the certification cards or records during operator-monitoring activity.

9. Safety and Antipollution Motivation Program. The study reveals a consensus that human error is a greater contributor to accidents and pollution than equipment failure. One of the most effective means for combating human error is through a well-organized information and motivation program. The USGS does not require nor participate in any formal motivation programs. Discussion with oil companies reveals that, in general, maintaining an industry comparable wage scale is considered adequate employee motivation. A poster campaign is conducted by at least one company. Top managers of another company indicated that they strongly support their company safety program.

It is recommended that USGS initiate an OCS-wide safety and antipollution motivation program. Such a program could be effective in terms of obtaining industry response and favorable publicity. A program consisting of at least the following elements is suggested.

a. Visual aid package consisting of dramatic evidence of the results of carelessness and human error (pictures of platform fires, etc.) accompanied by analysis of typical events leading to accidents and pollution.

b. Periodic review of accident (safety and pollution) records, from available statistics, with appropriate awards for top performance. The awards should be public ceremonies with maximum possible publicity.

The Government program could be put together by an outside company specializing in the field but should be conducted by USGS.

Additional elements recommended to be implemented by offshore operating companies, with some USGS participation are:

a. Safety training for all field personnel to include identification and proper use of all safety equipment. Review of all emergency procedures with periodic drills. Instructions concerning daily operations to avoid pollution and minimize hazards.

b. Periodic review of accident and pollution history to field employee level with recognition for good performance. Recognition would assist in obtaining cooperation for better reports of incidents.

c. Employee suggestion program regarding safety improvements for both equipment and operations. Again, a recognition system is recommended for accepted suggestions.

A possible implementation tool would be the creation of a motivation/training subcommittee of the Offshore Operators Committee under the leadership of the USGS.

SYSTEMS DESIGN ANALYSIS FOR OIL PLATFORM EQUIPMENT

The concept of a system design analysis has been successfully utilized by MSFC to determine critical effects for space systems. Because of the environment hazards resulting from oil well failures in the Gulf of Mexico, NASA has been requested to study the feasibility of applying these techniques for the analysis of offshore oil platform equipment.

In order to evaluate this approach, a preliminary analysis of the Surface Safety System of one of the OCS production platforms was initiated. This effort was not completed because of time considerations and the lack of detailed documentation of the system; however, an analysis of the basic sensor types and the master control box has been included to demonstrate the technique. From the effort involved in preparing this analysis, it is apparent that an analysis of the Surface Safety System itself will provide little suitable information. However, an analysis of the entire platform could result in the following types of data:

1. Determination of all equipment failure modes that can lead to environmental or safety problems

2. Determination that all potential failures are protected by the safety system

3. Optimization of the safety system design to provide maximum protection while minimizing possibility of "shut ins" from erroneous sensor indications

4. Determination that the safety system is the best system available to protect from hazards, i. e., evaluate several potential safety systems configurations

5. Provision of a documented analysis of the platform showing conformance to required safety and environmental standards.

Of these five results, the receipt of a documented analysis appears most noteworthy as it provides the responsible agencies with documented assurance that imposed safety requirements have been properly incorporated.

TABLE 1. EXAMPLE OF FAILURE EFFECT ANALYSIS

Component	Function	Failure Type	Critical Effect	Remarks
Master control box	The master control box regulates the input pneumatic pressure to 20 psi for use in the level and pressure sensors. It also allows input pressure to flow to the safety shutdown valve unless any sensor indicates a failure. When this occurs, the master control box bleeds the control pressure of the safety shut down valve (valves) thereby, closing the valve and shutting in the well	Premature operation	Actual Loss Shuts down the well without cause.	
		Fails to operate as required.	Actual Loss The well is not shut down as required.	This failure necessitates a manual shutdown by platform personnel from one of the safety panels. An oil spill or a fire hazard may result.
		Fails to reset.	Actual Loss Unable to restart the system before repairs are made to the box.	
High-level indicator	The high-level indicator monitors the level in the storage tank and shuts down the	Fails to operate when required.	Actual Loss The storage tank will be overfilled resulting in an oil spill.	

SAMPLE

TABLE 1. EXAMPLE OF FAILURE EFFECT ANALYSIS (Continued)

Component	Function	Failure Type	Critical Effect	Remarks
High-level indicator	system to prevent an oil spill.	Operates when not required. (internal leakage)	Actual Loss The well will be shut in when there are no failures.	
		Fails to cease operation. (Does not drop out when the level drops.)	Actual Loss Unable to return the well to service until the sensor is repaired or replaced.	
Low-level sensor	This sensor monitors the fluid level in the L. P. separator and shuts in the well when the level is low	Fails to operate when required.	Actual Loss The well will not be shut in when required allowing oil to spill or a fire hazard.	
		Premature operation	Actual Loss The well will be shut down unnecessarily.	
		Fails to cease operation.	Actual Loss Unable to start the operation of the well.	

TABLE 1. EXAMPLE OF FAILURE EFFECT ANALYSIS (Concluded)

Component	Function	Failure Type	Critical Effect	Remarks
Pressure sensor	This sensor monitors pressure in the L. P. Header. It reacts to high or low pressure to shut in the well.	Fails to operate. (low pressure)	Actual Loss The well will not be shut in when required creating a hazardous condition or an excessive oil spill.	
		Fails to operate. (high pressure)	Actual Loss The well will not be shut in when required creating a hazardous condition or an excessive oil spill.	
		Operates prematurely.	Actual Loss The well will be shut in without cause stopping production.	

EXAMPLE

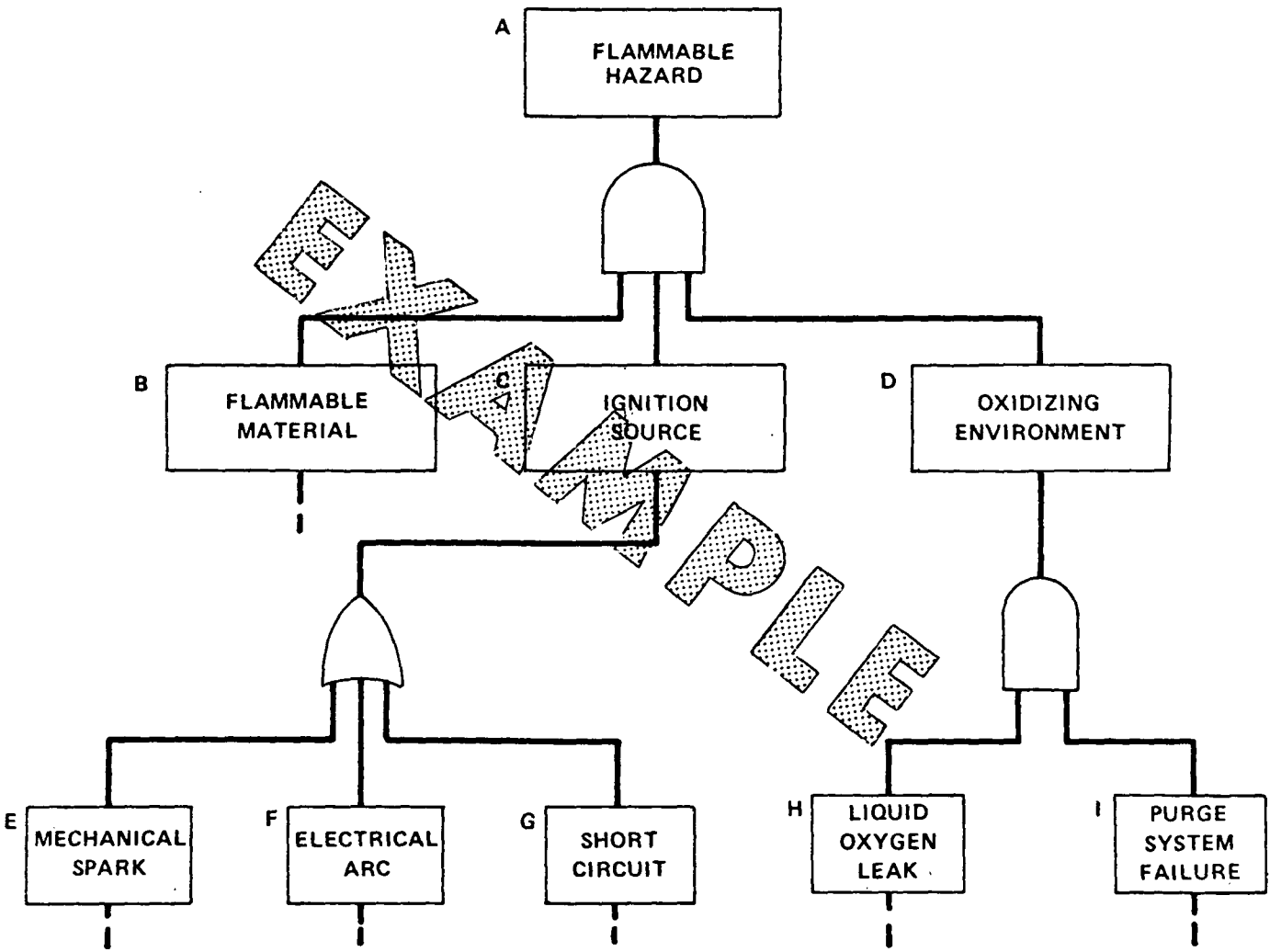

Figure 2. Fault Tree.

B. USGS

1. Development of OCS Order Management Program Plan. One of the prime functions of the USGS Regional Office is to assure compliance with lease provisions, particularly those detailed in OCS Orders. This function is similar to that performed by NASA quality personnel in assuring that contractors comply with contract provisions. NASA has found that effective assurance of compliance requires planning and implementing an overall quality management program. USGS has presently in effect a portion of a planned OCS order management (quality control) effort. (See Section IV. E., Adequacy and Scope of OCS Orders.) The need now exists for a complete OCS Order Management Program Plan to be developed that will outline in detail the responsibilities, inspection areas, requirements, assigned functions, and the overall operations of the USGS region and the districts. With the present number of districts, the increased number of personnel involved in surveillance activities and the enlargement of scope and complexity of the operations, the need for a plan is acute.

It is recommended that the USGS regional office extend the current effort by staffing, at the earliest possible time, with personnel experienced in quality management and capable of developing, documenting, and assisting the regional supervisor in implementing this type of program. As a minimum, this program plan should contain the following information:

a. Organization chart

b. Functional statement for each section, district, and unit

c. List of reports required of each section, district, and unit

d. Personnel training records

e. Detailed procedures outlining the functions to be performed by USGS personnel at both the district and regional levels

f. Assignment and frequency of inspection functions

g. List depicting areas to be controlled in performing inspection functions

h. Guideline procedures covering inspection and/or tests to be witnessed by USGS district personnel

i. Waiver/departure procedure.

It is recommended that NASA documents NPC 200-1A, "Quality Assurance Provisions for Government Agencies," and NHB 5330.7, "Management of Government Quality Assurance Functions for Supplier Operations," be used as guidelines (Item 44, Bibliography).

The USGS should require that all data generated from this planned quality effort be assembled at the regional and Washington offices to be analyzed and evaluated to determine the effectiveness of the district operations. (Refer to Recommendation No. 2, Section V.A., Information Exchange, page 14.)

The plan feature of the OCS Order Management Program is valuable as a management tool not only for regional operations, but for USGS Headquarters, in that regional resource needs and activity will be more visible.

2. Operational Use of USGS Water Resources Division Data Development Techniques. That portion of a planned OCS Order Management Program referenced in the previous recommendation concerns the Water Resources Division study. It is understood that the Conservation Division intends to adopt the data development techniques used in the study for continued use.

In order that the transition from the study effort to the operational program can be made as rapidly and effectively as possible, the following recommendations are made.

a. The data processing equipment, that the team was advised is being considered for location in the Regional office, should be installled at the earliest possible time.

b. The presently used Potential Incidence of Non-Compliance (PINC) list should be modified to separate the gathering of descriptive information (e. g., number of wells/platforms) from compliance information (e. g., satisfactory operation of check valves).

c. A method should be established to ensure that compliance characteristics of the PINC list are maintained current as OCS Orders are revised or added.

d. Conservation Division should devise a "best method" of adapting study techniques to the needs of region operations. An operating procedure should then be developed and implemented as soon as possible in order to provide uniform guidance to all concerned personnel. The procedure should include the instructions for using the information generated by district, region and headquarters.

e. The procedure referenced above should be integrated into the overall OCS Management Program Plan.

3. OCS Order Development. This study group has recognized the importance of the OCS Orders and their effect on the operation and control of Federal oil, gas, and sulphur leases in the OCS, Gulf Coast Region. New technology, additional requirements, and unforeseen and/or unknown changes in safety and antipollution equipment will necessitate changes in the existing OCS Orders or require that new Orders be written.

In order to remain abreast of the ever-changing needs, the following recommendation is made. The USGS Regional Office should organize an OCS Order development and implementation function. This function, technical in nature, involves many hours of research, investigation, and discussion and should be assigned to a small committee of qualified people selected by the supervisor. This committee should perform the following:

a. Schedule meetings periodically to review current needs and evaluate existing Orders

b. Meet with USGS region management to determine their overall reaction to the proposed order and/or change

c. Schedule meetings with the Offshore Operators Committee and/or subcommittee and discuss the change and the impact it will have on the operators and other companies operating in the OCS and document their comments and/or suggestions

d. Schedule meetings with the USGS district engineers and chief technicians, discuss the proposed changes, and document their comments

e. If needed, consult with or solicit advice from field officials of other Government agencies and document their comments

f. Assemble and consolidate the comments into a report for USGS region management review and evaluation

g. Coordinate for approval with the Washington level

h. After the new Order and/or change has been agreed to by all concerned, develop the final draft to submit to Washington for signature

i. After the Order is approved, serve in an advisory and assistance capacity to USGS management in assuring that concerned USGS and operator personnel thoroughly understand requirements before implementation and during implementation.

Adoption of this recommendation should provide a more effective overall program for developing OCS Orders.

4. Standardization of Forms. This recommendation concerns two reports that are presently being reviewed by region personnel, the contents of which are important to lease management. The OCS operators are required to record and report oil spills that occur in the Gulf waters. In reviewing these reports, a lack of uniformity appears to be in the method of reporting, which results in information being obtained that is not always sufficient to properly evaluate the occurrence.

It is recommended that the USGS revise the pollution report form, presently being utilized in the district offices, and require its use by the operators for those spills presently requiring written confirmation. The form should include as a minimum the following:

a. More detailed information, especially in the area of cause and corrective action. For example, if equipment malfunction is the cause, the reason should be recorded in detail.

b. The "corrective action taken" remarks should include, in detail, the repair, if any, that was accomplished to correct the immediate problem.

c. Information should be provided as to action taken to prevent recurrence.

The OCS Order No. 8 requires the recording of specific test results at certain intervals and that they be maintained in the field. Operators obtain these results in two ways: perform the required tests utilizing company personnel or acquire the services of a third party. Several different forms are presently being used to record the same type of information. It is recommended that:

a. The USGS develop a form for the recording of test results that would standardize this type of reporting by operators or third party personnel. The form should include cause of and action taken to correct discrepancies found during performance of required tests.

b. The form be provided to operators and its use required; or operators be required to develop their own forms which will include the same layout and required information.

c. Operators be required to summarize these results periodically to determine overall problems.

d. Intended use and completion of the form be included in operator training courses for personnel to perform tests.

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National Aeronutics and Space Administration
Marshall Space Flight Center, Alabama 35812, March 3, 1972

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