Safety Assessment of Management Systems

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ACKNOWLEDGMENTS

(Place holder page)

Note to Reviewers: Please submit names to be included in final report.

ABSTRACT

Many marine accidents are initiated or made worse by human and organizational errors. However, existing methods of risk assessment, safety indexing and safety management system evaluation largely ignore specific evaluation of human and organizational factors (HOF). The Safety Assessment of Management Systems (SAMS) project is a two-year joint industry project designed to examine the factors that cause human and organizational errors in offshore platforms and at marine terminals and to develop a generic method for assessing these factors.

EXECUTIVE SUMMARY

This report summarizes work conducted for the Safety Assessment of Management Systems (SAMS) Joint Industry Project. The objective of the SAMS project is to develop a generic safety management assessment system for assessing hydrocarbon risks associated with offshore platforms and marine terminals with a focus on Human and Organizational Factors (HOF) that can lead to a loss of containment and result in releases, fires and explosions.

After reviewing current methods for assessing risks associated with platforms and terminals, two methods were developed for this project: Factors of Organizations and Operating Teams (FOOT) and Marine Assessment of Safety Technique (MAST). Both methods are attempts to structure the way in which an audit team reviews documentation, focuses on important issues, conducts site visits and interview of operating staff, and analyses the results to determine whether HOF have been adequately considered and appropriately implemented in the operation of a specific offshore platform or marine terminal.

Both FOOT and MAST start with the evaluators applying general questions from a set of Minimal Basic Questions (MBQ). FOOT evaluators focus on 3 to 6 Areas of Concern (AOCs) and evaluate organization and operating team factors for each AOC. The results are graphically displayed using a bar chart for each of the nine assessment categories. MAST is also based on the MBQs, but includes a separate physical qualities assessment and a second-tier of detailed questions to be used by assessors in evaluating safety management systems.

Both techniques attempt to assess whether or not HOF were adequately considered in the hazards analysis and to evaluate whether or not operating procedures and knowledge are indeed in place, understood and used in practice, and sufficient to assure appropriate levels of safety. It is likely that further testing in the field will indicate that a combination of the two techniques is optimal.

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1.0 INTRODUCTION

The Safety Assessment of Management Systems (SAMS) project is a two-year joint industry project designed to examine the factors that cause human and organizational errors (HOE) on offshore platforms and at marine terminals. While industry's emphasis continues to be placed on building larger and more complex facilities with sophisticated safety systems, a review of the history of high consequence accidents in a wide variety of marine systems has shown that a large majority of accidents are caused by human error. This statement is supported by the post-accident analyses of a number of marine industry catastrophes, where human and organizational factors were listed as primary causes. These include the Ocean Ranger, Piper Alpha, ARCO South Pass 60, the Exxon Valdez, the Herald of Free Enterprise, and the Braemar. However, this pattern is not unique to the marine industry. Williams and Hurst documented the following in their paper about Safety Management effectiveness for the Major Hazards Onshore and Offshore Conference in October 1992.

> Joscheck (1981) for example, suggests that 80-90% of the chemical industry's incidents and accidents involve the human element, and Singleton (1989) reinforces these estimates by suggesting that between 50-80% of system failures can be ascribed to human error. The strength of the human contribution to system failure and hydrocarbon loss has been confirmed by Instone (1989), who observes that, "It can be argued that virtually all causes of loss excluding natural perils are as a result of Human Error."

Williams and Hurst also point out that

> Studies by Rasmussen (1980), Samanta *et al.* (1981), Ghertman and Griffon-Fouco (1985), and Bellamy *et al.* (1989) suggest that it may be possible not only to identify the causes of human failure, but via safety management measures, find ways to reduce their overall likelihood.

Research conducted at the University of California, Berkeley, (UCB), during the past several years confirms that for both marine and non-marine systems roughly 80% of major compromises in the quality of a physical plant or its operation can be attributed directly to human and organizational factors (HOF). It was the aim of this project, SAMS, to investigate methods for identifying such causes, and then to propose new means that could allow assessments of management systems and HOF.

1.1 HOF IN THE MARINE INDUSTRY

The UCB research indicates that about 80% of low frequency high consequence accidents in the marine industry are caused by HOF. This finding is supported by California State Lands Commission spill data from 1991 to 1995. Their internal evaluations have shown human error as a cause in 76% of California marine terminal oil spills. The US Coast Guard (USCG) has identified similar patterns, and their post-accident analyses have estimated 75-96 % of marine casualties have resulted from human error. Additionally, the US Department of the Interior's Minerals Management Service (MMS) Director Cynthia Quarterman has publicly stated that 80% of offshore accidents are caused by human error.

Thus, the safety benefits that can be achieved through engineering and technology modifications to systems diminish rapidly even after the optimum safety systems have been selected if an effective safety management scheme is not adopted or if continuing analysis is not done to correct deficiencies that might lead to human errors or organizational failures.

A large percentage of these compromises in quality can never be mitigated to any appreciable extent if this focus on HOF is not integrated within the Safety Management Systems (SMS). This clearly indicates the need to focus on minimizing human and organizational errors that are the primary causes of such accidents and compromises in quality.

In presentations for the ongoing USCG Prevention Through People (PTP) project, the USCG states that a reduction in loss of containment events and increases in safety can only be achieved if the industry undergoes a culture change. The USCG notes that such a cultural change can only be achieved in the marine industry if the industry does the following:

- Moves away from prescriptive regulations
- Moves to systematic, non-regulatory approaches
- Promotes cooperation between government and industry
- Shifts the focus from engineering to human solutions

1.2 OBJECTIVE

The objective of the SAMS project was to develop a generic Safety Management Assessment Method that could be used by industry and government to assess HOF that can lead to a loss of containment and result in releases, fires and explosions on offshore platforms and marine terminals. In order to do this, a judgment was made by the project team members that SMS as well as HOF would be critical elements of any useful evaluation tool.

1.3 SCOPE

The scope of the SAMS project included development of a method or methods for assessing potential risks which could result in loss of containment events manifesting themselves as fires, explosions, releases or spills on offshore platforms and marine terminals. Within the scope of the project was the goal of developing a generic safety management assessment method that would focus on potential hydrocarbon risks. In order to do this, the project team members included evaluation of SMS as well as HOF in the project scope. This project did not concentrate on risks associated with traditional safety concerns such as injuries to backs, fingers, repetitive strains or cumulative trauma disorders.

1.4 THE SAMS METHODS

Two assessment methods were developed for the SAMS project. These methods will be referred to in the text of this report as:

- Factors of Organizations and Operating Teams (FOOT), and
- Marine Assessment of Safety Technique (MAST).

1.5 OVERVIEW OF FOOT

The objective of the FOOT method is to explicitly address HOF in marine systems. The premise of FOOT is that in order to reduce human and organizational error (HOE), HOF must first be identified and then evaluated. This method uses a list of HOF related to high reliability organizations, and a process to identify and evaluate these HOF.

There are two parts to the FOOT method. The first part is a review of organization and operating team factors, and the second part is a process to identify and evaluate the factors. The organization and operating team factors are listed in Table 1.5.1, Organization and Operating Team Factors.

Table 1.5.1: Organization and Operating Team Factors

Organization Factor	Operating Team Factor
Process Auditing	Communications
Culture	Selection
Appropriate Risk Perception	Education
Emergency Preparedness	Limits and Impairment
Command & Control	Organizing Ability
Training	Experience
Communications	Training
Resources	External Environment

In the second part of the FOOT method, a four-step process is used to evaluate these factors. The steps are presented in Table 1.5.2, Process for Evaluating Organization and Operating Team Factors.

Table 1.5.2: Process for Evaluating Organization and Operating Team Factors

Step	Description
1	Answering Minimal Basic Questions (MBQ) to evaluate the system's Safety and Environmental Management Programs.
2	Identifying a manageable number (3 to 6) of Areas of Concern (AOC) from the MBQ answers and various other previously conducted hazards or risk studies. These AOCs provide a context for consequence.
3	Visiting the system to confirm the AOC, and then to evaluate the Organization and Operating Team Factors for each AOC.
4	Combining the AOC consequence with the likelihood related Organization and Operating Team Factors to create a Relative Risk value for each AOC. Those AOC with the highest relative risk can be mitigated by either reducing the consequence or the likelihood.

1.6 OVERVIEW OF MAST

The basis for MAST is a view of risk that includes the physical aspects of a facility and the safety management practices governing the design, operations, and modifications. The premise of MAST is that both should be evaluated in order to form a complete assessment. For this reason, MAST consists of two essential elements: An evaluation of the Physical Qualities (PQ) evaluation and an assessment of the Safety Management System (SMS).

The PQ evaluation is based on a compilation of selective sets of criteria relating to a facility's physical qualities. The PQ evaluation provides a screening tool for evaluators of platforms or marine terminals by identifying those installations which inherently have more risk associated with them due to their location, the type and quantity of materials handled, or the complexity of the operation. Subsequently, the evaluator can use the SMS assessment tool to review how the facilities that are selected for further evaluation are managed from a process safety viewpoint.

The SMS assessment consists of questions that are reviewed for the facility. The original source for the general SMS questions was a set of questions referred to as the Minimal Basic Question (MBQ) set. The MBQs were developed during the initial stages of the project and serve as a basis for both FOOT and MAST. For MAST, the MBQs were expanded to provide thorough coverage of HOF. The resulting general questions are divided into the nine MBQ categories.

The categories are as follows:

- Management and Organizational Issues
- Hazards Analysis
- Management of Change
- Mechanical Integrity
- Operating Procedures
- Training and Selection
- Safe Work Practices
- Emergency Response
- Investigation and Audits

Although all the SMS categories contain HOF elements, the majority of the questions relating explicitly to HOF can be found in the categories referred to as Management and Organizational Issues, Hazards Analysis, Operating Procedures, Training and Selection, and Safe Work Practices.

In the SMS assessment of MAST, questions are scored using a scale that ranges from 1 to 7, representing a low-to-high level of compliance. The SMS tool includes a second tier of detailed questions that supplement the general questions. Using the detailed questions, the assessor can conduct an in-depth analysis of certain SMS elements within an SMS category. The in-depth analysis allows the assessor to more thoroughly evaluate the strengths and weaknesses of a facility's management practices prior to scoring the facility and drawing conclusions about the facility's SMS.

1.7 REPORT FORMAT

An Abstract and Executive Summary are provided at the beginning of the report. Section 1 contains introductory information for the SAMS project. Section 2 contains a description of the project background and historical risk assessment methods. Section 3 contains the minimal basic question set. Section 4 is a description of Factors of Organizations and Operating Teams (FOOT). Section 5 is a description of Marine Assessment of Safety Technique (MAST).

Project Results and Conclusions are presented in Section 6. References are presented in Section 7. Appendices to this report include a Glossary as Appendix A. Course materials for the Safety Assessment of Management Systems (SAMS) Training Program are provided in Appendix B. Appendix C contains supplementary material for Section 4, describing organization and operating team factors. Appendix D contains information relating to the table-top exercise of a marine terminal in northern California using the FOOT Method.

2.0 BACKGROUND AND HISTORICAL ASSESSMENT APPROACHES

2.1 INTRODUCTION

Various approaches to risk assessment, safety indexing methods, and safety management system evaluations have been developed. Methods generally recognized by industry include the following:

- Quantitative Risk Assessment
- Hazard Analysis techniques such as HAZOP, Event Trees, Fault Trees, Failure Modes and Effects
- Safety Indexing Methods, including FLAIM I and HESIM
- Safety Management Systems Assessment methods including discussion on approaches suggested by CCPS; API RP75; PFEER; ISO; ISM; the MANAGER technique from HSE; Petersen; Bird & Germain; Geller; Krause, Hidley & Hodson, Bellamy & Geyer; and Harrison.

2.2 RISK ASSESSMENT

Risk assessment methods can be categorized into the following five categories:

- Probabilistic
- Narrative
- Checklist / Questionnaire
- Ranking
- Index Methods

The following is a brief description of each method , its basic steps, a list of example methods, a summary of their deficiencies for identifying and evaluating human and organizational factors, the qualifications of a person using the method, and the final output of the method.

2.2.1 Probabilistic

Probability theory states that with sufficient statistical data, probabilities can be determined to predict future performance. These types of methods rely on a large statistical database to establish failure probabilities.

For example, to establish the probability of failure of a new type of pump, a test laboratory will take 100 pumps and run them until the pumps break. Let's say the results are: five break before 1,000 hours, ninety break between 1,000 to 2,000 hours, and five break after 2,000 hours. Using this statistical data, a probability of failure for this type of pump is 5% at less than 1,000 hours.

To conduct probabilistic analyses, human factors experts take the following four steps to determine the probability of failure of a human in a given process. First, the expert decomposes a process into individual steps. Second, the analyst either uses existing databases with human failure data rates such as THERP or HEART or the expert uses personal experience to assign a probability of failure to each step. Third, the probabilities of failure for each step are combined to determine the entire process probability of failure. Fourth, performance shaping factors are assigned by an expert to the process probability of failure.

Some of the terms given to methods which use this approach include Human Reliability Analysis (HRA), Quantitative Risk Assessment (QRA), and Probabilistic Reliability Assessment (PRA). It should be noted that these terms are generic, and specialized techniques comprise each category. For example, under the term "human reliability analysis" many well-known techniques exist including:

- Absolute Probability Judgment (Seaver and Stillwell, 1983; Hunns and Daniels, 1980), an expert based technique.
- Paired Comparisons (Hunns, 1982) uses expert judgments between two choices.
- THERP: Technique for Human Error Rate Prediction (Swain and Guttman, 1983) uses a database of human error probabilities.
- HEART: Human Error Assessment and Reduction Technique (Williams, 1986) is based on human factor literature.
- SLIM-MAUD: Success likelihood Index Method Using Multi-Attribute Utility Decomposition (Embrey, Humphreys, Rosa, Kirwan, and Rea, 1984) is a computerized technique originating from decision analysis.
- HCR: Human Cognitive Reliability (Hall, Fragola, and Wheathall, (1982) is a model which assess the influence of time and performance-shaping factors on human error probabilities.
- ASEP: Accident Sequence Evaluation Program (Swain, 1987) is a shortened version of THERP.

Reviews of these HRA techniques, as well as others, can be found in the book entitled "The Human Reliability Assessors Guide." (Humphrey, (ed.), 1988) and in Kirwan's book (1994) entitled "A Guide to Practical Human Reliability Assessment." Another excellent review can be found in the article "Human Error Data Collection and Data

Generation" by Kirwan, Martin, Rycraft, and Smith (1990). As far as HRA techniques, the following conclusions by Kirwan (1994) are set forth to summarize the position and philosophy of the techniques currently in use:

- There are sufficient tools available for assessing many, if not most, human-error scenarios and contributions to the given level of risk.
- These tools fall into the reasonably simple framework that is the HRA process. Within this framework, there are usually multiple techniques for each stage of the process, so that the assessor enjoys some degree of flexibility in deciding which tools to implement according to his or her criteria.
- In a number of case-study applications, and in many real PSAs/HRAs, HRA methods have proven useful in first calculating and then reducing the risk element incurred as a result of human error.
- The HRA approach still requires significant amounts of skill and judgment on the part of the individual assessor, and there is still no substitute for experience. In this way, HRA is still as much an art as a science, though not necessarily a difficult art to learn. What this means is that books such as this one are limited in the degree to which they can be prescriptive.
- On the theoretical-and empirical-validation front, HRAs have a fair way to go. Nevertheless, HRA methods look better when seen in an applied setting than they do in a theoretical one, so it is more constructive, therefore, to judge a HRA by its *practical* merits than by its theoretical standing.
- The HRA method offers a useful overall approach to modeling the degree of human impact on systems in a system context. And this approach could easily, moreover, be extended to other spheres of human involvement. The degree to which this occurs remains to be seen.

In addition to the problems discussed above, the data used in human error probabilities usually provide insufficient amounts of statistical data to calculate human and organizational errors. There are three reasons for this. The first is that it is unethical to experimentally break humans and organizations for the purpose of gathering data. The second reason is that investigation information may assign "human error" as the cause of an accident, but often it does not include possible organizational influences due to liability issues. The third reason is that humans and organizations can be unpredictable, even with a large amount of statistical data.

The bias of the expert when assigning a probability of failure for a step and a performance-shaping factor can introduce another deficiency. If the outcome for an analysis is a number, a single probability of failure, this single number does not necessarily take into account the evaluator's uncertainty.

The determination of overall risk for a complex installation such as an offshore platform or marine terminal would be a massive undertaking, requiring the modeling of numerous human actions, each with many chains of events which could lead to fires, explosions, releases or spills. Historically, in performing such studies, evaluations have tended to concentrate on that which is easier to quantify, failure rate of hardware rather than on HOF.

2.2.2 Narratives

Narrative methods use words to describe possible hazards and failure opportunities and avoid the use of numbers. These methods use inductive analysis to systematically study the causes and effects likely to affect the components of a system. (Villemur, 1992)

The basic steps for narrative analyses are as follows:

- Define the system, its functions and components
- Identify the component failure modes and their causes
- Study the failure mode effects
- Draw conclusions and recommendations (Villemur, 1992).

Examples of methodologies which could be narrative alone and not include calculated probabilities, include Hazards and Operability Studies (HAZOPs) and Failure Modes and Effects Analyses (FMEA).

One criticism of the narrative type of approach is that different teams of evaluators may reach differing conclusions as to the importance of a design detail or HOE to the overall system safety. The use of trained experts and an organized system of analysis, such as that provided by HAZOPs minimizes but does not eliminate this problem. In addition, the amount of time required to complete an analysis may be substantial.

Persons conducting the narrative assessment may be from outside the system, although during such analyses system experts (e.g., operators and maintenance personnel) typically are included within the assessment team.

2.2.3 Checklist/Question-Based Approaches

A Checklist Analysis uses a written list of items or procedural steps to verify the status of a system. Traditional checklists vary widely in level of detail and are frequently used to indicate compliance with standards and practices. (CCPS, 1992)

Question-based methods are similar in that criteria are provided in question form. One difference that may exist between these two methods is that checklists may not require the assessor to seek assistance from others in order to draw conclusions, while question-based approaches may use both observation and interviews to obtain answers. Also, depending on the type of checklist the assessor may not require training in the checklisting method, where in most cases, question-based methods require evaluator training.

In the end, an assessor employing a checklist method compares existing conditions to a set of standards. Using a question-based method, the assessor must make observations at the facility and interview facility personnel.

Checklist and question-based methods commonly require the evaluator to compare the results and interviews to establish criteria and/or a standard. For each checklist item or question, the assessor will answer "yes," "no," "not applicable," or "needs more information." Qualitative results vary with the criteria or the specific situation, but generally they lead to a "yes" or "no" decision about compliance with standard procedures. Since the calculation of results is often limited to the "yes/no" answers, uncertainty may not be calculated or reflected in any score given for compliance.

Another problem with these approaches is that the checklists or question set may be long and thus require significant amounts of time and effort for their completion. However, one reason for the popularity of their use is that they provide a common basis for management review of the analyst's assessments of a process, operation, facility design, or safety approach.

The actual questions may or may not be shared with those being interviewed or with other personnel within the facility being evaluated. The expert may also have a second set of more detailed questions, each related to a general question. This second set of detailed questions is used only when the expert determines that further inquiry is needed in a general question area. The expert records their answers and, together with any conclusions, produces a written report.

Checklist methods are frequently used for both facility hazards analysis and for human factors evaluations. A thorough coverage of Checklisting Approaches for hazards analysis is given in CCPS's book "Guidelines for Hazards Evaluation Procedures". (1992) Commonly used human factors checklists can be found in NUREG-0700 (1980), Woodson, Tillman, and Tillman's book (1992), and various military standards including MIL-STD-1472D.

Question-based evaluation methods for assessing the safety and organizational culture of a facility include the International Safety Rating System (Bird and Germain, 1985), MANAGER (Bellamy and Geyer, 1992), and Tripod-Delta (Reason, 1991). In addition, knowledge of these deficiencies usually leads to an easily developed list of possible safety improvement for managers to consider. (CCPS, 1992) The results are usually binary (i.e., "yes" or "no").

2.2.4 Ranking

Ranking methods use predetermined criteria (i.e., risk or importance) to order or prioritize a list of items. This is done by comparing two items and asking the question, "Is this item riskier than this other item?" as when using the Paired Comparisons Technique.

Generally, an assessor will obtain a list of items and the criteria by which they are to be ranked. Using the system as the context, the items are ranked according to this criteria. Two items from the list are ranked at a time. The method expert, using the operator as the system expert, will use such questions as mentioned in the previous paragraph. The system expert goes through the entire lists and the end result is a ranking of these items.

Examples of Ranking Methods include:

- Analytical Hierarchy Process (AHP)
- Paired Comparisons
- Ranking/Rating
- SLIM-MAUD
- Operational Safety Review Team (OSART)

Criticisms of these methods include the fact that they can be very time consuming in their application when using a long list of items. Ranking can become difficult to manage when more than one criterion is used, and the lists of items to be ranked could easily exclude low likelihood/high consequence events. The capturing of all significant items and the definition of the criteria by which they are ranked is the key to a successful analysis but this can be very difficult to achieve. To assure repeatability, the method is usually applied by a method expert with the assistance of several system experts who evaluate the items independently. The results are often a list of items ranked from highest to lowest.

2.2.5 Indexing Methods

Indexing methods have characteristics that are common to probabilistic, narrative, and checklist/question type methods. The two methods reviewed for this subsection of the report were Fire and Life safety Assessment and Indexing Methodology (FLAIM) and Human Error Safety Indexing Method (HESIM). The two methods reviewed have a set of categories containing criteria in the form of questions. Within each category, there are different levels of questions to be answered, a first tier with general questions, a second tier with more detailed questions, and a third level with even more detailed questions.

To perform a FLAIM evaluation, the assessors complete the following steps:

- Experts select questions to be evaluated.
- Experts assign a weight for each question.
- Assessors visit the system and assign a grade to each question (A = excellent, B, C, D, F = fails)
- The computer program combines the grades and weights to determine an overall "Grade Point Average" (GPA) for each system module.

For HESIM, the methodological steps are:

(Text for this section to be completed by UCB)

One criticism of each of these methods is that experts are required to select questions and assign weightings. Method users require extensive industry experience and methodology training. Weight assignments are difficult to assign without the use of a large database. While methodology training is judged to be important, no selection criteria nor training program was established for the assessors using these methods.

In the FLAIM technique, the result of the analysis is a final grade point average for each module. This GPA is a result of the weightings assigned by the experts, and the grades assigned by the assessors.

The result of HESIM analyses are:

(Text for this section to be completed by UCB)

Table 2.2.5.1 is provided as a synopsis of Risk Assessment methods reviewed during this project:

Table 2.2.5.1: Synopsis of Risk Assessment Methods Reviewed

General Method Category	Some Actual Methods	Brief Method Description	Reasons for Rejection as a Basis for SAMS Methods
Probabilistic (Quantitative)	HRA QRA PRA PHA	1. Decomposes tasks into individual steps. 2. Assigns probability of failure to each step. 3. Combines probabilities for each step to determine task failure rate. 4. Adjustments made through Performance Shaping Factors (PSF) determined by experienced experts.	1. Very little data to support failure rates. 2. Outside "experts" are required to use methods. 3. Uncertainties are introduced at least three times. 4. Consistency difficult to obtain. 5. Takes a long time to conduct. 6. Uncertainty of experts can't captured. 7. Operators not integral part of assessment team.
Narratives (Qualitative)	FMEA HAZOPs	1. Takes an overview of the system. 2. Focuses on High Consequence--High Likelihood Areas. 3. Written reports qualitatively describe the problem areas.	1. Outside "experts" are required to use method. 2. High Consequence--Low Likelihood events are eliminated. 3. Takes a long time to conduct. 4. Uncertainty is captured in components. 5. Operators are not an integral part of the assessment team.
Checklists / Questions	MANAGER ISRS	1. Lists of items that should be present or true (prescriptive). 2. Experts check of those items present or true. 3. Items without checks are reported as needing to be fixed.	1. Method only as good as the checklist (cannot be exhaustive). 2. Outside experts required. 3. Uncertainty of experts not captured. 4. Non-discriminatory on higher priority items. 5. Operators not integral part of assessment team.
Rankings	Paired Comparisons Ranking / Rating SLIM-MAUD OSART AHP	1. Questions used to prompt the experts. 2. Experts rank a list of items according to importance. 3. Mitigation decisions are based on list.	1. Method only as good as the questions. 2. Outside experts required to rank. 3. Ranking does not capture uncertainty. 4. Operators not integral part of assessment team.

2.3 SAFETY MANAGEMENT

In recent years, there has been a growing awareness in the marine industry of the need to identify, evaluate, and manage risks. Such risks include fires and explosions, releases, and ship collisions. The emphasis on managing such risks has increased greatly since the 1988 Piper Alpha accident in the North Sea and the 1989 Exxon Valdez in Alaska. These accidents, as well as those at Flixborough, Three Mile Island, Bhopal, and Chernobyl have emphasized to industry that there are factors beyond engineering that can influence whether an accident occurs and the extent of damage from the accident. Furthermore, it has been recognized that traditional approaches to safety such as focusing on engineering improvements do not prove adequate nor result in the desired reduction in the probability of such events. It is also recognized that most accidents, if not all, are the result of human failings linked to ineffective management systems (King, 1992). It is accepted that as a part of risk management, organizations must create comprehensive schemes for managing safety that include emphasis on human and organizational factors. It has become accepted that satisfactory health, safety, and environmental standards can only be achieved by positive management approaches. Safety management systems (SMS) approaches should be used to guide facility design, safety reviews, operations, modifications, maintenance, inspections, and the training of personnel.

In their paper, "Incorporating Human Factors into Formal Safety Assessment: The Offshore Safety Case," Bellamy and Geyer have defined safety management as the control of identifiable contributors to hazardous incidents and accidents. They state that the concept of control is central to safety management. The goal is to control hazardous processes and minimize the likelihood of loss of containment incidents and to establish mitigation systems to best control the consequences of such incidents where they occur.

To accomplish this, it is necessary to assess and, where required, to alter the factors which shape those management processes which affect safety.

Internationally, industry and government agencies have accepted a model by which SMS can be organized for effectiveness. The philosophy of SMS is that organizations need to apply the management principles of planning, organizing, implementing, and evaluating to all aspects of safety, and that these efforts should be based on principles that aid in identifying, evaluating, and reducing operational risks with the particular emphasis being placed on the prevention and/or mitigation of uncontrolled and toxic releases.

A graphical representation of the SAMS model is presented in Figure 2.3.1, Key Elements to Successful Health and Safety Management. This model is adapted from the UK HSE's publication "Successful Health and Safety Management." By using this model an organization develops a policy for safety, creates an organization to implement the policy, develops plans for controlling the company's activities, and sets out standards by which performance can be measured. The system also has monitoring and auditing functions to measure performance and ensure that the needs for improvements are fed back into the organization.

Further detail on how an organization might meet the proposed SMS model is presented in the publication "Management at Risk" published by the UK Atomic Energy Authority. (1991) It is stated in this publication that "Corporate management must continually develop and maintain a Safety, Health, and Environmental Program culture by demonstrating conviction and commitment through certain activities."

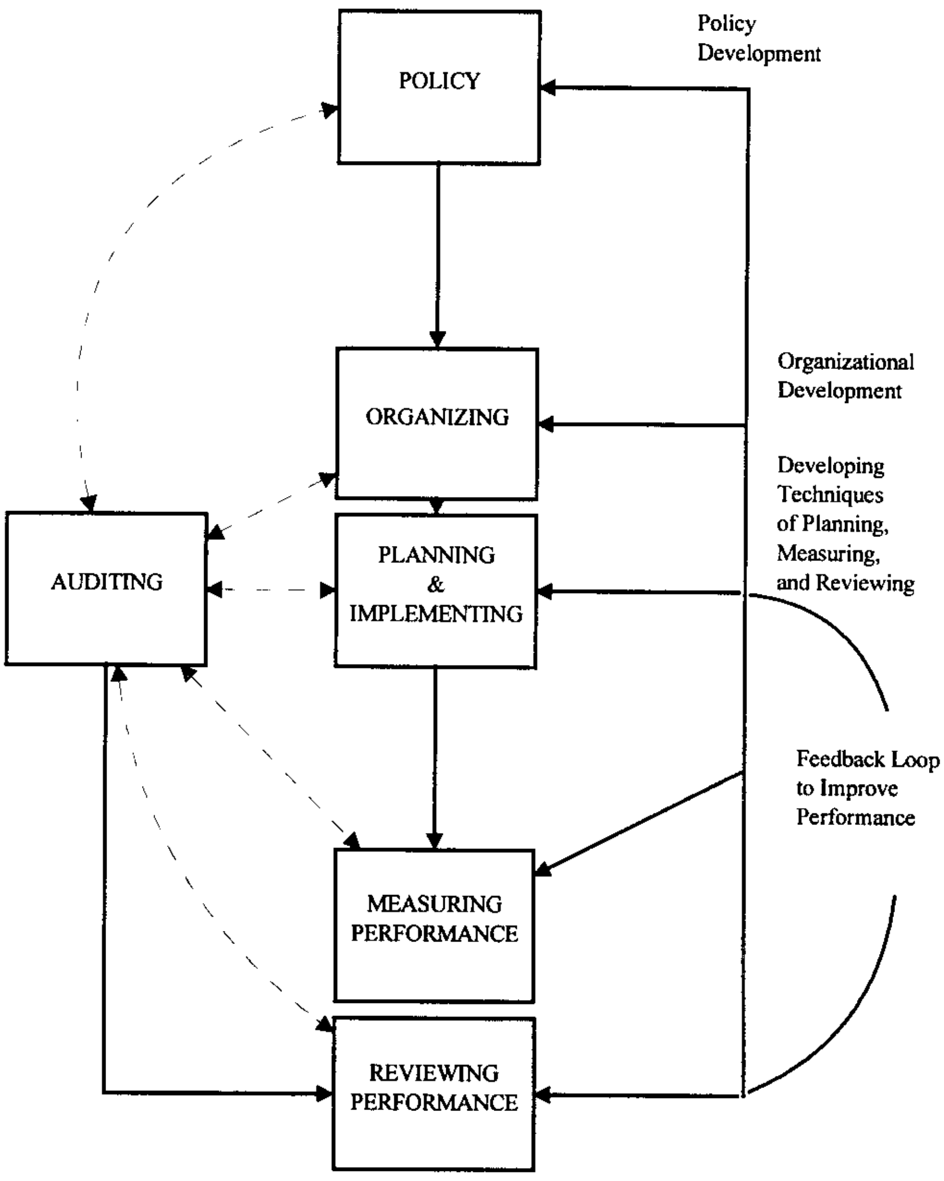
These activities include:

- Setting out written policy
  - objectives
  - standards
  - priorities
  - authorities
  - decision reference points
  - management and communication structures that allow policy to be implemented and performance to be monitored

- Implementing policy by
  - propagating and communicating policy
  - defining accountability
  - raising awareness and involvement of individuals
  - providing adequate resources

- Monitoring the performance of policy by
  - listening
  - taking proactive follow-up measures
  - eliminating deficiencies
  - taking initiatives (external auditing, training, analysis, assessment)
  - reviewing policy
  - rewarding good performance
  - auditing

FIGURE 2.3.1: KEY ELEMENTS TO SUCCESSFUL HEALTH AND SAFETY MANAGEMENT



Ref: Health & Safety Executive. Success for Health and Safety Management (HS(G) 65) London: HMSO, 1991.

A key aspect of SMS is the creation of performance standards. These performance standards act as criteria for measuring whether safety goals are being met and whether those standards are meeting their intended goal of minimizing risks. The performance criteria are used to monitor, audit, and review the SMS standards. Throughout the application of SMS, it is important not only that monitoring, auditing, and reviews occur but also that modifications are made to the SMS when deficiencies are noted, or when information on new ways of making improvements become known. The SMS must remain a living system where continuous improvement is established as an objective. SMS improvements can go hand in hand with Total Quality Management efforts.

Jenkins, Brearley, and Stephens (1991) point out that improvements in attitudes to safety often have knock-on effects in improving the reliability and availability of production systems. However, SMS does not guarantee immunity from failure but will at least provide:

- A framework for continual improvement, and
- A demonstrable conviction and commitment to health, safety, and environmental policy.

Just as the basic model of planning, organizing, implementing, and evaluating has been accepted by many organizations worldwide, it is agreed that successful application of the model within a company will depend on human activity. Those human activities include:

- Decision making
- Performance monitoring
- Communicating

Persons within an organization will be responsible for making decisions about what framework will be used for establishing an SMS for an organization, as well as determining how the framework can be explained to others and how success or failure will be monitored. If we take a further look at the Human Factors which influence SMS, we find that one goal of safety management is to reduce the potential for human errors, as well as to reduce equipment or system failures. Accordingly, Bellamy and Geyer (1992) have suggested the foremost human factors objectives that should exist within SMS:

- To provide personnel with
  - a design that they do not have to fight
  - procedures which are not bureaucratically cumbersome, difficult to perform, or hazardous
  - necessary and unambiguous information
  - a working environment conducive to minimizing stress and discomfort
- To select and train personnel such that their knowledge and skills are appropriate to the tasks which they have to perform, and to maximize personnel performance capabilities, not reduce them.
- To motivate people to perform safely and minimize pressure to do otherwise.
- To monitor performance, identify deviations from safety standards and to eliminate conditions conducive to error or procedure violations.

Amazingly, there is large agreement about the elements needed within the framework of a good SMS to ensure that human factors, organizational issues, and technological concerns are met.

The Cullen Report (1990), which was issued in the United Kingdom after the Piper Alpha accident, identifies some of the topics that are considered integral to a proper SMS. The topics include:

- Organizational structure
- Management personnel standards
- Training for operations and emergencies
- Safety assessments
- Design procedures
- Procedures for operations, maintenance, modifications, and emergencies
- Management of safety by contractors
- The involvement of the work force in safety
- Accident and incident reporting, investigation, and follow-up
- Monitoring and auditing of the operation of the system
- Systematic re-appraisal of the system in light of the experience of the operator and the industry.

Most organizations also agree that to assess SMS, an auditing approach should be used. This allows a way for different elements or factors within an SMS to be quantified. Such quantification allows benchmarking, and thus a means for measuring performance and determining whether improvement is occurring. Some of the first people to suggest the use of some type of auditing scheme for evaluating safety management include Frank Bird (see Bird & Germain, 1985) and Dan Petersen (Petersen, 1982). The International Safety Rating System, ISRS, (Bird & Germain, 1985) has been developed as an auditing technique to provide a score on the quality of safety management. Petersen outlined accident causation models and mechanisms for system failures as well as assessment schemes for determining the quality of a company's safety management scheme in his book “Human Error Reduction and Safety Management” published in 1982 A third evaluation technique is the Instantaneous Fractional Annual Loss, IFAC, technique. It has been developed to indicate where there may be potential losses that could be attributable to safety management effectiveness (Whitehouse, 1987).

Other examples of SMS auditing approaches similar to those suggested by Bird , Petersen and Whitehouse include the following:

- The HSE safety auditing scheme (1985)
- Chemical Industries Auditing scheme (1977)
- DNV Technica’s MANAGER Technique (Pitblado, et al. 1990)
- The Management Factor Technique (Powell & Canter, 1985)
- OSART programme (Bliselius & Franzen, 1985, Rosen 1988)

A brief review of the elements of these techniques, as well as similar work by Boyen, Brandes, Burk & Burns,(1987), Lees (1989) and Brian (1988) is provided in Harrison (1992). Further useful information about the origins of SMS and the historical development of the SMS concepts can be found in Bellamy & Geyer (1992).

From these early SMS systems, many industries or their related professional societies have developed their own SMS guidance tools to match the unique needs of their applications. Recent well known and widely used industrial SMS guidelines for auditing schemes include:

- API RP 75, Recommended Practice for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities

- AIChe's CCPS, Guidelines for Auditing Process Safety Management Systems
- ISO/CD 14 690, Petroleum and Natural Gas Industries--Health Safety and Environmental Management Systems (HSEMS)
- International Maritime Organization's International Code, International Management for Safe Operation of Ships and for Pollution Prevention
- OSHA 1910.119, Process Safety Management of Highly Hazardous Chemicals
- UK HSE's PFEER, Prevention of Fire and Explosion and Emergency Response on Offshore Installations

All of these guidelines are set forth to assist organizations in creating their own SMS. Even those guidelines set as regulation, like OSHA 1910.119 and HSE's PFEER, or those which are industry recommended practices, like API RP 75, have as their basis a need for organizations to create their own systems of safety management Compliance to this guidance can only be proven through performance since none of these documents were created to be prescriptive in nature. Each relies on a company to set its own policies and objectives within the guidance framework. The organization is then expected to control its unique hazards and the possible effects of those hazards via its systems of work, auditing, policies, and practices.

Despite the differences in the industries, all these guidelines basically require some type of auditing approach be used to check compliance and to allow deviations or problems in the implementation or in the SMS itself to be identified and corrected. Another similarity is that all of these different documents contain the same basic elements and these elements are similar to those listed in the Cullen Report. One document might title their elements differently but basically the contents of the recommended SMS programs remain the same. A comparison of the elements of API RP 75 and ISO/CD 14 690 is given in Table 2.3.2 to demonstrate this point.

Table 2.3.2: Comparison of the Elements of API RP 75 and ISO CD 14 690

API RP 75	*ISO CD 14 690*
• Safety and Environmental Information	• Leadership and Commitment
• Hazards Analysis	• Policy and Strategic Objectives
• Management of Change	• Organization, Resources, and Documentation
• Operating Procedures	• Evaluation and Risk Management
• Safe Work Practices	• Planning
• Training	• Implementation and Monitoring
• Assurance of Quality and Mechanical Integrity of Critical Equipment	• Auditing and Reviewing
• Pre-Start-up Review	
• Emergency Response and Control	
• Investigation of Incidents	
• Audit of Safety and Environmental Management Program Elements	

If we can reduce the elements of safety management to a common set, using terms which would be familiar to operators of offshore platforms and marine terminals, that set would include:

- Management and Organizational Issues
- Hazards Analysis
- Management of Change

- Mechanical Integrity
- Operating Procedures
- Training and Selection
- Safe Work Practices
- Emergency Response
- Investigation and Audit

For Management and Organizational Issues, it is important that an organization set up criteria and a method by which policy is set, personnel responsibilities and accountabilities are assigned, resources for safety and health are provided and a plan for overall safety, health and environmental strategy is assigned.

Under Hazards Analysis, the safety management system should require that hazards analyses be performed with the purpose of identifying, evaluating, and where unacceptable, reducing the likelihood or minimizing the consequences of uncontrolled releases and other safety or environmental risks.

The Management of Change element sets forth the need for establishing procedures to identify and control hazards associated with change and maintain the accuracy of the safety information. Under this element, change is not limited to equipment or components but includes controlling and evaluating the effects of changes in organizations and personnel, as well.

Mechanical Integrity is another important SMS element and is aimed at ensuring procedures are in place and implemented so that critical equipment is designed, fabricated, installed, tested, inspected, monitored, and maintained in a manner consistent with appropriate service requirements, manufacturer's recommendations, or industry standards. This element includes items related to quality assurance as well as mechanical reliability.

Any safety program recognizes the importance of establishing, implementing, reviewing, and updating written Operating Procedures. These procedures are necessary to enhance and encourage safe, efficient, and environmentally sound operations.

Training and Selection of staff are integral to ensuring that a company chooses the right staff and then provides that staff with the proper skills and knowledge. To accomplish this a company must recruit, select, place, assess, promote, and train individuals so that they perform their jobs or assignments within prescribed guidelines which are compatible with health, safety, and environmental policy. Having the right people is as important as having the right equipment.

Over the last ten years, Safe Work Practices have been recognized as instrumental to ensuring safe operations and reducing the likelihood of accidental releases. It is important that within the SMS framework a method of work be established and implemented to minimize the risks associated with operating, maintaining and modifying equipment and systems, and also that the work practices specify how materials and substances will be handled to reduce the potential for ill effects to personnel or the environment.

While having an Emergency Response Plan will not necessarily prevent a loss of containment, by having pre-planned how such a response will occur, the consequences associated with loss of containment situation can be controlled or mitigated. In order to ensure this, emergency response plans must be in place, ready for immediate implementation, validated by drills, familiar to those responsible for carrying them out and updated when circumstances change or deficiencies are recognized.

Finally, most organizations and theorists would agree that an all encompassing SMS must included segments which require both Investigations of incidents and accidents and some means of Auditing the existing SMS for compliance and deficiencies. Both of these items are aimed at ensuring that based on available information, whether it be an investigation or audit, the SMS is continuously improved.

Bellamy and Geyer (19xx) remind us that during the audit process it is important to evaluate whether the human factors aspects of SMS have been met. In order to make such judgments the auditor or the auditing scheme must determine if:

- Human factors considerations of the demands to be placed on the individuals were undertaken during the design stages of a facility. Such consideration would be demonstrated if human reliability or task analyses were performed.
- The organization, through the human resources department, developed a systematic way to organize tasks into jobs, determined required skills and knowledge for a job, and selected and trained employees based on this system.
- Incentives exist to promote safety, and reduce or eliminate unsafe behaviors or practices. This would involve investigation into pay, team structures, personnel relationships, performance targets and associated rewards, personnel development, peer group and other organizational pressures, disciplinary systems, accountability, job satisfaction, and competing incentives (particularly production pressures).

Many industries, including the maritime and offshore oil and gas industries, agree that technological approaches are not sufficient to increase safety and reduce risk potential associated with hazardous operations. It is now recognized that organizations must be well managed and develop a system of safety management which includes not only systems of work aimed at technical issues but which also include human and organizational factors. The management principles upon which SMS should be based upon are planning, organizing, implementing, and evaluating. It is also recognized that an effective SMS can not be bought off the shelf since as Whalley-Lloyd (1994) points out, an SMS has to be developed to suit a company and the people working in it. For success, an SMS must involve key individuals within the organization during the development of the SMS scheme and all individuals in the organization need to be committed to its implementation. Not only must a particular organization develop, implement, communicate, evaluate, and update its SMS, but that organization should ensure that its program contains elements similar to the guidance that is commonly accepted by industry and regulators.

2.4 HUMAN AND ORGANIZATIONAL FACTORS

The origins of Human and Organizational Factors (HOF) can be traced back to the late nineteenth century. Frederick Taylor, in the 1880's, conducted motion by motion analyses of factory workers to increase their efficiency (Taylor, 1947). Psychologists Frank and Lillian Gilbreath, in the 1910's, pioneered time-and-motion studies (Greenberg and Baron, 1995). In the 1920's, Max Weber proposed the concept and characteristics of bureaucracy (Weber, 1921), and in the 1930's Elton Mayo developed the human relations movement (Mayo, 1933). In the 1940's, Henri Fayol's principles contributed to the development of classical organizational theory (Fayol, 1949). Mass production of equipment and weapons in factories during World War II moved these theories into application. Furthermore, military aviation began to examine human factors as losses of aviators and their planes increased (Beaty, 1969).

In the late 1950's the area of human reliability analysis was founded in the field of industrial engineering and operations research. It was during the early 1960's that there were systematic treatments of human performance involving complex technological systems. This work established the theoretical setting for a new field: the field of human reliability analysis. This field combined the organizational tools of systems engineering with the theoretical tools of probabilistic analysis (Dougherty and Fragola, 1988).

In the late 1960's, analysts attempted to apply this technology to the engineering and evaluation of human-machine systems. These practitioners found that there was very little in the way of human factors data. In addition, there were no generally accepted human performance theories or models. This recognition led to a variety of research projects which produced collections of human reliability data (Munger, et al., 1962; Berliner, 1964; and Swain, 1964).

The Sandia Human Error Rate Bank was created in 1967 with the objective of collecting human performance data on a continuing basis (Rigby, 1967). Several other human factors databases were also developed. A major missing factor in these databases was a generally accepted and systematic approach to the classification and description of human performance. It was about this same time that it was recognized that there was a need to account for the situation influences on task performance as well as the elements of human behavior in these databases (Askren, 1967 and Meister, 1969). Thus, work was started to define the causes and effects of human errors.

In the 1970's the majority of the work in human reliability was funded by the military. The Navy held seminars on human reliability in 1970 (Jenkins, 1970). In 1975, applications of human reliability engineering were advanced in the nuclear power plant environment (USNRC, 1975). The U. S. Navy published a manual for its NAVSEA Human Reliability Prediction System (US DOD, 1977). This manual described the Navy's approach in quantifying human errors in electronics systems operations and included quantified analyses of maintenance and personnel selection (Dougherty and Fragola, 1984).

The field of ergonomics or design of man-machine interfaces was founded during this time period. This work resulted in definitive guidelines and standards for engineering the interfaces between human operators and the systems they operate to minimize the likelihood of errors (Kirwan, 1996). These standards have continued to be developed and expanded to macro-ergonomics (consideration of organizational influences).

In 1979, the accident at the Three Mile Island nuclear power plant forced the nuclear power industry to recognize directly the roles of human error. An intensive effort to develop the technology to analyze human error sponsored by the Nuclear Regulatory Commission was started in 1980. This effort resulted in definitive guidelines for how human reliability could be integrated into probabilistic risk analyses. Classification and analysis systems were developed. Guidelines were developed for the conduct of studies of the potentials for human errors in plant operations (USNRC, 1982).

The crash of the Challenger space vehicle in 1989 served to focus the need for human factors research in the space industry. This experience illustrated the importance of organizational influences in causing catastrophic accidents. The National Atmospheric and Space Administration embarked on an intensive human factors research effort following this incident (Tillman, 1987). This work has been further reinforced by an extensive effort in the commercial aviation industry. This work has been largely focused on cockpit crew training and management and their interfaces with increasingly electronically computer controlled avionics (United Airlines, 1996).

About the same time, parallel work was being conducted in Europe to address human errors in operations of offshore platforms. Following the destruction of the Piper Alpha platform in the North Sea in 1989, an intensive effort was initiated to manage human errors in platform operations. This work led to personnel selection and training procedures that are now being implemented. The training procedures include the use of critical accident scenario simulators (similar to practices in the commercial aviation industry and the military) to give operating personnel experience in how to bring potentially catastrophic escalating sequences of developments under control.

Research on HOF is continuing along many fronts. Efforts in the fields of management, psychology, cognitive science, and engineering are underway. Largely as a result of research in business administration and management and development of the ISO (International Standards Organization) quality standards, TQM (Total Quality Management) has developed and focused attention on the organizational and management aspects of human error minimization to achieve desirable quality in produced goods and services. Psychological research has been directed at understanding organizational behavior and culture (organizational psychology) (Proctor and Van Zandt, 1994).

At the present time, it is fair to say that this is a field that is rapidly evolving. It is also fair to say that this is a field that is very diffuse. There still is no commonly accepted classification and description system for human and organizational errors. Also, there are no generally accessible and comprehensive databases on human and organizational errors.

Human reliability analysis and human engineering is an activity that is just beginning to find its way into practice in the marine industries. In many parts of the marine industries, there is much skepticism about this field, and, in particular, the engineering aspects. However, in many parts of the nuclear power industry, commercial aviation industry, military, and space industry, human reliability analysis and human engineering have been highly developed. Intensive and extensive research on many fronts continues to be conducted. Human reliability analysis and human engineering have been translated successfully to practice by these industries.

2.4.1 HOF in the Marine Industry

The history and current status of HOF in the marine industry is assessed by examining four international workshops conducted over the past 12 years. The first three workshops were titled: the "Application of Risk Analysis to Offshore Oil and Gas Operations" (NBS, 1985), the "Reliability of Offshore Operations" (NIST, 1992), and the "Assessment and Requalification of Offshore Production Structures" (OTRC and UCB, 1993). These first three workshops examined the use of risk and reliability in the technical areas of offshore operations and recognized that human factors and organizational influences were important areas requiring further research and development. These findings resulted in the fourth workshop, called "Human Factors in Offshore Operations" (Primatech and UCB, 1996). The six workgroups of this workshop focused on HOF in:

- Design
- Fabrication and Installation
- Operations
- Management Systems

- Standards and Regulations
- Science and Application

The preliminary results of this workshop are that HOF needs to be addressed in each of these areas, both in the actual topic areas and in the implementation of HOF in the area.

This increased attention to HOF in the marine industry is also apparent in recent industry regulations and guidelines. The United Kingdom watershed for offshore safety was the Piper Alpha accident in which 167 workers were killed. One result was mandating Safety Cases for offshore platforms (Cullen, 1990). In the United States, the Minerals Management Services (MMS) in 1990 called for the development of Safety and Environmental Management Programs (SEMP). The American Petroleum Institute (API) created Recommended Practice 75, adding definition to SEMP (API, 1993), and industry with the encouragement of MMS is implementing SEMP on a voluntary basis. Debate continues on the effectiveness of a voluntary SEMP program. In the International Maritime community, the International Safety Management (ISM) code addresses safety management onboard ships and at marine terminals. It becomes mandatory in July of 1998 (IMO, 1993).

The issue of addressing HOF carries with it the challenges of first identifying HOF and, second, assessing these HOF. The UK safety cases, at an approximate cost of $1,000,000 per safety case, use the Human Reliability Analysis technique. This technique is briefly described later in this report. The SEMP and ISM codes have identified some HOF requiring attention; however, no method for assessing these HOF is included in the guidelines.

2.4.2 Human and Organizational Factors

A plethora of information about human and organizational factors is available through many sources. One main source is textbooks, both in Human Factors (e.g., Procter and Van Zandt, 1994) and in Organization Behavior (e.g., Greenberg and Baron, 1995). Additionally, research into high-reliability organizations provides a set of potentially useful characteristics (Libuser and Roberts, submitted for publication). HOF specific to the marine industry are found in: guidelines (e.g., API RP75), and regulations (e.g., ISM Code). A compilation of these sources is summarized in Table 2.4.2.1 for human factors and Table 2.4.2.2 for organizational factors. These factors represent a first step in defining a set of HOF to be evaluated for their relevance in a field test. Note that this is not an exhaustive list.

Table 2.4.2.1: Selected Human Factors Terms and their Definitions

Factor	Definition
Communications	The ability of the individual to clearly transmit information to others and to clearly understand information being received.
Selection and Training	The selection process by which the personality and individual characteristics are taken into account. The training of those individuals.
Education	The ability of the person to learn and understand information. The ability to counter ignorance.
Limitations and Impairment	Actual physical limitations and impairments due to a person's physical and emotional make-up.
Organization (Planning & Preparation, Changes)	The ability of the individual to plan, to prepare, to be organized and to adjust to changes.
Experience (Mistakes, Slips, Violations)	The work experience of a person, and how the person uses this experience to avoid mistakes, slips, and violations.
External Environment	The harshness of the environment (external, internal, and social) in which the person is working.

Table 2.4.2.2: Selected Organizational Factors Terms and their Definitions

Factor	Definition
Process Auditing	The action which takes place to monitor processes and, when necessary, taking actions to correct deviations which lie outside of the established norms.
Culture	The cognitive framework consisting of attitudes, values, behavioral norms, and expectations shared by organization members. In High-Reliability Organizations, this includes a high state of quality and an appropriate reward system. **Mission/Vision:** The goal of the organization is accepted and wholeheartedly believed by all personnel.
Appropriate Risk Perception	The organization's acknowledgment of risks that are both known and unknown.
Emergency Preparedness	The organization's plans to minimize risks and plans to minimize the severity of an incident by preparing plans to mitigate an incident. This also includes drills and exercising of emergency plans.
Command and Control Functions	The organization's structure for making decisions. This includes migrating decision making, redundancy, rules, seeing the "big picture", requisite variety, and alert systems.
Training	The organization places emphasis on training, which can be indicated by the amount of money and time invested in training and how the people of the organization feel about the relevance of the training.
Communications	The ability of the organization to clearly and accurately transmit and receive information throughout the organization.
Resources	The ability of personnel on the front-line to receive resources quickly and in adequate quantities.
Equipment and System Maintenance	The organization places significant emphasis on the procurement, installation, construction and maintenance of equipment and systems. Quality equipment is installed and properly maintained. "Gerry rigging" is not allowed, and repair parts are quickly delivered.
Procedures	This topic covers all documentation required by regulatory agencies and any internal audits the organization has. Procedures are in place for safe work practices and regulation compliance. Procedures are involved in the documentation of work completed, certification of personnel and the reporting of accidents

Discussions at the recent (December 1996) International Workshop on Human and Organizational Factors in the Safety and Reliability of Offshore Platforms reinforced the importance of these factors.

2.4.3 Assessment Methods

Textbooks written on reliability primarily focus on equipment (e.g., Villemeur, 1992). These methods discussed in such books tend to rely heavily on failure rate data obtained either through operating history or experimental tests. Since these methods were successful in the realm of equipment, they carried over into the human and organizational sphere. The following two sections examine such assessment methods for human factors and organizational factors, but by no means represent reviews of HOF assessment techniques.

2.4.3.1 Human Assessment Methods

Most methods for assessing human reliability focus on tasks. The most widely known method is Human Reliability Analysis (HRA) method, and most other human reliability assessment methods evolved from HRA. Using this method, human tasks that can lead to system failure are identified by human factors analysts. Each of these tasks is then decomposed into steps. These steps are assigned Human Error Probabilities (HEP). The HEP for each step are combined to obtain an HEP for the task. Based on expert judgment, a Performance Shaping Factor (PSF) is multiplied with the task HEP to obtain a probability of failure for the system due to the failure of that specific task. In the absence of industry specific HEP, similar step HEP from other industries are used (Dougherty and Fragola, 1988).

Human Error Probabilities are determined from several sources. The primary source is through accident or incident data; however, as previously mentioned, human errors are not well defined in accident reports. Another source of human error data is simulation; however, as some argue, the simulator environment is not realistic enough and thus produces skewed HEP.

There are four significant weaknesses to the HRA method. The first is that human judgment, in the form of analysts or experts, adds uncertainty to three steps in the HRA process. First, the selection of tasks leading to failure, then the selection of HEP from other industries, and third, the use of PSF. This leads to inconsistent evaluations among separate teams, as demonstrated by Pouchet (1989) and Humphreys (1990). The second weakness is that low-probability, high-consequence events are eliminated early in the task identification process by human factors analysts. Weights are assigned to human error probabilities in the form of PSF and to questions in the form of a numerical value. The reason for using weights is so that different systems can be compared, allowing assessors to highlight those areas of a system warranting special attention. The fourth weakness is that the uncertainties of the analysts and experts are not captured.

2.4.3.2 Organization Assessment Methods

Methods for assessing organizations generally take the form of questionnaires or surveys. These methods use human analysts and experts to evaluate a system by answering pre-weighted questions with a grade. Two such methods are called MANAGER (Management-safety-systems-assessment guidelines in the evaluation of risk) and ISRS (International Safety Rating Scheme).

There are two major weaknesses with these methods. The first is that the operators of the systems are not an integral part of the evaluation team, although they can serve as subject matter during the assessments. The second is inconsistent evaluation of the same system by separate teams due to the use of weightings and/or expert judgment in grading. It can be argued that the assignment of weights within ISRS adds another layer of uncertainty to data.

2.4.3.3 Assessment Methods in Other Industries

A review of other industries' methods for assessing human and organizational factors was conducted. The results are in Table 2.4.3.3.1, Assessment Methods by Industry.

Table 2.4.3.3.1: Assessment Methods by Industry

Industry	Method
Nuclear Power Plants	Human Reliability Analysis (HRA), checklists, Probabilistic Risk Assessment, Management Assessments
Chemical Industry	Human Reliability Analysis, Quantitative Risk Assessment, Hazards Assessments, Process Safety Management Evaluations
Commercial Aviation	Databases, Simulators
Space Program	Simulators, Design Checklists, Experimental Studies
Naval Aviation	Simulators, Checklists
Highway Safety	Accident database
Nuclear Medicine	Relative risk assessment
Health Risk Appraisal	Risk factor screening
Fire Risk Ranking	Narratives, checklists, rankings, probabilistic methods

The first six industries and their primary method for assessing human and organizational factors (e.g., HRA, simulators, and accident database) have previously been reviewed. The next section will briefly describe the last three methods, the first being used in nuclear medicine, the second used in health risk appraisal, and the third used in fire risk.

In nuclear medicine, the Gamma knife is a new technology that uses gamma radiation to remove brain tumors. As a new technology, it had very little data and expertise to conduct an HRA and obtain an overall absolute human operator failure rate. The researchers assess the knife's reliability by asking the operators and designers of the knife to list the steps in its operation and then rank them according to likelihood of error and consequence of error. The likelihood and consequence were then multiplied together to determine the risk of that step, thus giving this technique the name Relative Risk Assessment. The highest relative risk steps were then focused on to determine how to lower the knife's overall risk level (Jones et. al, 1995). The next method takes another approach.

The Health Risk Appraisal method first identifies health risk factors. These factors are determined from mortality data. The Michigan Department of Public Health method lists the following seven risk factors:

- High Blood Pressure
- Physical Fitness and Exercise
- Dietary Choices
- Smoking
- Driving Behavior and Seat Belt Use
- Alcohol and Drug Misuse/Abuse
- Stress.

The method involves a trained nurse who, in participation with the patient, answers questions related to each of the above risk factors. The number of questions for each risk factor ranges between two and eight. This screening method is used to identify risk factors and to determine if more invasive tests are required. Following the screening, additional information is provided to patients to help them reduce their risk (MDPH, 1985). The strengths of this method are the involvement of the patient and the short amount of time required to conduct the method; however, one weakness is the difficulty of establishing trust in order to obtain truthful answers.

Fire protection engineers also encounter uncertainties when evaluating risk. Four methods of fire risk assessment are:

- Narratives
- Checklists
- Ranking
- Probabilistic methods.

Narratives are used to describe a risk and to judge it acceptable or not, depending on whether it complies with some type of published recommendation. Narratives do not attempt to quantify risk. Checklists aid fire protection engineers in understanding and tracking compliance to requirements. Checklists can be adapted to the requirements of specific projects; however, they do not distinguish the importance of different fire risk factors. Ranking schedules use expert judgment and past experience to assign risk values. These values are then combined to create a single risk value for comparison to other assessments. Probabilistic methods take fire safety variables and manipulate using recognized theoretical principles (Watts, 1995).

Fire protection engineers realize that absolute risk methods such as the Probabilistic Risk Assessment require very detailed analysis, which can cost thousands or even millions of dollars worth of statistical studies and fire testing, and are complex and time-consuming. With this in mind, they looked to a ranking system. The fire risk ranking methods define the relationship between hazard and exposure by using more simplistic models requiring less data and less analysis. These methods focus on screening for high-risk catastrophic-type situations where the analyses are consequence-oriented. One of these risk ranking methods is called the Gretnener Method. It defines the fire risk as the product of two components, the probability that a fire will start (likelihood) and the fire hazard, degree of danger or probable severity (the consequence) (Watts, 1995).

Another method for determining fire risk is Dow's Fire and Explosion Index, which uses tables based on data and expert judgment. This method is focused on technical aspects and does not address human and organizational factors. In general, this method is a decomposition method that divides the process plant into separate operations or units and considers each of these individually. The Hierarchical approach examines from top down the management decision making levels, from policy to objectives, strategies, parameters and survey items. HOF play a small part in the personnel and management parameters (Watts, 1995).

The fire risk ranking systems are helpful in that they move away from the hard-to-quantify risks and focus on relative risks. The Gretnener method breaks risk into two components, likelihood and consequence. Once relative risks are established, those items with the highest relative risks can be targeted for mitigation efforts. The next section examines research that addresses the assessment of HOF in the marine industry.

2.4.3.4 Marine Industry Research Projects in HOF Assessment

Three methods for assessing HOF in operating marine systems were reviewed during the literature search. These methods are:

- FLAIM -- Fire and Life safety Assessment and Indexing Methodology (Gale et al., 1994)
- HESIM -- Human Error Safety Index Method (Moore and Bea, 1993)
- Tripod Delta (Hudson et al., 1994)

FLAIM (Gale et al., 1994) is a combined qualitative-quantitative assessment method focused on offshore oil platforms. The method has several modules, the majority of which address physical aspects, while a few address the human and organizational aspects.

The method has four levels:

- Red-Level: Predetermined important questions
- Tier 1: A set of general questions
- Tier 2: More detailed questions tied to each general question
- Tier 3: Even more detailed questions tied into Tier 2 questions

FLAIM has two steps:

Step 1: Experts pre-select questions from different tiers and then assign weightings for each question prior to the start of the assessment.

Step 2: Assessors, who are not the experts, answer the questions using a grading value: (A = excellent; B, C, D, and F = bad), numeric (quantity) values, or binary values.

As assessors input these grades/values into the computer program, an evaluation similar to an academic grade point average is calculated for each module. Those modules with the lowest grade point averages are then targeted for improvement. Assessors are given the flexibility to change the question weightings which the experts had originally programmed.

Strengths of this method are that weights are useful when sufficient historical data are available, which is the case with equipment. Second, letter grades provide a means of qualitatively assessing a range of values (for example: an A can be a value from 90% to 100%).

There are also some weaknesses to this method. Weightings are difficult to assign when historical data are lacking, as is the case with human and organizational factors. Inconsistency may occur when expert judgment is used. The assessors must know the system well enough so that a single letter grade can be assigned, and the assessors' uncertainty is not explicitly captured.

FLAIM is a very good tool for addressing areas that have good historical databases, such as equipment and hardware, since it relies on weightings. However, for areas that do not have good historical databases, such as human and organizational factors, it is very weak and will produce inconsistencies when expert judgment is involved in question selection and weight assignments. Additionally, the assessors are required to have some expertise in human and organizational analysis to be able to assign single value grades.

HESIM is a method that uses heuristics to systematically evaluate the effects of factors on a system's overall safety index. This method uses quantitative analysis to assist in identifying factors of higher risk, not just to produce numbers. These factors include human factors, organizational error, system, and environmental. An algorithm is used to collect information on an accident, and these data are used to update a database so that in the future when sufficient data are available, a probabilistic method can be employed (Moore and Bea, 1993). This method relies upon expert judgment and weightings and is focused primarily on post-accident analysis.

Tripod Delta is a checklist method that attempts to identify underlying factors that cause accidents. The eleven factors examined are:

- Hardware
- Design
- Maintenance
- Error Enforcing Conditions
- Procedures
- Housekeeping
- Incompatible Goals
- Communications
- Organization
- Training
- Defenses

This method uses system operators as an integral part of the assessment. The assessors use a checklist of questions answered with a simple yes or no. These answers are then combined under the factors to determine a relative risk value. Those with higher risks are targeted for mitigation (Hudson et al., 1994). The weaknesses of this method include its inability to capture the assessor's uncertainty, and it does not take into account both likelihood and consequence as key components of risk. Since the questions are proprietary, further examination was not carried out.

As a result, another approach is proposed for assessing human and organizational factors in marine operating systems. The next section discusses the reasons for a new approach, method requirements, and proposed steps to the new method.

3.0 MINIMAL BASIC QUESTION SET

3.1 INTRODUCTION

The objective of the SAMS Joint Industry Project was to develop a methodology for evaluating the safety of maritime systems, which include platforms and marine terminals. This report documents two methodologies that SAMS team members have developed for this purpose: Factors of Organizations and Operating Teams (FOOT), which is discussed in Section 4 of this report, and Marine Assessment of Safety Techniques (MAST) which is discussed in Section 5.

In developing FOOT and MAST, team members sought to ensure that these methodologies would allow for assessment of safety and environmental management programs as well as evaluation of human and organizational factors. These assessments would focus on process safety as it relates to a facility's catastrophic potential in terms of fires, explosions, and releases..

A set of questions referred to as Minimal Basic Questions (MBQs) was established as an initial means for gathering information on facilities and their safety management policies, procedures, and practices. As of January 1997, the set included approximately 80 general assessment questions. The background, basis, and source material used for the MBQs are presented in Section 3.2. The organization of the actual MBQs are also presented in Section 3.3.

3.2 BACKGROUND AND BASIS

3.2.1 Guidelines for Question Set Development

Several guidelines were established for development of the set of MBQs. One guideline was to ensure that the question set be kept to a reasonable number of questions to allow rapid initial assessments but still provide coverage of topic areas, safety management systems, and human and organizational factors. While many tools exist for evaluating both safety management systems and/or human and organizational factors, most of these are labor-intensive, and many involve answering large numbers of questions. For example, FLAIM contained modules that reviewed both safety management systems and - to some degree - human and organizational factors, but the total FLAIM framework included more than 1300 questions. Another tool used by many organizations for the evaluation of management systems relating to health and safety is the International Safety Rating System. This tool has more than 650 questions. It was paramount that whatever tool resulted from the SAMS effort contain a reasonable number of questions to facilitate rapid assessments.

Another guideline used by the SAMS team was to establish questions that would be applicable to both offshore production facilities and marine terminals. Given this specific application, the SAMS team used background material from the marine and oil/gas industries as primary sources of questions. Such background material included documents from the American Petroleum Institute, the International Maritime Organization, the International Organization for Standardization, and the United Kingdom's Health and Safety Executive Offshore Installations Division.

Finally, it was also important to ensure that the MBQ set be provided in a framework that related to concepts and ideas already accepted within industry. Since the target assessors would be regulatory, ship classification society or operating company personnel, the SAMS team recognized that the language and terminology used should relate to familiar process safety and engineering concepts, such as hazard analysis, mechanical integrity, and safe work practices. Employing a similar framework to that provided in widely accepted industry documents helped the team to meet this goal.

3.2.2 Goals for the Question Set

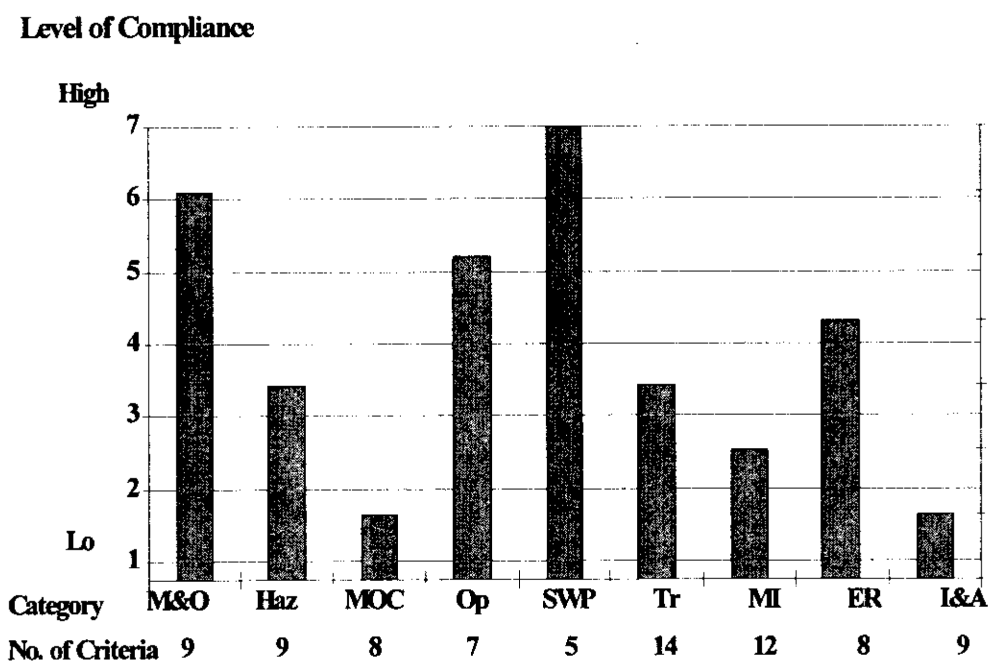
Once the ground rules for developing the MBQs were established, the purpose of the MBQs was outlined. The SAMS team intended that use of the MBQs would accomplish the following three goals:

- *Identifying strengths and areas of concern* - Using the MBQs, an assessor should be able to identify the strengths, weaknesses, and suspected deficiencies within a company's approach to process safety management. Deficiencies in the safety management program would also point to possible human and organizational concerns since the success of safety management lies within the development, administration, and application of policies, programs, and procedures. Such policies, programs, and procedures are highly dependent on human interaction, interpretation, and implementation. Through examination of policies, programs, and procedures, a first step toward evaluating HOF would be taken. The results of the MBQs evaluation would determine the focus of further investigations.

- *Generating a graphical representation of a facility's compliance* - Upon completion of an evaluation using the MBQs, a profile of the results would be generated. This profile would provide graphical indications identifying which process safety areas had high levels of compliance with questions and which had low. Using a bar chart, a tall bar (i.e., close to 7 on an identifying scale from 1 to 7) would imply that, during the assessment, a facility was found to have a high level of compliance with the questions within a particular safety management systems area. A short bar, a bar approaching 1 on the graph, would indicate that little or no correlation existed between the MBQs for a process safety area and the practices at a facility (see Figure 3.2.2, Example Graphic Representation of Evaluation Results).

- *Tracking results to standards and guidelines* - Due to the fact that the MBQs would be coded according to their literature sources, at the end of an evaluation using the questions, an assessor could easily correlate compliance or noncompliance to questions in various documents. If a facility were located in the United States, an assessor could determine which questions related to compliance with SEMP criteria, while results for a British facility could be correlated to PFEER criteria.

Figure 3.2.2: Example Graphic Representation of Evaluation Results



Key: **(Nine MBQ Categories)** M&O - Management & Organizational Issues, Haz - Hazards Analysis, MOC - Management of Change, Op - Operating Procedures, SWP - Safe Work Practices, Tr - Training and Selection, MI - Mechanical Integrity, ER - Emergency Response, I&A - Investigation and Audit

3.2.3 Source Material

The MBQs were synthesized from different standards, guidelines, company policies, and research. The primary sources included:

- *SEMP*, the American Petroleum Institute's Recommended Practice 75 (RP75): Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities

  RP75 provides guidance for using Safety and Environmental Management Programs (SEMP). These recommended guidelines are applicable to the management of safety and environmental hazards associated with all phases of the initial design, start-up, ongoing maintenance, and monitoring and modification of new and existing operations and facilities for the OCS. RP75 provides guidance and suggested criteria for the development and application of safety and environmental programs. The eleven areas outlined in the document include:

  - Safety and environmental information
  - Hazards analysis
  - Management of change
  - Operating procedures
  - Safe work practices
  - Training
  - Assurance of quality and mechanical integrity of critical equipment
  - Pre-start up review
  - Emergency response and control

- Investigation of incidents
- Audit of safety and environmental management program elements

- *ISM Code, the International Management Code for the Safe Operation of Ships and* for Pollution Prevention

  The ISM Code's main objective is to ensure safety at sea for all ships, to include prevention of human injury and loss of life and avoiding damage to the marine environment and property. The code describes functional requirements for a Safety Management System (SMS) as applicable to ships. The following six functional requirements of an SMS are defined in the ISM Code:

  - A safety and environmental policy
  - Instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international flag State legislation
  - Defined levels of authority and lines of communication between, and among, shore and shipboard personnel
  - Procedures for reporting incidents, accidents, and non-conformities with the provisions of the ISM Code
  - Procedures to prepare for and respond to emergency situations
  - Procedures for internal audits and management reviews.

- *ISO*, International Organization for Standardization's Standard for the Development of Safety, Health and Environmental Management for Oil and Gas Production Operations and Facilities: ISO/CD 14 690

ISO/CD 14 690 is an international standard which covers all aspects of the development of safety, health and environmental management systems (HSEMS) for oil and gas production operations and facilities, both offshore and onshore. This standard is similar in many ways to API RP75. The standard was designed to support existing company systems and practices and is based primarily on documents prepared by API and E&P Forum. ISO/CD 14 690 is also based on the principles of the International Standard on quality systems, ISO 9000, and consists of seven key elements which are listed below.

- Leadership and commitment
- Policy and strategic objectives
- Organization, resources, and documentation
- Evaluation and risk management
- Planning
- Implementation and monitoring
- Auditing and reviewing.

- *PFEER*, United Kingdom's Health and Safety Executive's Offshore Installations - Prevention of Fire and Explosion, and Emergency Response

This publication is an Approved Code of Practice and Guidance (ACOP) which was approved by the Health and Safety Commission in the United Kingdom to provide guidance for offshore operators and contractors to comply with existing health and safety laws. It consists of regulations which support the general requirements of the Offshore Installations (Safety Case) Regulations (SI 1992/2885), the Offshore Installations (Safety Representatives and Safety Committees) Regulations (SI 1989/971), the Health and Safety at Work Act 1974, (HSW Act), and the Management of Health and Safety at Work

Regulations (SI 1992/2051). All of these health and safety laws place general duties on employers to ensure the safety and health of their employees and to undertake risk assessments which identify the measures which will help prevent accidents and protect people.

The PFEER Regulations support these general legal requirements by specifying particular goals for preventive and protective measures to manage fire and explosion hazards. The regulations also recognize that on an offshore installation, the operator or owner should have the responsibility to secure effective emergency response. PFEER consists of 25 listed regulations as follow:

- Citation and commencement
- Interpretation
- Application
- General duty
- Assessment
- Preparation for emergencies
- Equipment for helicopter emergencies
- Emergency response plan
- Prevention of fire and explosion
- Detection of incidents
- Communication
- Control of emergencies
- Mitigation of fire and explosion
- Muster areas etc.
- Arrangements for evacuation
- Means of escape

- Arrangements for recovery and rescue
- Suitability of personal protective equipment for use in an emergency
- Suitability and condition of plant
- Life-saving appliances
- Information regarding plant
- Certificates of exemption
- Amendment of the Offshore Installations (Safety Representatives and Safety Committees) Regulations 1989
- Amendment of the Offshore Installations (Safety Case) Regulations 1989.
- Revocation

- State of California, State Lands Commission, Marine Terminals Inspection Guidelines

  The primary purpose of these regulations from the State of California is to provide the best possible protection of the public health and safety and the environment by using the best technology available. This regulation is primarily geared towards marine terminals, and protecting the health and safety of the public and the environment by preventing oil spills. It does not apply to oil transfer operations at offshore platforms, tank cleaning, or oil transfer operations to or from vessels which carry less than 250 barrels. The Marine Terminals Inspection Guidelines have the following 23 guidelines listed below.

  - Inspections and Monitoring
  - Notification
  - Exchange of Information
  - Declaration of Inspection
  - Requirements for all Transfer Operations

- Requirements to Prevent Electrical Arcing at Onshore Terminals
- Fire Prevention for Transfer Operations
- Unauthorized Visitors
- Warning Signs
- Permit to Work and Hot Work Permits
- Lighting
- Communications
- Requirements for Persons in Charge
- Limitations on Hours of Work for Terminal Personnel
- Equipment Requirements
- Operations Manuals
- Additional Requirements at Offshore Terminals
- Spill Containment for Ballasting or Deballasting Operations for Tank Vessels at Marine Terminals
- Mitigation Monitoring Requirements
- Notifications regarding Apparent or Threatened Violations
- Notifications regarding Discharge Threat
- Enforcement Procedures

• *FLAIM*, Bill Gale's Fire and Life Safety Assessment and Indexing Methodology.

FLAIM is a safety assessment methodology for safety management of existing oil and gas production platforms in the U.S. Outer Continental Shelf (OCS). This methodology is intended to be a simple and adaptable means of assessing fire and life safety risks and accounting for mechanical systems and management systems safety. FLAIM is another supporting tool to existing (more thorough) risk assessment techniques of offshore platforms. It's intention is to assist operators and regulators in improving existing safety management programs by integrating both human factors and design considerations to assess and manage platform safety.

The key difference in FLAIM as compared to the above sources is the indexing system used to measure safety management and risk contributors. Another difference in FLAIM compared to more vigorous risk assessment techniques is the focus on the risk contributors found in human and organizational factors rather than the risk contributors which process mechanisms incur. This is not to say that FLAIM does not address the process mechanisms, but that it also looks at human and organizational errors as a risk factor. The FLAIM methodology consists of the assessment of risk contributors listed below:

- General Factors Assessment
  - Platform Description
- Loss of Containment Assessment (LOCA) Factors
  - Fuel Factors
  - Wellbay LOC Factors
  - Import/Export Risers
  - Platform Design Capacity and Operating Conditions
  - Material compatibility for service conditions
- Vulnerability to Escalation Assessment (VESA) Risk Factors
  - Equipment Risk Factors
- Layout and Configuration Assessment (LACA) Factors
  - General Arrangement Considerations
- Operational/Human Factors Assessment (OHFA) Factors
  - Maintenance and Repair Work (MARW)
  - Multiple Operations Assessment (MULOPS)

    - Operational Management of Change (OPSMOC)
    - Assessment of Operator Dependence and Response (OPSDAR)
    - Operational History (OPHIST)
- Lifesafety Assessment (LISA) Factors
    - Lifesafety Assessment of Accommodations (LISAA)
    - Lifesafety Factors for Platform (LISAP)
- Risk Reduction Assessment (RIRA) Factors
    - Active Fire Protection & Life Protection Systems
    - Platform Water Systems
- Safety Management System Assessment (SAMSA) Factors
    - Management Systems Safety Culture Assessment (SCULA)
    - Organizational Responsibility and Resources
    - Company Policies and Procedures (POLPRO)
    - Accountability and Auditing (ACAU)
    - Fire Preparedness Assessment (FIPA)
    - Safety Training Assessment (SATA)
    - Management of Change Management Program (MOCMAP)

Secondary sources for general questions included a Safety Management System audit from a major oil company and a variety of research documents. The University of California, Berkeley, used additional material for defining the Minimal Basic Question set, including two theses, one by Libuser and another by Boniface, as well as a variety of documents written by Bea and Roberts. Additional useful sources of questions for the latter stages of question set development included research reports from Britain entitled Organizational, Management and Human Factors in Quantified Risk Assessment (Bellamy & Geyer, 1992; Harrison, 1992).

After identifying the sources that would be used to develop questions, the SAMS team reviewed all of the material and determined where commonalties and unique questions existed. The pool of questions was then reduced or combined to eliminate redundancies. A categorization framework was created to allow questions to be grouped into meaningful sections. The nine categories for the MBQs are as follows:

- Management and Organizational Concerns
- Hazards Analysis
- Management of Change
- Operating Procedures
- Safe Work Practices
- Training
- Mechanical Integrity
- Emergency Response
- Investigation and Audit.

Each question was placed within the nine assessment categories. Each question is coded according to relevant sources. The questions are organized as shown in Section 3.3.

3.3 MINIMAL BASIC QUESTIONS (MBQs) BY CATEGORY

3.3.1 Management and Organizational Issues

MBQ Topic	Description and Source Reference
1. Safety Policy	A written safety policy exists and is endorsed by management. The policy is widely distributed and employees are generally aware of its contents. (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)
2. Safety Culture	A formalized safety program exists which includes assessments for safe behavior as well as assessments for management's and individuals' knowledge concerning safety. (Krause, Hidley & Hodson; Geller; Harrison; SEMP 1.2.2.h)
3. Management Structure Includes Health and Safety	The company has established a management structure that clearly sets forth responsibilities for safety and ensures that those persons with overall accountability do not have conflicting objectives (e.g. safety versus production). (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.a)
4. Management Responsibilities and Accountability for Safety	Safety responsibilities are defined and measured for individual managers. (Petersen; Harrison; Bird & Germain; SEMP 4.3)
5. Management Monitoring for Health and Safety	The company ensures that periodic audits and reviews occur for safety statistics, measures, and job descriptions and that the results are discussed at management meetings. (Bird & Germain; Petersen; Harrison; CCPS; Krause, Hidley & Hodson; SEMP 1.2.2.g)
6. Resources Exist for Health and Safety	The company designates safety personnel within the organization and provides funding for such positions and for safety studies, audits, and equipment. (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)

3.3.1 Management and Organizational Issues (continued)

MBQ Topic	Description and Source Reference
7. Defined Communications Channels for Safety Concerns	The company has established a formal means for personnel to report safety concerns or potential hazards. (Geller; Harrison: SEMP 1.2.2.b)
8. Safety Manuals and Information	Safety Manuals or handbooks that outline potential hazards and control/mitigation measures exist and are available at work locations. (SEMP 1.1; CCPS; Harrison)
9. Safety Promotions	The company conducts safety promotions, as evidenced by signs or meetings. Staff is aware of safety promotions and program effectiveness is periodically evaluated. (Bird & Germain; Harrison)

3.3.2 Hazards Analysis

MBQ Topic	Description and Source Reference
1. Policy	The company has a general policy statement, either at the corporate or local level, that specifies when a hazards analysis is required and provides guidelines for selecting the study methodology, conducting the analysis, and choosing team members. (SEMP 3.1 & 3.5; API RP14J)
2. Policy or Procedure	The company specifies the objectives of a hazards analysis, including the need to identify the hazards of the process, review past incidents for potential catastrophic consequences, and evaluate the consequences of engineering and administrative controls failures. (SEMP)
3. Schedule	The company has a policy or procedure that defines a rationale, priority order, and schedule for completing hazards analysis for existing facilities (from the most complex system to the simplest, from the systems considered highest-risk to those considered lowest). In addition, a policy or procedure defines time frames for revalidations for hazards analyses. (SEMP 3.3.1, 3.4)
4. Documentation	The hazards analysis policy or procedure specifies the documentation that is required for the study and the way the study will be documented. This policy also states that the hazards analyses and supporting materials will be retained for the life of the facility. (SEMP 3.6)

3.3.2 Hazards Analysis (continued)

MBQ Topic	Description and Source Reference
5. Methodology	The company's current hazards analysis is thorough, and the methodology used was appropriate (for type, age and complexity of facility) or was in compliance with API RP 14J or similar industry standards. (Requires review of a typical hazards analysis.) (SEMP 3.3, 3.4, 3.5, 3.6; PFEER 5; HSEMS 3.4.4, 3.4.1; Company X #2; *Op Team #7)*
6. Layout and Configuration	The hazards analysis includes an evaluation of whether the platform systems were designed and placed within the facility such that the risk of fire and explosion is reduced. (SEMP 2.2, 2.3, 3.2; API RP 14J)
7. Hazard and Risk Reduction	The company has addressed and implemented, where appropriate, the conclusions of the hazards analysis. (HSEMS 3.4.2, 3.4.3, 3.4.6; Company X #2)
8. Process Design/Safety Information	Documentation, such as process flow or piping and instrumentation diagrams, which specifies acceptable set points and upper and lower limits for temperature, pressure, flow, and composition, as appropriate, exists. Mechanical and facilities design information also exists. Set points and limits are available at the corporate and local levels and are current. Evidence exists that the appropriate process safety, mechanical design and facility design information was used during the hazards analysis. (SEMP 2.2 & 2.3; HSEMS 3.3.7.1.D2; PFEER 21; Company X #6)
9. Communication of Hazards Analysis Results	Information concerning hazards identified during a hazards analysis and recommended actions for control of hazards is communicated to appropriate personnel. (SEMP 3.6)

3.3.3 Management of Change

MBQ Topic	Description and Source Reference
1. Policy	The company has a general policy statement, both at the corporate and local level, that specifies what constitutes a modification or change with regard to facilities or personnel and outlines required analysis to be completed before the implementation of a change. Both permanent and temporary change requirements are addressed. This policy also states the requirement for maintaining accurate safety and design information. (SEMP 4.1)
2. Documentation	The policy or procedure specifies the documentation that is required for a particular type of change and that which is required in the change packages. (SEMP 4.1)
3. Change in Facilities	The company ensures that risks are identified, evaluated, and managed when changes in facilities are made. (SEMP 4.2; HSEMS 3.5.4.I1; Company X #5; and FLAIM B5.3, B8.4)
4. Change in People	The company takes into account the possible effects of personnel and organizational changes in terms of risks and manages these effectively (including the use of contractors). (SEMP 4.3; HSEMS 3.5.4.I2; ISM 6.3; Company X #5; FLAIM B5.3, B8.4)
5. Pre-Start-Up and Environmental Review	The company's safety management program requires that the commissioning process include a pre-start-up and environmental review for new and modified facilities. (SEMP 9)

3.3.3 Management of Change (continued)

MBQ Topic	Description and Source Reference
6. Communication and Training	The company ensures that changes are accompanied by training and communications, including updating of relevant procedures or practices, before the commissioning of new or modified facilities. (SEMP 4.4, 5.3, 7.4; HSEMS 3.3.6; ISM 6.7)
7. Authorization of Changes	A policy or procedure specifies the authorization requirements for changes, the people who are qualified to authorize changes, and the requirement that changes cannot occur before authorization. Such material outlines any differences in the authorization process based on whether the change is permanent or temporary. (SEMP 4.4g)
8. Process Safety Information	A policy or procedure requires the review of process safety information before a change is made and outlines the way modifications to process safety information will occur as the result of a change. (SEMP 4.4e)

3.3.4 Operating Procedures

MBQ Topic	Description and Source Reference
1. Content of Operating Procedures	The company has procedures that address the following operations: start-up, normal operations, temporary operations, simultaneous operations, emergency shutdown and isolation, and normal shutdown. (SEMP 5.2; FLAIM B8.1.2)
2. Consequences of Deviations	Operating limits are included in procedures, and consequences of deviations from limits are documented, along with steps required to correct or avoid deviations. (SEMP 5.2c)
3. Temporary Changes	The company has a general policy statement, both at the corporate and local level, that specifies what constitutes a modification or change with regard to temporary procedural changes (or temporary procedures) and outlines required analysis to be completed before the implementation of a change.
4. Periodic Review	The company periodically reviews operating procedures in terms of validity for current and actual operating practice. Reviews should also ensure that the procedures are written according to the level of experience, understanding, and knowledge of the user and that the procedures are easy to read. (SEMP 5.3; HSEMS 3.5.3)
5. Plan Preparation	The company has guidance for preparing plans, procedures and instructions. This guidance identifies the need for assigning qualified personnel to this preparation task. (ISM 7)
6. Follow-Through	The company ensures that operating procedures are understood and followed. (Company X #4; FLAIM B5.2)

3.3.4 Operating Procedures (continued)

MBQ Topic	Description and Source Reference
7. Document Control	The company has a system for controlling policies, procedures, and plans such that: • These documents are available at relevant locations • Changes are reviewed and authorized before distribution (SEMP 5.3.) • Changes are communicated to appropriate personnel (SEMP 5.3) • Obsolete documents are promptly removed (ISM 11; HSEMS 3.3.7.2; FLAIM B8.1.2)

3.3.5 Safe Work Practices

MBQ Topic	Description and Source Reference
1. Safe Conduct of Work Activities	The company's safe work practices apply to all modes of operation, including maintenance and modification activities as well as simultaneous operations, and meet current regulatory requirements. These practices consider and manage hazards and risks during the following activities: • Opening of equipment or piping • Lockout and tagout of electrical and mechanical energy sources • Hot work and other work involving ignition sources • Confined space entry • Crane operations (SEMP 6.2; FLAIM B5.1, B8.1.2)
2. Work Permit or Authorization	A work authorization system is used in conjunction with specific work practices to ensure adequate communications during work activities, and the work authorization system addresses steps to be taken for communications concerning unfinished work at shift change or crew change. (SEMP 6.2)
3. Control of Inventories and Material	Written materials that outline inventories and special precautions to be taken by personnel to avoid environmental damage and personnel exposures to toxic or hazardous materials exist. These materials are available at the local level. (SEMP 5.2d, 6.3)

3.3.5 Safe Work Practices (continued)

MBQ Topic	Description and Source Reference
4. Hazard Communications	The company has a method for providing communication regarding hazards to personnel. Such communication may involve: • Making MSDSs available • Marking containers or equipment containing hazardous materials • Providing signs in areas where hazards may be present • Designating on safe work permits the personal protective equipment that is needed for hazards. (SEMP 6.3)
5. Contractor Selection	The company obtains and evaluates information regarding a contractor's accident record and training program and uses this information in contractor selection. (SEMP 6.4; HSEMS 3.3.5; Company X #8)

3.3.6 Training

MBQ Topic	Description and Source Reference
1. Initial Training	The company ensures that the following initial training takes place as appropriate and is documented: • All personnel receive orientation training per API RP T-1 before being transported offshore for the first time. (SEMP 7.2.1) • All personnel regularly assigned offshore receive training in non-operating emergencies in accordance with API RP T-4, rescue of persons per API RP T-7, and fire fighting per API RP 14G. (SEMP 7.2.1)
2. Operator Training	The company has established a formal training program for operations staff that includes clear definition of required skills and knowledge for each position. The program also requires that operators are assessed for competence and periodically receive refresher training.
3. Operating Instructions	Personnel and contractors receive training in implementing operating instructions pertaining to their job assignments. (SEMP 7.1, 7.5)
4. Hazards Training	All personnel and contractors receive appropriate training in the hazards of the process before undertaking work in the facility. Training concerning simultaneous operations and hazard communications to appropriate personnel is also provided. (SEMP 7.1, 7.5, 8.5)
5. Safe Work Practices	Personnel and contractors receive training in safe work practices pertaining to their job assignments. (SEMP 7.2.1c, 7.5, 8.5)

3.3.6 Training (continued)

MBQ Topic	Description and Source Reference
6. Emergency Response and Evacuation	All personnel, including contractors, receive training in emergency response and evacuation. (SEMP 7.1, 7.5, 10.4)
7. Maintenance and Mechanical Integrity	The company has a mechanism in place to verify that the personnel and contractors who are responsible for maintenance tasks and/or mechanical integrity inspections and testing have received appropriate craft training and, where appropriate, hold required certifications before conducting such tasks. (SEMP 7.2.1, 7.5, 8.5)
8. Topic-Specific Training	Personnel and contractors receive specific training where appropriate in: (SEMP 7.2.2; 7.5; 30 CFR 250 Subpart O; HSEMS 3.3.4.2e, f, g, h; FLAIM B8.3) • Safety and anti-pollution device training. (API RP T-2; 30 CFR 250.214; HSEMS 3.3.4.2g; FLAIM B8.3) • Crane operations and maintenance. (API RP 2D; 30 CFR 250.20; HSEMS 3.3.4.2I; FLAIM B8.3) • Non-operating emergencies. (API RP T-4; FLAIM B8.3) • Well control training. (API RP T-6, RP 59, if hydrogen sulfide, API RP 49, 55, 30 CFR 250.210; HSEMS 3.3.4.2h; FLAIM B8.3) • Hydrogen sulfide training, if applicable. (30 CFR 250.67; HSEMS 3.3.4.2e) • Environmental protection and pollution control. (30 CFR 250.43; guideline UKOOA "Environmental Training Position Paper"; HSEMS 3.3.4.2f, g, h) • Welding and burning. (30 CFR 250.52)
9. Hazardous Materials	Personnel and contractors receive training on handling hazardous materials in accordance with MSDS information. (SEMP 6.3; 7.5)

3.3.6 Training (continued)

MBQ Topic	Description and Source Reference
10. Personal Protective Equipment	Personnel receive training on proper use of personal protective equipment. (SEMP 6.3; 7.5)
11. Procedures	The company ensures that personnel and contractors receive training on procedures and changes in procedures, as appropriate. (SEMP 7.4, 7.5; HSEMS 3.3.6; ISM 6.7)
12. Training Documentation and Refresher Training	All training is documented, and appropriate refresher training is scheduled and conducted. (SEMP 7.3, 7.5)
13. Management Training	The company ensures that the senior person in charge at the facility has been formally trained on safe work practices and emergency and contingency plans for hazard prevention and response. (ISM 5, 6.1, 6.2, 6.4, 6.5, 6.6)
14. General Training and Selection	The company has established a formal training and selection program for all categories of personnel. The program clearly defines requirements for positions and the need for assessment for competence.

3.3.7 Mechanical Integrity

MBQ Topic	Description and Source Reference
1. Quality Assurance Strategy	The company has a program that assures that critical equipment is procured, fabricated, and installed in accordance with appropriate quality standards and specifications. (SEMP 8; ISM 10; PFEER 19; HSEMS 3.5.2; Company X #3)
2. Policy	The company has a policy that requires that a list of critical equipment be established and states that reviews will be conducted to assess ongoing mechanical reliability, remaining life and suitability of critical equipment and facilities, depending on service. This policy also states that methods, intervals, criteria and limits be established for testing and inspection. (SEMP 8.5, 8.6)
3. Mechanical Reliability - Containment	The company regularly assesses, tests, and inspects equipment containing hydrocarbons and other hazardous material to assure integrity. These efforts include testing material compatibility and reviewing wall thickness for service conditions, including erosion and corrosion. (SEMP 8.5; API 510; ISM 10.3, 10.4; PFEER 19.4; FLAIM B2.5, B3)
4. Mechanical Reliability - Rotating Equipment	The company has a preventative and/or predictive maintenance program for rotating equipment in critical service. (SEMP 8.5)
5. Mechanical Reliability - Pressure Relief	The company regularly assesses, tests, and inspects equipment related to pressure relief to ensure that relief can occur when necessary. (SEMP 8.5)

3.3.7 Mechanical Integrity (continued)

MBQ Topic	Description and Source Reference
6. Mechanical Reliability - Shutdown Systems, both Emergency and Process	The company regularly assesses, tests, and inspects shutdown systems to ensure reliability. (SEMP 8.5)
7. Mechanical Reliability - Emergency Response Systems	The company regularly assesses, tests, and inspects fire fighting, spill control and other equipment used for emergency response. (SEMP 8.5)
8. Mechanical Reliability - Evacuation Systems	The company regularly assesses, tests, and inspects mechanical components and equipment associated with evacuation systems. (SEMP 8.5)
9. Spare Parts	The company has identified critical spare parts and included these on an inventory and ensures that they are available within acceptable time limits. *(Organization #8)*
10. Documentation	Documentation concerning assessment methods, assessment procedures, acceptance criteria, and the results of tests and inspections is kept. Information concerning replacement of equipment, instruments, and components is documented. Such documentation is retained for a minimum of two years. (SEMP 8.6)

3.3.7 Mechanical Integrity (continued)

MBQ Topic	Description and Source Reference
11. Deficiencies	Equipment deficiencies that are judged to be outside limits (as defined in the process safety information) are corrected before further use or are corrected in a safe and timely manner after necessary steps to assure safe operations have been taken. (SEMP 8.6)
12. Review and Authorization of Changes	A system for reviewing and authorizing changes in procedures, tests and inspection exists and is aimed at managing hazards and risks. (SEMP 8.5)

3.3.8 Emergency Response

MBQ Topic	Description and Source Reference
1. Emergency Response and Evacuation Plans	The company has emergency response and contingency plans in place for loss of containment, including releases, fires and explosions, and spills. Such plans or policies outline the company's philosophy and the components of appropriate responses (e.g., for fire: whether to stand and fight, evacuate, etc.). (SEMP 10.1; ISM 1.4.5; PFEER 6,12; *Organization #4*; FLAIM B8.2)
2. Emergency and Contingency Response Equipment	The emergency response and contingency plans identify emergency equipment that should be available for use during response.
3. Emergency Management Authority and Compliance with Regulations	The emergency or contingency plans assign authority to appropriate qualified person(s) and address emergency reporting and response, complying with the most current revision of one or more of the following regulations (as applicable): • Emergency evacuation plans. (USCG-33; CFR 146.140) • Oil, gas and sulfur operations in the OCS. (MMS-30; CFR parts 250, 256) • Pipeline emergency plans. (USDOT-49; CFR 192, 195; SEMP 10.2; ISM 8; FLAIM B6.2, B8.3)
4. Emergency Control Center	An Emergency Control Center has been designated for each facility and includes the following: • Emergency Action Plan • Oil Spill Contingency Plan • Safety and Environmental Information (SEMP 10.3)

3.3.8 Emergency Response (continued)

MBQ Topic	Description and Source Reference
5. Revision Process for Plans	The actual persons who will respond to loss-of-containment situations (including releases, fires, explosions, spills and other contingencies) are included in the review of plans for such events, and a mechanism exists for these personnel to provide comments regarding such plans to management. (PFEER 8)
6. Drills	The company has drills that are effective in regard to testing plans and correcting weaknesses. (SEMP 10.4; PFEER 8)
7. Communications	Emergency warnings for fires and explosions in the facility are audible and, where appropriate, visual. (PFEER 11) (PFEER 11.2 - types of visual and acoustic warning signals)
8. Emergency Equipment and Systems	The company has evaluated fire and life protection systems and has provided adequate protection. (FLAIM B7)

3.3.9 Investigation and Audit

MBQ Topic	Description and Source Reference
1. Investigation Policy	The company has procedures in place to promptly investigate, document, and report all accidents and incidents with qualified personnel to help prevent similar occurrences. (SEMP 11.1; ISM 1.4.3, ISM 1.4.4, ISM 9; HSEMS 3.6.5; Company X #9; HSEMS 3.6.4)
2. Investigation	Company investigations address the following: • The nature of the accident or incident • The factors that contributed to the accident or incident and the mitigation actions that should be taken to prevent or minimize the effects of a recurrence. • Recommended actions identified as a result of the investigation (SEMP 11.2)
3. Investigation Follow-Up	The company distributes findings of an accident or incident investigation to appropriate personnel and similar facilities. The company has procedures in place to ensure that corrective actions are completed. (SEMP 11.3; HSEMS 3.6.6)
4. Investigation Record Retention	The company ensures that accident and incident investigation documentation is retained for a minimum of two years. (SEMP 11.3)
5. Auditing System	The company has a system in place to ensure that periodic audits of the safety and environmental management system are conducted. Such an audit includes review of hazards analysis, management of change, mechanical integrity, operating procedures, training, safe work practices, emergency response, and investigation systems. (SEMP 12.1)

3.3.9 Investigation and Audit (continued)

MBQ Topic	Description and Source Reference
6. Auditing Personnel	Audits are conducted by personnel who are independent of the areas being audited. (SEMP 12.1; ISM 1.4.6, ISM 12; HSEMS 3.6.2, 3.7.1; FLAIM B8.1.1, B8.1.3 [Safety Assurance Program])
7. Audit Reporting	The company has procedures in place to ensure that audit findings are provided to appropriate personnel and that actions are taken to resolve inadequacies. Audit reports are retained until the completion of the next audit. (SEMP 12.2; HSEMS 3.6.3)
8. Schedule	An initial audit should be conducted within two years of the initial implementation of the process safety management program, and the interval between audits should not exceed four years. (SEMP 12.1)
9. Reviewing	The company's senior management, at appropriate levels, should review audit results to ensure that findings and resolutions are satisfactory in terms of managing hazards and risks. Similar reviews should occur for company policies. (SEMP 12.2; HSEMS 3.7.2)

3.4 SCORING

A mechanism was needed to allow assessors to make objective decisions about a facility's compliance or lack of compliance with the MBQs. Providing such a mechanism would also promote consistency between assessors and from one audit to another. The result would provide a common baseline for assessment. It was also important that a means be developed by which a score could be computed for a question and for a category of questions. The scoring mechanism would take qualitative judgments, convert them to a "point" or score, and then allow quantitative computations to be made for a category of questions. The "points" would provide means for comparing levels of compliance from one question to another.

FLAIM had also included objective criteria assigned point values that assessors scored. FLAIM used a scoring system based on the concept of academic grades. The result was a scale with five indices which could be converted to numerical values. Depending on the question an assessor was answering, the descriptors (as known as scale anchor points) would change. Table 3.4.1 includes examples of Gale's FLAIM letter grade scheme (Gale, Bea & Williamson, 1994).

Table 3.4.1: FLAIM Letter Grade Scheme

Grade	Value	Examples of Descriptors for Grade		
A	4.0	Excellent	All	< 120 feet
B	3.0	Good	Most	< 90 feet
C	2.0	Fair	Some	> 60 feet
D	1.0		Few	> 30 feet
F	0.0	Poor	None	< 30 feet

For the MBQs, it was recognized that a similar scoring system would be useful. However, based on input from Dr. Karlene Roberts of the University of California, Berkeley, it was decided that seven indices or anchor points would be used. Dr. Roberts has found that people are reluctant to use the extremes of scales during rating exercises and also that better variance can be obtained when seven-point rather than five-point scales are used (Roberts, 1996). This approach was a departure from the scoring systems used in FLAIM for individual questions.

To create the common baseline for scoring of questions, operational definitions were developed for each anchor point on the MBQ set assessment scale. Table 3.4.2, SAMS MBQ Set Assessment Scale Anchor Points, contains a description of the assessment scale anchor points and the corresponding point value. With the scale defined and the anchor points described, a means was provided that would allow assessors to score individual questions from the MBQ set.

Table 3.4.2: SAMS Minimal Basic Question Set
Assessment Scale Anchor Points

Score (Level of Compliance)	Anchor Point Description
7 (Complete compliance and additional risk or safety studies)	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization. • In addition, the company has taken further measures in this area such as conducting studies or training sessions. • Studies may involve risk assessment, human factors analyses, or integrated risk, safety, environment, quality and loss control programs.
6	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization.
5	• The company addresses this concern in writing and in practice, and implementation is occurring fully at most levels of the organization although minor deficiencies were noted during the assessment process.
4	• The company addresses this concern in writing, but evidence of practice at all levels of the organization is incomplete. • Still, implementation is under way and at an advanced stage.
3	• The company addresses this concern in writing, but evidence of practice at all levels of the organization does not exist. • Implementation is under way and at the initial stages.
2	• Some written guidance exists. • Steps are being taken to meet this criterion in practice. • A schedule for finalizing written guidance and for beginning implementation exists.
1 (Little or no compliance)	• Little or no written guidance exists. • Practice is inconsistent, and no implementation is occurring.

It is anticipated that each item in the MBQ set would be investigated and eventually be assigned a score based on the terms defined in the SAMS MBQ set Assessment Scale. The result of the score assignment and assessment process would be an indication of an organization's strengths, weaknesses, and deficiencies and guidance regarding the issues that assessors may wish to investigate further.

As mentioned previously, once all questions received a score, an assessor could compute an average score for all questions in a category. This average could then be used to compare levels of compliance to questions from one assessment category to another.

4.0 FACTORS OF ORGANIZATIONS AND OPERATING TEAMS (FOOT)

4.1 INTRODUCTION

The purpose of the FOOT assessment method is to identify and then evaluate human and organizational factors at a facility, within the context of an Area of Concern (AOC). An AOC is defined as a physical location where hydrocarbon loss of containment may occur, thus leading to a fire or explosion.

The FOOT method is intended for use after a physical assessment has identified possible loss of containment (LOC) areas. The original FLAIM (Fire and Life safety Assessment and Indexing Method) program, developed at the University of California, Berkeley, and applied to a hypothetical offshore oil production platform, is one method that could provide this physical assessment. However, validation by the offshore oil industry is required to assess FLAIM's utility. Potential LOC areas can also be identified through Probabilistic Risk Analysis (PRA), Hazards and Operability (HAZOP) studies, Failure Modes and Effects Analysis (FMEA), and a number of other risk assessment methods.

The FOOT method's basic assumptions are:

1. Risk is the product of Likelihood and Consequence,
2. There are limited resources to correct deficiencies,
3. Operators can best evaluate the facility, operators, and organization,
4. With training, operators can identify and evaluate HOF,
5. Fires and explosions may occur when hydrocarbon containment is lost, and
6. Human and Organization Factors permeate a system.

Based on these assumptions, the specific number of AOC are irrelevant because if HOF are deficient they will repeatedly surface when evaluating AOC.

Several risk assessment methods were reviewed and evaluated (see Section 2). Deficiencies, as they relate to human and organization factors, were identified. Two major deficiencies are that HOF are not explicitly addressed and uncertainty is not captured.

FOOT is designed to fill a unique niche in assessing systems for safety. It focuses specifically on screening systems for human and organization factors. It was designed to take a short period of time (4 days) and to use a team of system operators as assessors. A computer program is needed to carry out calculations, thus allowing the assessors to concentrate on making evaluations for likelihood and consequences. FOOT uses the concept of relative risk to capture uncertainty in both the assessor and the human and organization factors.

4.1.1 Relative Risk

Relative Risk is a comparison of accident scenarios based on their individual likelihood and consequence. Comparing risk is useful when statistical data and their derivative probabilities are unavailable, which is the case for human and organizational factors.

Using relative risk also allows for focusing attention and limited resources on those items with the highest risk. Relative risk is used in Nuclear Medicine for identifying steps with the highest relative risk, and then focusing attention on reducing the risks associated with those steps (LLNL, 1995).

4.1.2 Health Risk Appraisal (HRA)

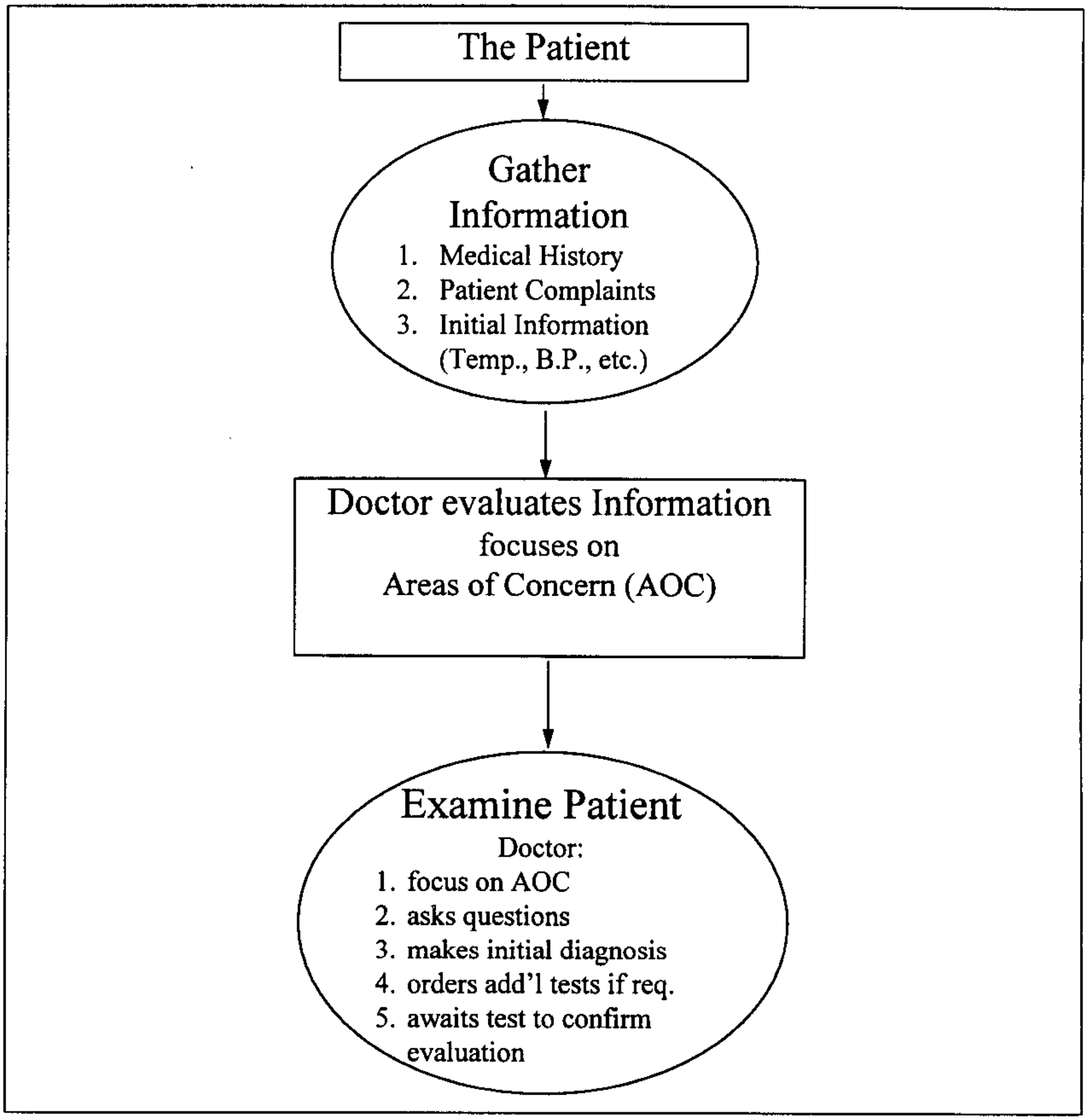
Another method which can be related to the assessment of HOF is the medical field's Health Risk Appraisal (HRA) method. The HRA method is composed of four steps (Figure 4.1.2.1). The first step is identifying the patient to be examined. The second step is evaluating the body using information provided by the patient. Information is gathered through an extensive medical history questionnaire, a listing of complaints, and by a preliminary examination conducted by a trained nurse to obtain the patient's temperature, blood pressure, and other vital signs. Before the doctor ever examines the patient, a third step is conducted by evaluating all the information and identifying specific areas of interest. The fourth step occurs when the doctor evaluates the patient in the examination room.

During the actual examination, the doctor first makes a general examination of the patient. The doctor asks their medical history and complaints, and then focuses on the areas identified during step three. Following the initial diagnosis the doctor also orders additional tests to confirm this diagnosis. The doctor may prescribe some medicine for the ailment while awaiting the test results to confirm the diagnosis.

In this example, the doctor and the patient must interact to obtain the correct diagnosis and treatment. The doctor has the medical knowledge to make a diagnosis based on the information provided; however, the patient must know his body and be able to articulate what pains him. Incomplete or incorrect information can lead to a misdiagnosis. It is important to note that the doctor works with a range of values instead of an exact number when evaluating a patient. The doctor also looks for trends in values to determine if a condition is improving or deteriorating (MDPH, 1985).

The following section presents the FOOT method.

Figure 4.1.2.1: Annual Physical Examination Methodology



4.2 THE FOOT METHOD

The FOOT method is based on HRA and is similar to how medical doctors conduct an annual physical examination (Figure 4.2.1). FOOT has the following four general steps:

1. Identify a physical system,
2. Gather and evaluate information on the system's Safety and Environmental Management Program,
3. Identify physical AOC, then select a handful of AOC to create scenarios, and
4. Evaluate each of these selected AOC for Human and Organization Factors.

This methodology first obtains an overview of the physical system by using the results of other physical assessment methods. An overview of the system's Safety and Environmental Management Program is gained by answering the Minimal Basic Questions. These answers are obtained by reviewing manuals, documentation, and conducting interviews. Through this process, assessors identify physical AOC and then select a handful of AOC and incorporate into scenarios, thus providing context. These AOC will then have Human and Organization Factors applied to them through a set of likelihood and consequence questions. Again, based on the assumptions, the specific number of AOC are irrelevant because the deficient HOF should surface repeatedly in any of the AOC evaluated.

4.2.1 FOOT Method Phases

There are four phases to the FOOT evaluation process. These phases are:

1. Training Assessors
2. Onshore evaluation of documentation
3. Facility Visit
4. Onshore evaluation of data

The following paragraphs further define these phases.

In the first phase, assessors are selected and trained. The selection criteria and training plan were previously promulgated in the joint industry project report dated May 1996. One of the topics during training is to help the assessors assign estimates of the most likely value for a likelihood, along with a "not greater than" value and a "not less than" value. This range of values captures the uncertainty of both the assessor and the HOF being assessed. Once the assessors have been trained, the next phase is identifying AOC.

The second phase, identifying AOC, is discussed in Section 4.3.1.

The third phase is the evaluation of each AOC. The assessors at this point will have approximately five AOC and the consequence evaluation for each. The assessors will then take the eight Operating Team Factors and systematically go through this list for each AOC. Using an anchor scale, the assessors will assign a "most likely value", along with values for "not greater than" and "not less than." This will produce a range of likelihood values for each Operating Team Factor that applies to each AOC. The assessors will also do the same for the eight Organization Factors, producing another list of likelihood evaluations for each AOC. Additionally, the assessors will make comments relating to the values to capture the basis for their evaluation. The assignment of these values may take place during the review of documentation, the system visit, or the post-visit conference.

The fourth phase is the calculation of relative risk, which is addressed in Section 4.5. The best tool for making these calculations is a computer. The calculations use the selected values ("not less than," "most likely," and "not greater than") to draw triangular distributions for the AOC consequence and each Operating Team and Organization Factor likelihood. These two distributions, consequence and likelihood, are combined using the Algebra of Normal Functions to determine a relative risk distribution for each factor of the AOC. The mean values of the resultant relative risk distribution for each of the factors will be graphed on a bar graph. The factors with the highest relative risk bars will stand out above the other factors. These factors are the ones that will require mitigation efforts, similar to the relative risk method discussed previously in Section 4.1.1. Additionally, the assessors' comments will be noted along with the relative risk distributions to assist in determining mitigation efforts.

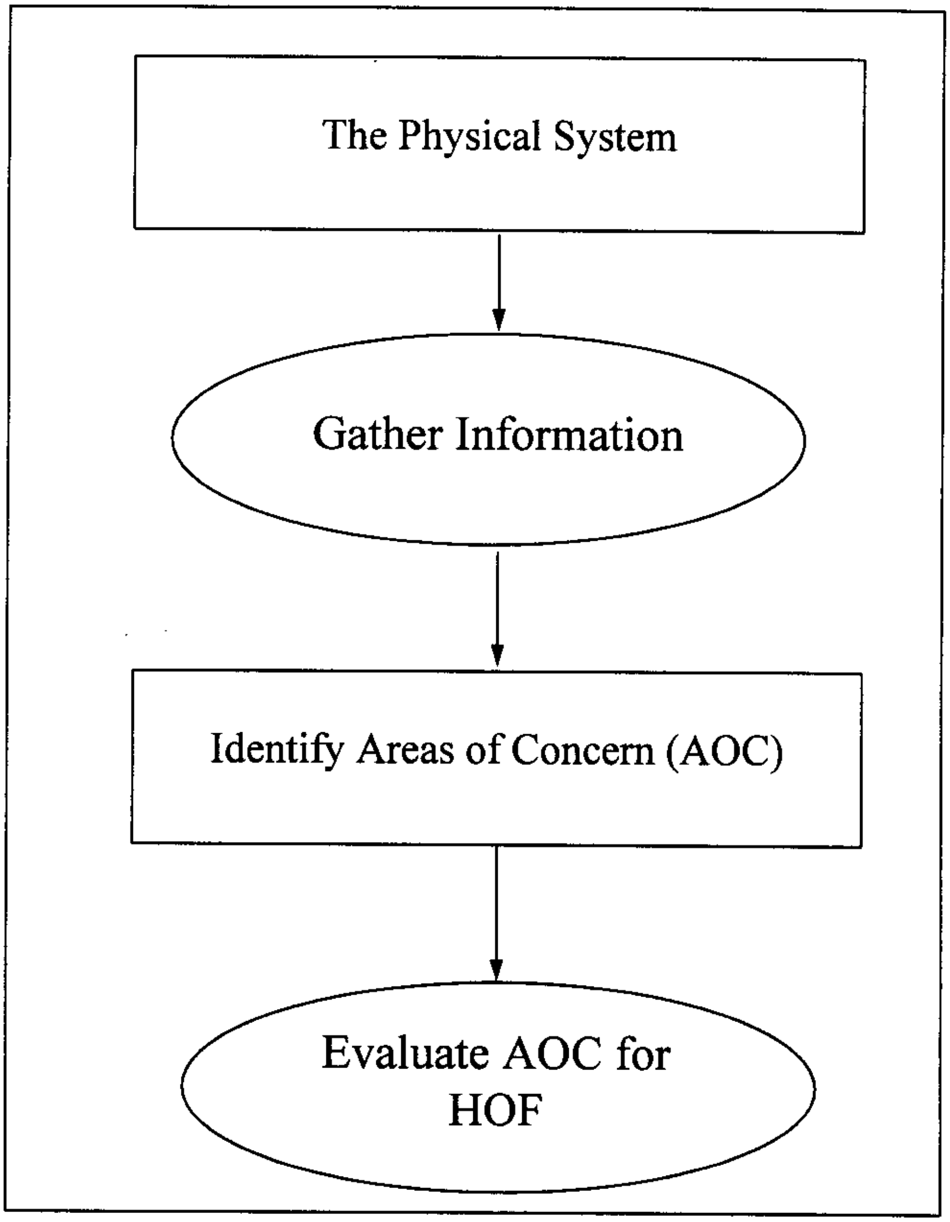
As a review, the following are the steps for evaluating likelihood by using HOF:

- Phase 1 Preparation
  - Train assessors on HOF and how to evaluate them
  - Train assessors to make an estimate of likelihood
- Phase 2 Identifying AOC
  - See section 4.3.1
- Phase 3 Evaluating AOC
  - AOC consequences are evaluated
  - Assessors evaluate Operating Team Factors for AOC

- Use seven-point anchored scale
- Select a range of answers for each HOF
- (most likely, not less than, and not greater than)
- Comments to capture reasoning for value assignment
- Assessors evaluate Organization Factors for AOC
- Use seven-point anchored scale
- Select a range of answers for each HOF
- (most likely value, not less than, and not greater than)
- Comments to capture reasoning for value assignment

- Phase 4 Calculate relative risk
  - Calculate relative risk distribution for each factor of an AOC
  - Presents a bar graph showing mode value for relative risk distribution
  - Displays assessor's comments with relative risk distributions.

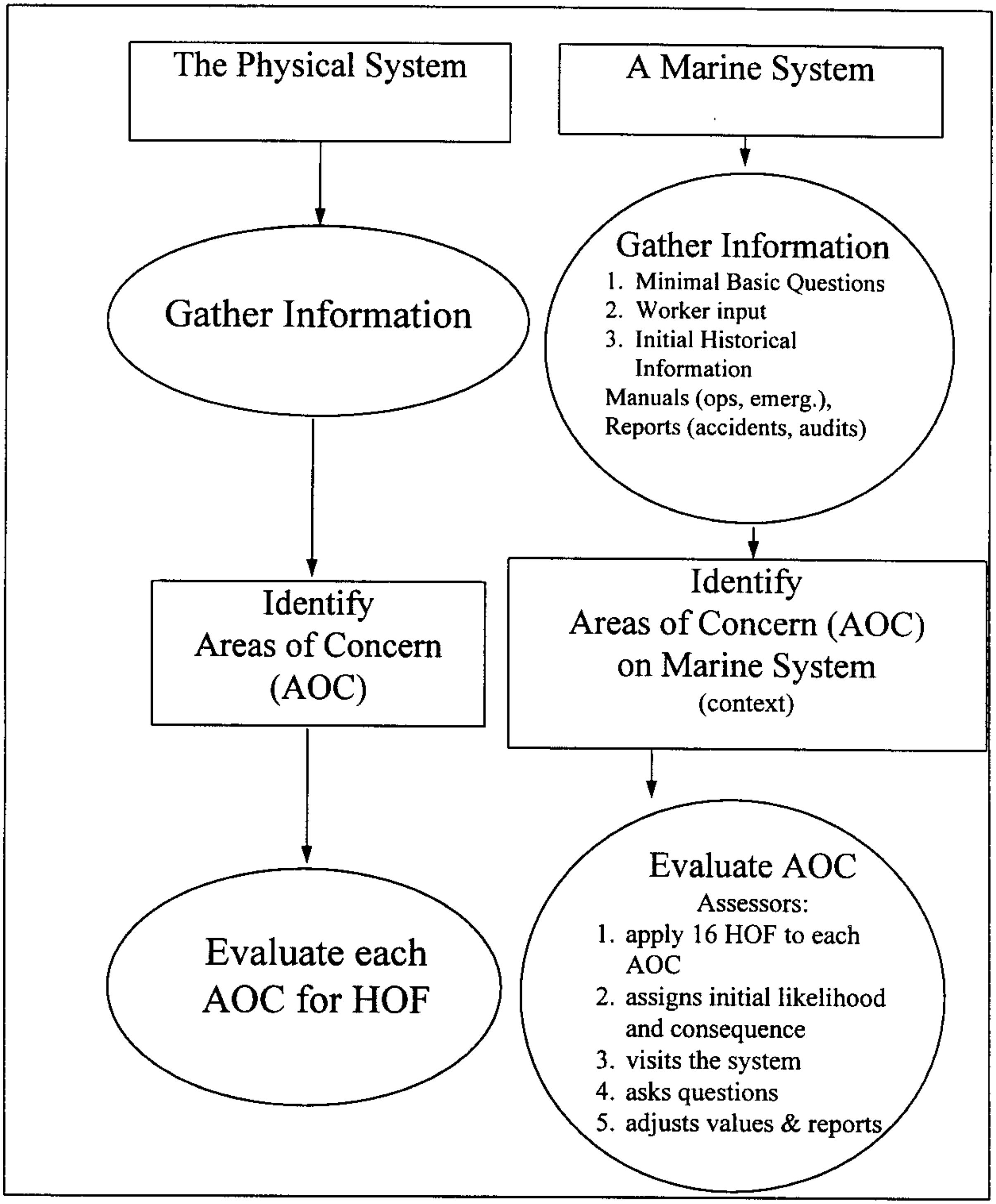
Figure 4.2.1.1: FOOT Diagram



4.2.2 Applying FOOT to a Marine System

FOOT for a marine system is also a four-step process (Figure 4.2.2.1). The first step is identifying a marine system. The second step is evaluating the system's Safety and Environmental Management Program by responding to a set of Minimal Basic Questions using historical information and worker input. Step two provides information for step three, which identifies a handful of physical AOC on the marine system. Once these five AOC are identified, step four applies Human and Organization Factors to each of the areas of concern. In FOOT's terminology, the Human Factors are identified as Operating Team Factors.

Figure 4.2.2 FOOT Applied to a Marine System



4.3 AREAS OF CONCERN (AOC)

Areas of Concern (AOC) are defined as physical locations at which hydrocarbons can be released. This section covers how AOC are identified and then evaluated.

4.3.1 Identifying Areas Of Concern

Since the purpose of FOOT is to efficiently assess human and organization factors, a review of the following documents will help provide some initial information. AOC can be identified by first tracing the flow of hydrocarbons through a facility using the following documents.

- Hydrocarbon flow diagrams
- Locations along flow where humans interact with hydrocarbons (pumps, valves, joints, etc.)

This step assists the assessor in determining the physical flow of the hydrocarbon and the physical layout of the facility. Since the SAMS project is focused on the loss of containment which can lead to fire and explosion, this step helps the assessor identify all hardware through which hydrocarbons flow and helps the assessor prioritize those areas that receive the most human interaction. For example: a pump on an operating system will receive more human interaction than a section of pipe with no openings.

This review of the hydrocarbon flow will also orient the assessor to the quantities of hydrocarbon flowing through the system. Those physical areas on the system with the most hydrocarbon flow and the most human interaction are considered as first-priority AOC. The second priority assignment goes to the areas with medium-to-low hydrocarbon flow and high human interaction. The third priority goes to medium-to-low hydrocarbon flow and medium human interaction, and the lowest priority for assignment goes to areas without any human interaction. The goal of the assessors is to identify approximately five of the highest-priority AOC, not all possible AOC.

Another set of documents that has related information is procedures. Operating procedure manuals can provide the following information:

- Hydrocarbon flow rate - maximum capacity
- Pipeline sizes
- Pump capacities
- Hydrocarbon storage when system is shut down

This information is important because, should a loss of containment occur, the quantity of hydrocarbons available for release is a key factor to the amount of pollution and the magnitude of a fire or explosion.

The next step is reviewing various conducted Hazards studies and Safety Reviews. These studies may have already identified areas where the possibility of hydrocarbons loss exists. The following is a sample list of some of these studies:

- Hazards analysis
- Hazards and operability (HAZOP)
- Failure Modes Effects and Analysis (FMEA)
- Event Tree
- Fault Tree
- What If Analysis

- Checklist Analysis

These studies are reviewed to identify hazardous areas and recommended actions for hazard reduction. Assessors will note and randomly check to see if actions were completed. Additionally, the following documentation should also be reviewed:

- Safety discrepancies reported but not corrected
- Discrepancies from internal and regulatory inspections
- Procedures:
  - Operating
  - Emergency response
  - Watch turnover
  - Safe work practices

The above documentation will assist in answering the Minimal Basic Questions, which are discussed in Section 3 of this report. When completed, this step will result in an assessment of the system's Safety Management System.

Once a handful of AOC are identified, the assessors are briefed by at least two of the company's representatives, one from the corporate office, and the other from the system operating team. Additional AOC may arise out of these briefings based on comments or concerns of the briefer, and the assessors may add these to the initial list.

Another means of identifying additional AOC is through the system visit. During the visit, a walkdown of the system is first conducted. Following the walkdown, the following events or tasks are observed:

- Emergency drills
- Maintenance procedures
- Watch/shift turnovers

Should the assessors observe an AOC, it may be added to the list. Now that the different ways of identifying AOC have been discussed, the next step is evaluating them.

4.3.2 Evaluating Areas Of Concern

After AOC are identified, they are then evaluated. The initial evaluation occurs by any of the three following means.

Documentation Technical experts have evaluated and documented various items associated with the system. For example: California State Lands Commission - Marine Facilities Division has conducted a level one structural survey of all marine terminals in California. Additionally, the Commission conducts regular inspections of equipment, operating procedures, and emergency response plans.

Interviews Expert knowledge is resident in workers who operate the system daily. These operators know the system intimately, and after being given training, should be able to evaluate their systems for technical and non-technical safety-related items.

Observations Outside experts, operators of similar systems, may be able to identify and evaluate AOC that over the years have become accepted as "normal."

Each AOC must be evaluated for two items: Consequence and Likelihood. The following is a description of how each of these evaluations will be conducted.

1. Consequence evaluation - Consequence is calculated specifically for each AOC. The consequence is the hydrocarbon flow rate or the hydrocarbon storage capacity in and adjacent to the AOC. If the quantity is small (small is defined for this report as being the amount of hydrocarbons that can be cleaned up with on-hand assets), the assessor may set aside this AOC and evaluate another. The assessor is given the flexibility to assign a range of values to capture the consequence uncertainty.

2. Likelihood evaluation - The absence of failure rate data makes it very difficult to establish or assign likelihood. Adapting the previously discussed Health Risk Appraisal method to the marine industry will assist in determining likelihood, specifically, by evaluating the system against a list of characteristics of highly-reliable humans and organizations. These high reliability humans and organizations have few or no accidents, thus making a link between likelihood and HOF. The first step to evaluating likelihood is to establish a list of these characteristics (Tables 4.4.1.1 and 4.4.2.1 found in Section 4.4).

To outline, the following are the steps for evaluating likelihood:

- Evaluating AOC

1. AOC consequences are evaluated
2. Assessors evaluate each Operating Team Factors for AOC assessing the state of that operating team factor as practiced at the facility and specifically how detected shortcomings will contribute to a failure at this AOC:
   - Use seven-point anchored scale
   - Select a range of answers for each HOF
   - (most likely, not less than, and not greater than)
   - Comments to capture reasoning for value assignment
3. Assessors evaluate Organization Factors for AOC assessing the state of that organization factor as practiced at the facility and specifically how detected shortcomings will contribute to a failure at this AOC:
   - Use seven-point anchored scale
   - Select a range of answers for each HOF
   - (most likely value, not less than, and not greater than)
   - Comments to capture reasoning for value assignment

4.4 ORGANIZATION AND OPERATING TEAM FACTORS

A literature review was conducted and is documented in Appendix C. The following are the four basic source areas:

1. Regulations/ Guidelines
2. Textbooks
3. Assessment methods
4. Research

The selection criteria focuses specifically on the organization and humans of the system. The following criteria were used to eliminate those factors that are addressed elsewhere.

1. Factors dealing with human and machine interface were excluded since they are addressed during ergonomic studies.
2. Factors involving structural integrity are addressed by annual inspection requirements.
3. Factors involving equipment/mechanical integrity are addressed by monitoring and inspections.
4. Factors involving procedures are addressed by regulatory procedural reviews.
5. Environmental issues are reviewed by regulatory agencies.

The above factor selection criteria were used to create the following two tables. These tables identify and define high reliability Operating Team and Organization Factors.

4.4.1 Operating Team Factors

Table 4.4.1.1 lists the high reliability Operating Team Factors.

Table 4.4.1.1: Operating Team Factors

Factor	Definition
Communications	The ability of the person to clearly and accurate transmit and receive information to others.
Selection and Training	The selection process by which the personality and individual characteristics are taken into account. The training of those individuals.
Education	The ability of the person to learn and understand information. The ability to counter ignorance.
Limitations and Impairment	Actual physical limitations and impairments due to a person's physical and emotional make-up.
Organizational (Planning & Preparation, Changes)	The ability of the individual to plan, prepare, organize and adjust to changes.
Training	The quantity of quality of training which the person receives.
Experience (Mistakes, Slips, Violations)	The amount of work experience a person has to avoid mistakes, slips, and violations.
External Environment	The harshness of the environment (external, internal and social) in which the person is working.

4.4.2 Organization Factors

Table 4.4.2.1 on the following page lists the high reliability organizational factors.

Table 4.4.2.1: Organization Factors

Process Auditing	The action of monitoring processes and when necessary, taking actions to correct deviations which lie outside the established norms.
Culture	The cognitive framework consisting of attitudes, values, behavioral norms, and expectations shared by organization members. In High Reliability Organizations, this includes a high state of quality and an appropriate reward system. **Mission/Vision:** The "Big Picture" goal of the organization is accepted and wholeheartedly believed by all personnel.
Appropriate Risk Perception	The organization's acknowledgment that risks are both known and unknown.
Emergency Preparedness	The organization's plans to minimize risks, and plans to minimize the severity of an incident by preparing plans to mitigate an incident. This also includes the drills and exercising of emergency plans.
Command and Control Functions	The organization's structure for making decisions. This includes migrating decision making, redundancy, rules, seeing the "big picture", requisite variety, and alert systems.
Training	The organization places significant emphasis on training. This is indicated by the amount of money and time invested in training and how the people of the organization feel about the relevance of the training.
Communications	The ability of the organization to clearly and accurate transmit and receive information within the organization.
Resources	The ability of personnel on the front-line to receive resources quickly and in adequate supply.
Equipment and System Maintenance	The organization places significant emphasis on the procurement, installation, construction and maintenance of equipment and systems. Quality equipment is installed and properly maintained. "Gerry-rigging" is not allowed, and repair parts are quickly delivered.
Procedures	This topic covers all of the paperwork which is required by regulatory agencies and any organizational internal audits. Procedures are in place for safe work practices and regulation compliance. Procedures are involved in the documentation of work completed, certification of personnel, and the reporting of accidents

4.4.3 Scoring/Evaluation

Human and Organization Factors are very difficult to evaluate. As previously outlined in Section 2.0, single probability of failure values for specific human tasks lacks statistical support. Without statistical data, probabilities of failure are based on "expert judgment". Expert judgment adds uncertainty to the values. Additionally, humans and organizations can never be given a single probability of failure number with confidence.

To address and capture uncertainty, a scoring system which allows the evaluator to select a range of values was created. For the FOOT method, a seven-point scale was decided upon, where "1" is the best and "7" is the worst. Anchor points are attached to each of the seven points. The method for evaluating a factor is as follows: The evaluator selects a value which is his best estimate. He or she then selects a second value which is the highest possible value and then selects a third value which is the lowest possible value. By doing this, the evaluator captures his uncertainty. The narrower the range of values, the more certain the assessor is of the evaluation; conversely, the wider the range of values, the more uncertain the evaluation. This scoring system is applied to each of the Organization and Operating Team Factors to determine likelihood. It is also applied to the AOC using the system's hydrocarbon storage and flow characteristics to determine consequence. For example, a value of one would indicate that no hydrocarbons are released, while a seven would indicate that the maximum amount for that facility would be released. The gradations between these two extremes is determined by the assessors.

A relative risk is then calculated for each of the factors using the procedure described in Section 4.5. Thus, for each AOC there are eight operating team relative risks and eight organization factor relative risks. Those which rank highest, are targets for improvement.

4.5 CALCULATION OF RELATIVE RISK

Relative risk is an important part of the FOOT method. This section is a discussion on how the relative risk value is calculated. Risk is defined as the product of consequence and likelihood. The AOC represents consequence and the Organization and Operating Team Factors represents likelihood. The next task is multiplying the consequence with the likelihood. The evaluators have selected a range of values for each AOC and for each Organization and Operating Team Factor as they relate to that AOC. The AOC provides the context in which the Organization and Operating Teams are evaluated. These three values are the three points of a triangle, whose area is equal to one.

Figure 4.5.1 Large Uncertainty

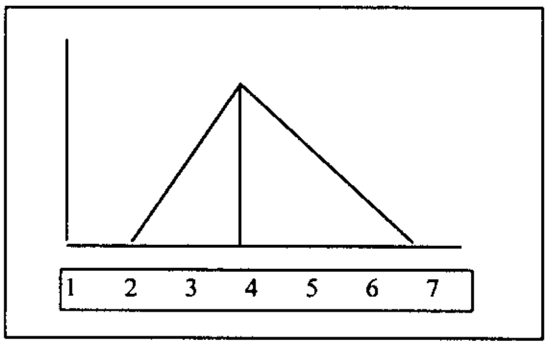
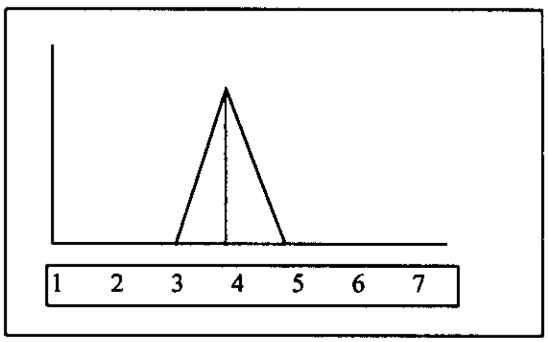


Figure 4.5.2: Small Uncertainty



Using the following equations, the mean and the standard deviation of the triangle are calculated.

4.5.1 Mean and Standard Deviation

The following are equations for determining the mean and standard deviation parameters for triangular distributions.

Step 1.

To determine the mean value of Relative Risk, multiply together the mean values for likelihood and consequence. The mean for a triangular distribution is defined as:

1. Mean

$$\mu = \int_{-\infty}^{\infty} x f(x) dx = \frac{2}{c-a}\left[\int_a^b \frac{x(x-a)}{b-a} dx + \int_b^c \frac{x(x-c)}{b-c} dx\right]$$

$$\mu = \frac{1}{3}(a+b+c)$$

Where:

a = minimum value
b = most likely value
c = maximum value

Step 2.

To determine the standard deviation of the Relative Risk distribution, first determine the standard deviation of both the likelihood and consequence distributions.

2. Variance

$$\sigma^2 = \int_{-\infty}^{\infty}(x-\mu)^2 f(x)dx = \int_{-\infty}^{\infty}x^2 f(x)dx - 2\mu\int_{-\infty}^{\infty}xf(x)dx + \mu^2\int_{-\infty}^{\infty}f(x)dx$$

$$\sigma^2 = \int_{-\infty}^{\infty}x^2 f(x)dx - \mu^2$$

$$\sigma^2 = \frac{2}{c-a}\left[\int_a^b \frac{x^2(x-a)}{b-a}dx + \int_b^c \frac{x^2(x-c)}{b-c}dx\right] - \left(\frac{a+b+c}{3}\right)^2$$

$$\sigma^2 = \frac{1}{18}\left[a^2+b^2+c^2-ab-ac-bc\right]$$

Then, applying the Algebra of Normal Functions, determine the Relative Risk standard deviation.

4.5.2 Algebra of Normal Functions

The following are equations for using the Algebra of Normal Functions. These functions are used to combine distributions.

$$Z = XY$$

Where:

X is the likelihood distribution

Y is the consequence distribution

Z is the relative risk distribution

$$\overline{Z} = \overline{XY}$$

Where:

$\overline{X}$ is the Factor's Most Probable Value mean

$\overline{Y}$ is the Most Probable Value of the consequence

$\overline{Z}$ is the Relative Risk mean

$$\sigma^2_{Risk} = \left(\mu^2_L * \sigma^2_C + \mu^2_C * \sigma^2_L + \sigma^2_L * \sigma^2_C\right)$$

Where:

μ^2_L = Mean value of Likelihood

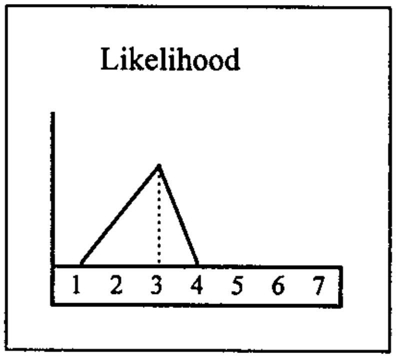
μ^2_C = Mean value of Consequence

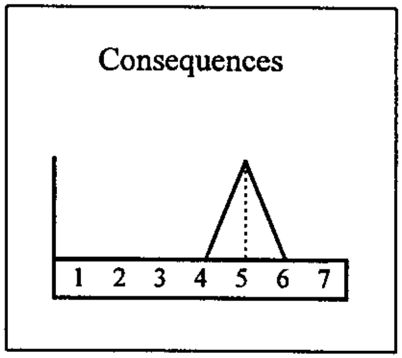
σ_L = Standard Deviation of Likelihood

σ_C = Standard Deviation of Consequence

4.5.3 Calculation example

Given the following two triangular distributions, calculations will be made using the above equations.





Step 1: Determine Relative Risk mean value:

Relative Risk (mean) = Likelihood (mean) X Consequence (mean)

Relative Risk (mean) = [1/3 (1 + 3 + 4)] [1/3 (4 + 5 +6)] = 13.3

Step 2.: Determine the Standard Deviation for Relative Risk

First, determine Standard Deviation for both Likelihood and Consequence triangular distributions using formula in Section 4.5.1.

$$\text{Standard Deviation}^2 = (1/18)(a^2 + b^2 + c^2 - ab - ac - bc)$$

Likelihood

Where:

a = 1

b = 3

c = 4

Standard Deviation = (1/18) (1 + 9 + 16 - 3 - 4 - 12) = 7/18

Standard Deviation (likelihood) = 0.62361

Consequence

Where

a = 4

b = 5

c = 6

Standard Deviation (consequence) = 0.48248

To determine the Standard Deviation of Relative Risk, use the Algebra of Normal Functions, which states that when two distributions, X and Y, are multiplied together, the standard deviation of the resultant distribution, Z, is determined by the following formula:

Z Standard Deviation^2

$$\sigma^2_{Risk} = \left(\mu^2_L * \sigma^2_C + \mu^2_C * \sigma^2_L + \sigma^2_L * \sigma^2_C\right)$$

Where:

μ^2_L = Mean value of Likelihood

μ^2_C = Mean value of Consequence

σ_L = Standard Deviation of Likelihood

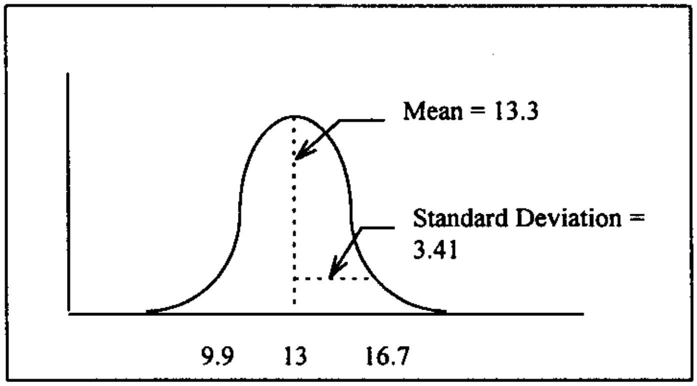
σ_C = Standard Deviation of Consequence

when the correlation factor is zero. It is assumed that likelihood and consequences are not correlated and therefore correlation is equal to zero.

From the above equation and continuing on this example, the standard deviation for relative risk is now calculated and shown in the figure following on the next page:

SD of Relative Risk = $[(5)^2(.62361)^2 + (8/3)^2(.48248)^2 + (.62361)^2 * (.48248)^2]^{.5}$

SD of Relative Risk = 3.41



4.6 STEP-BY-STEP DESCRIPTION OF FOOT

There are three phases to FOOT: Phase 1 is evaluating system information, Phase 2 is visiting the system, and Phase 3 is assimilating the information into a report.

4.6.1 Phase 1 - Evaluating Information Away from the System

Step 1: Evaluate Marine System using General Safety and Environmental Management Questions (Minimal Basic Questions) and assign initial values.

Result:

1. Evaluation report for SEMP and other guidelines resulting in:

    a. Bar chart for each category
    b. Comments for each category

2. Approximately five Areas of Concern (AOC) were identified by reviewing:

   a. Process Hazard Studies / Safety Reviews
   b. Physical layout and Hydrocarbon flow diagrams
   c. Input from workers/system operators
   d. Manuals (operating and other)

Step 2: Evaluate the Areas of Concern (context) using Operating Team Factors and Organization Factors and assign initial values.

How:

1. Take one AOC and describe the context or scenario
2. Ask "What is the likelihood that the state of Operating Team Factor X, as it exists at this facility and as it pertains to this area of concern, will cause a failure at this AOC?"
3. Ask "What are the consequences of a failure at this AOC?"
4. Obtain initial "mean", "not less than", and "not greater than" values
5. Repeat for each Operating Team Factor and Organization Factor.

Result:

Initial values for likelihood and consequence at each AOC for each Operating Team Factor and Organization Factor.

4.6.2 Phase 2 - Visiting the System

Step 1: Confirm the initial values for General Safety and Environmental Management Evaluation assigned during Phase 1.

Result:

Finalize SEMP and other guideline reports.

Step 2: Confirm and complete the evaluation of likelihood and consequence for each AOC.

Result:

Each AOC will have:

1. Mean values for the likelihood of each Operating Team Factor
2. Mean values for the consequences for each Operating Team Factor
3. Range of values, "not less than and not greater than," for likelihood and consequence for each of the Operating Team Factors
4. Operating Team Factor evaluation comments for each AOC
5. Mean values for the likelihood of each Organization Factor
6. Mean values for the consequences for each Organization Factor
7. Range of values, "not less than" and "not greater than," for likelihood and consequence for each Organization Factor
8. Organization Factor evaluation comments for each AOC.

Report will include:

1. Graphs with mean and range for each Operating Team Factor relative risk
2. Graphs with mean and range for each Organization Factor relative risk
3. Bar Charts for all Operating Team Factors relative risk at each AOC
4. Bar Charts for all Organization Factors relative risk at each AOC
5. Comments.

4.6.3 Phase 3 - Assimilating Information into Reports

Assimilation of Information:

Results:

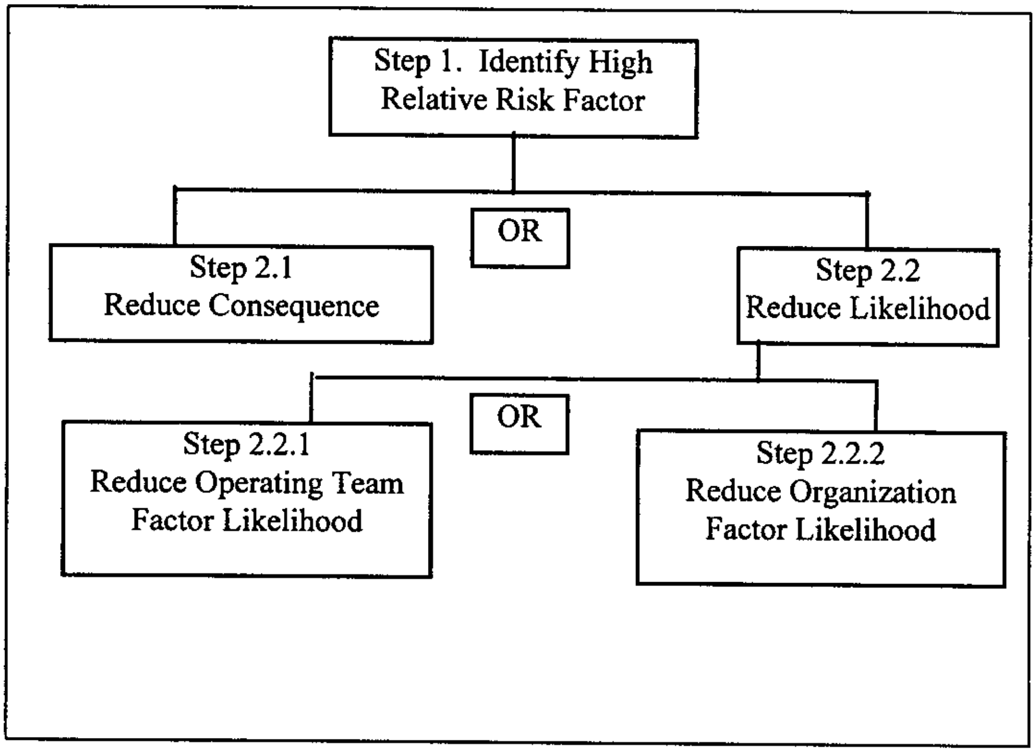
Final report to include:

1. Bar Chart with all categories evaluated. Indicates compliance with SEMP and guidelines
2. Operating Team Factors bar chart which indicates high relative risk factors
3. Organization Factors bar chart which indicates high relative risk factors

4.7 REDUCING RELATIVE RISK

Risk is a product of consequence and likelihood. To reduce relative risk, either consequence or likelihood or both must be reduced. Consequence is related to the flow of hydrocarbons through the facility and AOC. For example, a sampling station will have a lower flow of hydrocarbon than a 16 inch pipe, therefore the sampling station will have a lower consequence. Likelihood is the probability that an event will occur. A risk event is defined as an accident. High reliability organizations and humans, by definition, are less likely to have accidents. These Organization and Operating Team Factors are characteristics of high reliability organizations and humans. Figure 4.7.1 illustrates the risk reduction steps.

Figure 4.7.1: Steps to Reducing Risk at Area of Concern



The following is an explanation of Figure 4.7.1:

Steps:

Step 1: Identify Relative Risk Factors for Operating Team Factors and Organization Factors

Step 2: Reduce Relative Risk by reducing either Consequences or Likelihood

Step 2.1: Reduce Consequence by reducing hydrocarbons flow through the sampling area.

or

Step 2.2: Reduce Likelihood

Step 2.2.1: Reduce Likelihood by improving High Reliability Operating Team Characteristics (Factors)

Step 2.2.2: Reduce Likelihood in by improving High Reliability Organization Characteristics (Factors)

4.8 COMPUTER PROGRAM

To reduce the assessor's workload during the assessment, a tool is needed that will help gather information, make calculations, and display results. A computer can best meet this need. A computer program will guide the assessor through the method, and assist in gathering values and comments. During the FOOT method assessment, assessors will be selecting three values, a "most likely" value, a "best " value, a "worst" value, along with supporting comments. These values are a result of answering the BMQ, and evaluating the AOC and the Organization and Operating Team Factors. Once the values are input into the program, the computer can take those values and make the calculations identified in section 4.5, relieving the assessor of the burden of making calculations. The computer program will have the flexibility to allow the assessor to change values. Additionally, the assessors will add comments into the computer program to capture the basis for their evaluation. After the calculations are made, the computer program can place the results into pre-formatted reports. The following lists requirements should a computer program be developed for the FOOT method:

1. Assist the assessor through the assessment,
2. Stores assessor's values and comments,
3. Calculates means and standard deviations of triangular distributions,
4. Combines distributions using the Algebra of Normal Functions to determine a Relative Risk distribution, and
5. Places values and comments into pre-formatted reports.

4.9 TABLE-TOP EXERCISE

A table-top exercise was conducted to determine the practicality of the FOOT method. Practicality was measured by two criteria:

1. Results being useful and reasonable, and
2. Method is short.

The objective of this section is to document the table-top exercise. This section consists of three parts: background, steps taken during the table-top, and results. The next section is the exercise background information.

4.9.1 Background

Background for this table-top exercise includes information about the assessors, time needed to complete the assessment, and the exercise limitations.

The assessment team was made up of three people. Two of the team members are with the California State Lands Commission (CSLC)—Marine Facilities Division, Northern California Field Office, one an inspector and the other a specialist. The inspector has seven years of operating experience on the assessed marine terminal, and the specialist has several years of shipboard experience and is the primary oil spill investigator for northern California. The third team member is a graduate student from UC Berkeley.

Approximately 46 man-hours were needed to complete this table-top exercise: 20 hours of CSLC personnel time and 26 hours of graduate student time (not including the report write-up time). The graduate student spent approximately two days at the CSLC Field office; the inspector was with him for both days while the specialist joined for half a day. Another half day was spent walking down the marine terminal. The graduate student spent about 8 hours reviewing manuals and inspection sheets.

There were certain limitations on the amount of information obtained during this exercise. Since this was a table-top exercise, information was limited to what was available at the CSLC Field office. No requests were made for such additional information as the terminal's Management of Change Instruction, the Accident Investigation policy and reports, Hazards and Operability (HAZOP) studies, and the Auditing policy and reports. The visit to the terminal was considered informal, thus no request was made to observe (1) a maintenance procedure, (2) an emergency response drill, or (3) a watch turnover.

4.9.2 Minimal Basic Questions

The results after answering the Minimal Basic Questions consists of three items:

1. a value for each category with a bar graph depicting these values (Figure 4.9.2.1),
2. a short written summary
3. five AOC with an associated scenario.

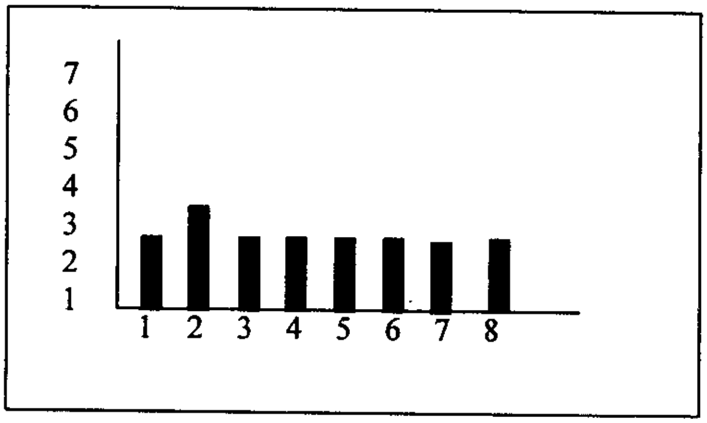
These three items are located below. The values are based on a 1 to 7 scale, where 7 is "the company does not do this," and 1 is "the company does this all of the time". The full answer sheet is located in Appendix D2, Answer Sheet to Minimal Basic Question Set.

Minimal Basic Questions - (Value) Category

Summary of the Table-Top Exercise Responses

1. (2) Hazards Analysis
2. (3) Management of Change
3. (2) Mechanical Integrity
4. (2) Operating Procedures
5. (2) Training
6. (2) Safe Work Practices
7. (2) Emergency Response
8. (2) Investigation and Audit

Figure 4.9.2.1: Minimal Basic Question Results



Written Summary:

This marine terminal shows compliance with all of the Safety and Environmental Management Program categories. This is reflected by the high compliance (2's and 3) evaluation on all categories. However, through this evaluation, five physical AOC have been identified and will be further examined to determine how Operating Team Factors and Organization Factors affect the safe operations of these areas.

The five AOC and their scenarios are:

1. Connections - scenario - a connection breaks during the steady flow state
2. Vessel openings overflow - scenario - topping off a vessel
3. Sample system - scenario - the sampling system was not properly closed
4. Vapor recovery system - scenario - a pin-hole leak develops, releasing natural gas
5. Sumps - scenario - during a cold, rainy night the sump pump fails.

4.9.3 Focus on One Area of Concern

To demonstrate the utility of FOOT, only one AOC was selected.

Sample System - scenario - the sampling system was not properly closed

The loss of hydrocarbons at a sampling station would be approximately 60 gallons before being detected, but not less than 1 pint and not more than 600 gallons. This was assigned a minimum value of 3, a most likely value of 5 and a maximum value of 6.

Table 4.9.3.1 depicts the likelihood, consequence, and relative risk assessment values for operating team factors.

Table 4.9.3.1: Operating Team Factors with Likelihood, Consequence, and Relative Risk

Op Team Factors	**Likelihood**	**Consequences (Mean = 4.67)**	**Relative Risk - mean**
1. Communications	Lo (independent) (1-2-3) (Sampling done by specialist independently & frequently)	Med-Hi (3-5-6)	9.33
2. Selection	Lo (good selection) (1-2-3) (Strict selection criteria by company)	Med-Hi (3-5-6)	9.33
3. Education	Med-Lo (know conseq.) (1-3-4) (Workers know the conseq. of loss of containment)	Med-Hi (3-5-6)	12.47
4. Limits & Impairment	Med-Lo (accessible) (1-3-4) (Most sampling stations are easily accessible.)	Med-Hi (3-5-6)	12.47
5. Organizing Ability	Med-Lo (med complex) (1-3-4) (Taking a sample requires some ability to organize tasks)	Med-Hi (3-5-6)	12.47
6. Experience	Med (know why) (1-4-5) (Worker's experience at taking samples greatly influences likelihood)	Med-Hi (3-5-6)	15.57
7. Training	Med (must know how) (1-4-5) (Worker's training on taking samples influences likelihood)	Med-Hi (3-5-6)	15.57
8. External Environment	Med (med influence) (1-4-5) (Rainy weather and high winds may distract worker's attn. to task)	Med-Hi (3-5-6)	15.57

Figure 4.9.3.1 is a bar chart of the relative risk values of the individual Operating Team Factors. The Operating Teams with the highest relative risks are Factors 6, 7, and 8. These factors are Experience, Training, and External Environment.

Figure 4.9.3.1: Operating Team Factor Relative Risk

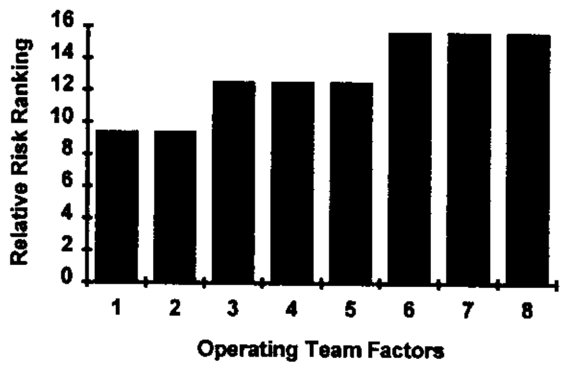
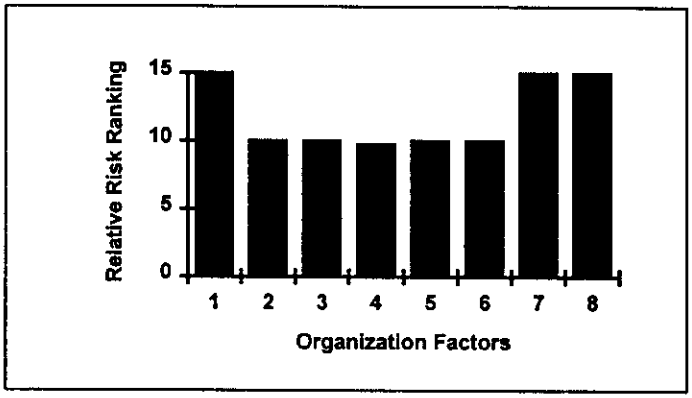


Table 4.9.3.2 depicts the likelihood, consequence, and relative risk value for each organization factor. Following the table is a bar graph showing the mean relative risk values for each organization factor as it relates to the sampling system scenario (Figure 4.9.3.2). The three highest relative risk factors are 1, 7, and 8, which are Process Auditing, Communications, and Resources.

Table 4.9.3.2: Organization Factors with Likelihood, Consequences, and Relative Risk

Organization Factors	Likelihood	Consequences (Mean = 4.67)	Relative Risk - Mean
1. Process Auditing	Med-Lo (checks) (2-3-4) (Uncertain if spot checking of sampling is being done)	Med-Hi (3-5-6)	14.01
2. Culture	Lo (check up) (1-2-3) (There is a very strong safety culture)	Med-Hi (3-5-6)	9.34
3. Appropriate Risk Perception	Med-Lo (understand) (1-2-3) (Org. realizes the risk involved with sampling, has procedures)	Med-Hi (3-5-6)	9.34
4. Emergency Preparedness	Med-Lo (drills) (1-2-3) (Org. conducts regular drills and has a good response manual)	Med-Hi (3-5-6)	9.34
5. Command & Control	Lo (good management)(1-2-3) (Org. allows sampler to do job without interference)	Med-Hi (3-5-6)	9.34
6. Training	Lo (know) (1-2-3) (Org. has extensive training program. Complacency may be a problem)	Med-Hi (3-5-6)	9.34
7. Communications	Med-Lo (feedback) (2-3-4) (Uncertain as to how feedback is received from refinery)	Med-Hi (3-5-6)	14.01
8. Resources	Med-Lo (able to do) (2-3-4) (Training budget is not meeting 15% of budget goal, sends strong message to workers)	Med-Hi (3-5-6)	14.01

Figure 4.9.3.2: Organization Factor Relative Risk



As a summary, the application of Operating Team and Organization Factor questions to this AOC identified three high relative risk factors for each. These factors are:

Operating Team Factors	Organization Factors
1. Experience	1. Process Auditing
2. Training	2. Communications
3. External Environment	3. Resources

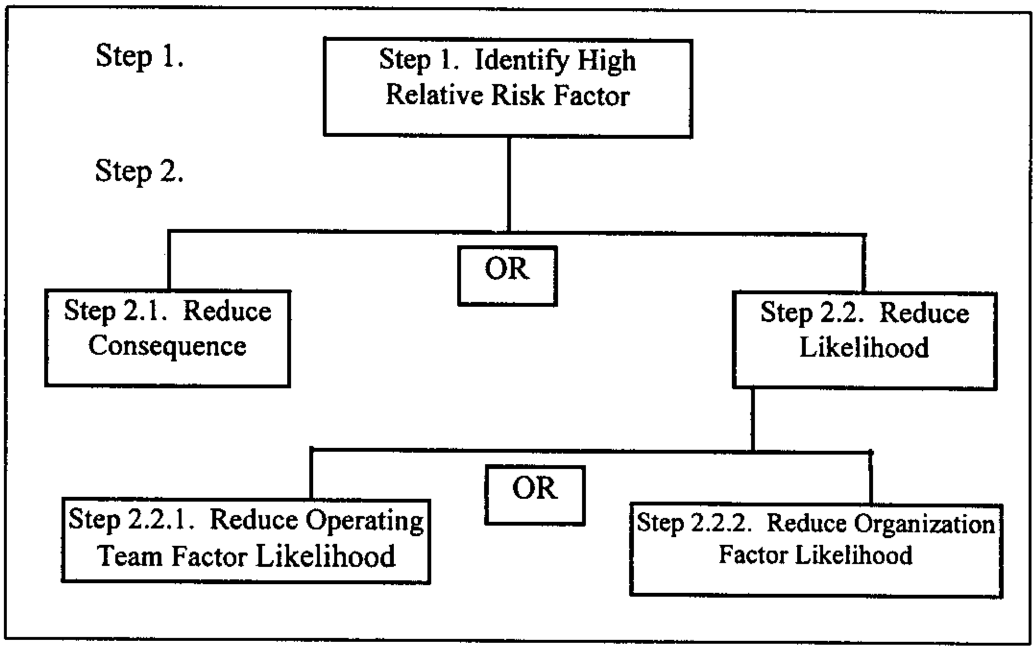
Appendix D3 shows the triangular distribution for each of the Operating Team Factors and Organization Factors, and Appendix D4 shows the relative risk distributions for each of the Operating Team Factors and Organization Factors.

Once these highest relative risk factors are identified, steps can be taken to reduce the risk. In this table-top exercise, the risk can be reduced by either reducing the likelihood or the consequence. This is examined in the following section.

4.9.4: Reducing Relative Risk at the Sampling System

Once the high relative risk factors have been identified, comments made by the assessors are used to determine ways to reduce the risk. The following are steps to reducing risks at this AOC (Figure 4.9.4.1).

Figure 4.9.4.1: Steps to Reducing Risk at Area of Concern



The following is an explanation of each of the steps in Figure 4.9.4.1.

Steps:

Step 1. Identify Relative Risk Factors for Operating Team Factors and Organization Factors

Step 2. Reduce Relative Risk by reducing either Consequences or Likelihood

Step 2.1 Reduce Consequence by reducing hydrocarbons flow through the sampling area.

or

Step 2.2 Reduce Likelihood

Step 2.2.1 Reduce Likelihood in Operating Team Factors

1. Experience: Complacency could develop for the worker who regularly takes samples. This can be countered with spot checks and allowing that worker to teach other samplers.

2. Training: Initial qualifications are good. May need to review refresher training and also train additional operators to do the task.

3. External Environment: When weather conditions are bad, two people may need to take samples so that short cuts and distractions do not occur.

Step 2.2.2 Reduce Likelihood in Organization Factors

1. Process Auditing: Check to see how frequently spot checks of the sampling procedures are done.

2. Communications: Feedback from the parent organization is required when any changes to procedures are recommended by the operators, especially those concerning safety.

3. Resources: Tightening of the refinery budget means there are less funds for training. Workers are feeling that profits are more important than training and their safety.

The results of the table-top exercise are shown in Appendix D2. A step-by-step description of how to reduce the high relative risk of this area of concern is included as Appendix D5.

While conducting this assessment, additional findings related to human and organization factors were uncovered and are presented in the next section.

4.9.5 General Findings

Additional information related to human and organization factors was uncovered during this exercise, and these may have an effect on risk. The following is a list of these items.

1. Communications: There is only one channel for hand-held radios on the terminal. When there are multiple vessels, interference on the radios could occur during an emergency.

2. Procedure input: Need to get input from workers on the terminal when updating any procedural manuals.

3. Computer system: Computer system in control room displays the hydrocarbon flow diagram of the entire terminal. When maintenance is conducted on a piece of equipment, the computer programmer is brought in to remove the equipment icon. When the piece of equipment is put back into operation, the icon is

programmed back in. This need for a third person, the computer programmer, to interact with the computer program could cause operator error if the task is not properly carried out.

4. Safety meetings: The attendance of "upper management" at safety meetings communicates to the workers that the meeting is even more meaningful.

5. Colored hard hats: The company recently changed from different colored hard hats for identifying different jobs to a single white hard hat. As one inspector noted, "When you saw all of the yellow hats (operators) running one way, you knew where the problem was." Although there is some validity for having a single color hard hat (e.g., teamwork), the differentiation by colored hats can be used to communicate quickly during an emergency.

6. Contractors: There appears to be a reduction in the use of contractors for conducting maintenance. Using company personnel for maintenance should bring in the company's safety culture. However, there may still be communications difficulties between maintenance and operations personnel.

7. Perks: Some company employees are disenchanted with the reduction of gifts given at retirement ceremonies due to budget cuts. This reduction is often compared to the number of gifts given in the past. The gifts seem to have been reduced to only a retirement cake and some juice.

8. Fire Fighting: AFFF (Aqueous Film Forming Foam). There are two 55 gallon drums at selected nozzle stations. Most berths have at least one or two 60 gallon skids. Berth one also has a 250 gallon tank. The flow rate at the nozzle is 250 gallons per minute, with the AFFF making up 6% of the solution. At that rate, the two 55 gallon drums of foam will last approximately 7.3 minutes. Another item that needs further examination is the use of remote-operated valves so that operators are not exposed to fire and smoke when turning on the firewater nozzles.

4.9.6 Table-Top Results

The methodology is practical. As a result of this exercise, the methodology met each of the practicality criteria.

First, the results are useful and reasonable. The assessors identified five areas of concern using the methodology and within one area of concern identified three high relative risk factors for both the Operating Team and the Organization. The assessors also identified other general findings related to human and organization factors.

Second, the method is short. Only 46 hours were required to conduct this assessment.

4.10 SUMMARY OF RESULTS

FOOT is a method focused on evaluating Organization and Operating Team Factors within the context of an Area of Concern. High reliability Organization and Operating Team Factors have been identified and a process for evaluating them has been developed. A four phase process to evaluate a system is presented. Areas of Concern are defined and one way of identifying and evaluating them is presented. Relative risk is also defined and a way to calculate it is also presented, along with a process for reducing relative risk. Requirements for a computer program to assist the assessors through this process is also listed. Finally a table-top exercise of the FOOT method was conducted and the results are presented.

The table-top exercise helped to prove the practicality of FOOT. The results were useful and reasonable, and the method requires a small number of hours. FOOT is very simple and therefore easy to use. Because of the limitations of a table-top exercise, the methodology was not fully tested, however the results are promising.

When the FOOT method was first developed the M&O category had not been developed and so the exercise described in this section and Appendix D does not include an evaluation of this category. FOOT as currently envisioned would contain as its first step an analysis of the whole revised MBQ set including M&O.

5.0 MARINE ASSESSMENT OF SAFETY TECHNIQUE (MAST)

5.1 INTRODUCTION

SAMS Marine Assessment of Safety Technique (MAST) involves the use of two separate sets of tools: one for offshore platforms and one for marine terminals. Regardless of the type of facility, however, MAST involves two separate evaluations: physical qualities (PQ) assessment and safety management system (SMS) assessment. The PQ evaluation involves assessment of the physical qualities of the facility as they influence the risks inherent in operations and engineering. The SMS evaluation involves assessment of safety management systems as they effect the efforts being made to mitigate the risks.

MAST's overall structure—including the division between physical qualities evaluation and safety management system evaluation—is supported by legislation, such as the Occupational Safety and Health Administration's 1910.119 rule, "Process Safety Management for Highly Hazardous Chemicals." This rule specifies assessment of both the engineering and administrative aspects of operations and correcting deficiencies to reduce the potential for or mitigate the consequences of loss-of-containment incidents.

The evolution of MAST's physical qualities evaluation strategy is discussed in Section 5.2. The evolution of MAST's safety management systems evaluation strategy is discussed in Section 5.3. The application of physical qualities and safety management systems for offshore platforms is discussed in Section 5.4 and for marine terminals in Section 5.5.

5.2 PHYSICAL QUALITIES ASSESSMENT

Assessment of the physical qualities of a facility (e.g., toxic gas, high/low pressure, location, etc.) is an important part of MAST. This factor is in keeping with the original proposal for the SAMS project and the concepts behind the FLAIM project created by Dr. William Gale. The physical qualities assessment should not be labor-intensive in either data collection, application, or scoring. For these reasons, MAST's physical qualities assessment strategy involves the use of an indexing scheme methodology.

5.2.1 Indexing System Background

Indexing systems are commonly used to allow a quick overview and rapid assessment of risk factors associated with an industrial facility These systems provide an excellent means to prioritize risks in a relative manner. In Appendix C of the book *The Role of Human Error in the Reliability of Marine Structures*, the following description of Safety Indexing Methods is provided:

> "The core of these methods [Safety Indexing] is formed by professional judgment based on qualified experience and training, historical records and in some cases, hazard evaluation techniques such as Hazard and Operability Studies (HazOps) and Event Tree Analyses (ETA). The core is used to identify, select, and define key variables that are risk contributors and risk mitigators."

Relative risk ranking techniques have been used for many years in onshore industries, including those associated with chemical plants and refineries. Dow and Mond Indexes are commonly used for such facilities. The results are considered to be valid by government and industry. In the text *Guidelines for Chemical Process Quantitative Risk Analysis*, the following discussion of these and other process hazard indexing schemes is provided:

> "Dow Chemical has developed techniques for determining relative hazard indices for unit operations, storage tanks, warehouses, etc. One generates an index for fire and explosion hazards (Dow, 1987), and another an index for toxic hazards (AIChE/CCPS, 1988). ICI's Mond Division has developed similar techniques (The Mond Index) and has proposed a system of using these indices as a guide to plant layout. (ICI, 1985) These techniques consider the hazards of the material involved, the inventory, operating conditions, and type of operation. While the values of the indices cannot be used in an absolute sense as a measure of risk, they can be used for prioritization, selection, and ranking."

Similar indexes have also been developed by both the US Coast Guard (USCG) and the State of Washington for marine vessels. The USCG currently has two indexing schemes. One was developed through the Port State Initiative and is a boarding matrix utilizing risk-based targeting to determine which vessels might be candidates for inspection. A second scheme, Class Society Targeting, is a candidate scheme for reviewing classification societies. Both schemes are documented in reports to the United States Congress. All of these tools can be used to prioritize risks and can serve as a guide for deciding where to concentrate resources for conducting inspections, improving safety, or modifying facilities.

5.2.2 General Approach to Physical Qualities Indexing

Once the basis of the indexing schemes was reviewed and the approach deemed acceptable, a review of schemes with applicability to the offshore and marine terminal environments was made. The reviewed schemes included the following:

- FLAIM (Gale, Bea & Williamson, 1994)
- FAME (Visser, 1992)
- Minerals Management Service (MMS) database materials
- J. Frank Davis' proposed appendix for API RP 14J
- US Coast Guard Foreign Vessel Targeting Matrix
- California State Lands Commission Priority Determination Scheme

Gale's FLAIM Methodology

Gale's FLAIM Methodology was reviewed to assist SAMS team members with forming better ideas of the types of factors that might be included in an indexing scheme. During this review, SAMS team members found that two modules of criteria seemed to match some of the ideas that were being considered. The General Factors Assessment and Loss of Containment modules were useful in defining candidate assessment criteria. The General Factors Assessment was divided into the following sections:

- Platform Physical Description
- Process Description
- General Condition of Platform
- General Assessment of Crew Makeup
- Operational Considerations

Under each General Factors Assessment section, different criteria were listed. The Loss of Containment (LOC) Assessment Factors also had information that influenced the MAST Indexing scheme. LOC factors that were considered included:

- Total inventory of flammables
- Total number of high-pressure (500 psi) wellheads
- Total number of platform import/export risers
- Total platform throughput (actual)
- Total platform throughput capacity
- Gas/oil ratio of unstabilized crude
- Hydrogen sulfide content of produced gas
- Operating pressure (actual) of first-stage separator and production manifold
- Discharge pressure of crude shipping (pipeline) pumps
- Discharge pressure of gas compressors
- Type/number/size (hp) of gas compressors
- Location of gas compression module
- Number of production separator trains
- Number of stages of separation in each train
- Corrosivity of production fluids
- Material compatibility for service conditions

Gale's assessment criteria were considered to be very thorough. Although Gale's assessment method provides users with an excellent means of completing thorough assessments, it appears time-intensive. It was the MAST formulators' challenge to determine which factors would be adopted and which would be eliminated in order to develop an effective field tool. The MAST scheme was not aimed at being exhaustive, but at choosing a subset of powerful indicators to fit the goal of a rapid, yet valid assessment of a facility's relative risk. Details of the factors in both the General Factors and Loss of Containment Factors assessments, as well as those relating to other FLAIM modules, can be found in a report by Gale, Bea and Williamson, 1994.

FAME Methodology

Another report that was influential in forming the criteria for MAST's indexing scheme. came from an MMS project entitled the FAME (*Facility Assessment, Maintenance and Enhancement)* Methodology published in 1992. In FAME data regarding fires and explosions on offshore producing facilities were analyzed. A database of 383 fire and explosion accidents that occurred in the nine-year period between 1981 and 1990 was developed, and an attempt was made to assign an initial cause from the one-paragraph descriptions of each accident. This database was merged with platform population databases, which contained data on all current and removed platforms in the Gulf of Mexico, including platform age, equipment listing, quarters size, operator, location, etc. The merged database permits a detailed analysis of a number of risk factors based on the population data.

Unfortunately, the FAME project was canceled before a detailed analysis could be undertaken. The following preliminary conclusions, however, were drawn:

1. Initial causes are shown in Figure 5.2.2a, Distribution of Fire and Explosion Causes. Further analysis of these causes was not undertaken in the FAME study or for this project.

2. The fire and explosion incident rate decreased significantly over the period, as shown in Figure 5.2.2b, Annual Fire and Explosion Incident Rate on Gulf of Mexico OCS Platforms. Visser, who led the FAME project, was unsure

whether this decrease was due to lower construction activity, changes in platform equipment mix, or better safety procedures.

3. The data depicted graphically in Figure 5.2.2c, Average Age of All Operating Platforms and Average Age of Platforms with Fire or Explosion by Year of Occurrence, indicate that probability of fire and explosion is not correlative to age. If anything, a negative correlation may exist.

4. The incident rates shown in Figure 5.2.2d, Average Annual Fire and Explosion Incident Rate on Platforms with Listed Equipment, indicate that platforms with certain equipment types were more likely to experience fire or explosion than the average of 0.5 percent per year for all other platforms over the nine-year period.

5. Data in Table 5.2.2a, Distribution of Fire and Explosion Incidents on Platforms with Compressors, show that many platforms with compressors have experienced multiple incidents. It was not evaluated, however, whether this factor is correlative to operatorship, type of compressor, facility size, equipment complexity, etc.

Figure 5.2.2a: Distribution of Fire and Explosion Causes

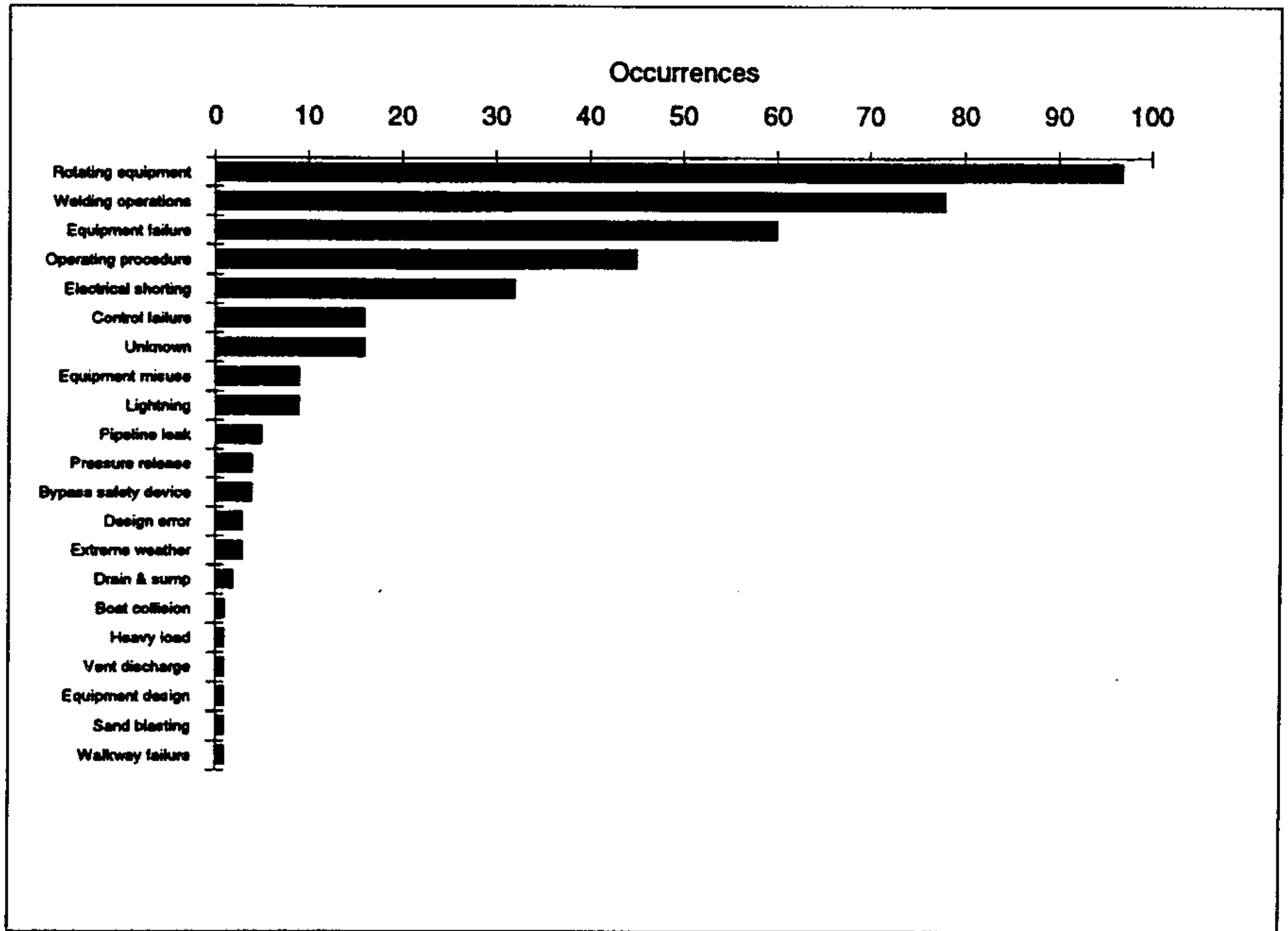
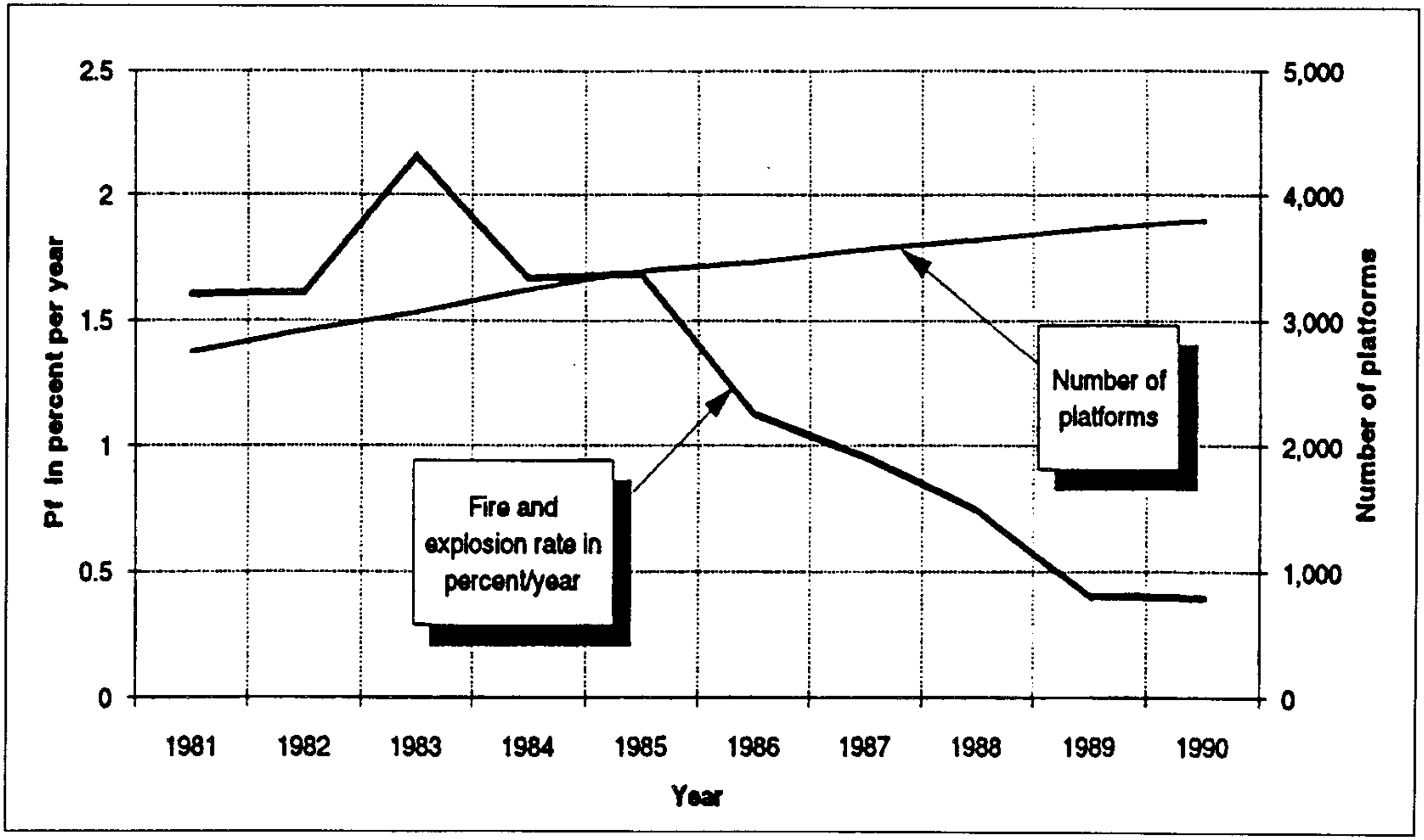


Figure 5.2.2.b: Annual Fire and Explosion Rate on Gulf of Mexico OCS Platforms



Other methods considered in developing the physical qualities criteria include MMS database materials, the US Coast Guard Foreign Vessel Matrix, and the California State Lands Priority Determination Scheme. These materials are not provided here but are generally available from the respective agencies.

The data summaries described above influenced the way the MAST formulators selected criteria. For example, the age of a facility was not included in the indexing criteria for platforms. In addition, items identified by Visser as the direct causes of fires and explosions were considered by the MAST formulators regarding what types of equipment or functions had historically been cited as causes in accidents.

Table 5.2.2a: Distribution of Fire and Explosion Incidents on Platforms with Compressors

Incidents per Platform	Number of Platforms
1	97
2	42
3	13
4	3
5	2
6	0
7	1

Davis' Proposed Appendix for API RP14J

Another scheme considered by SAMS engineers was Davis' Proposed Appendix for API 14J. This rating scheme was created for offshore platforms by J. Frank Davis. This scheme was prepared as an appendix for API RP 14J but was not included in the document upon publication. The scheme is presented in Table 5.2.2b, Davis' Risk Index for Offshore Production Facilities. As with Davis' model, the original idea for the MAST indexing scheme was a system of penalties and credits. Penalty points would accumulate if certain risk factors were present. "Credits" would be obtained if certain safeguards were provided to reduce or mitigate identified risk potentials. SAMS personnel used the data and approaches discussed above to develop an initial approach and list of candidate criteria.

Table 5.2.2b: Davis' Risk Index for Offshore Production Facilities

Quality of Concern	Evaluation Criteria	Penalty Points/Multipliers	Multiplier (if applicable)
Persons Quartered		5 points each	
Average Number of Active Oil and Gas Wells		1 point each	
Processing Pressure Vessels		1 point each	
Produced H_2S	10 to 100 ppm 101 - 500 ppm above 500 ppm	1.5 2.0 3.0	To be multiplied by no. of : • Well Points • Pressure Vessel Points • Compressor Points • Pipeline Points
Simultaneous Operations	Producing while drilling with one rig Producing while drilling with two rigs Construction while producing and drilling	1.50 1.75 1.50	To be multiplied by no. of: • Well Points • Pressure Vessel Points
Well Depth (Multipliers)	10,000 feet or less 10,001 to 15,000 Greater than 15,000	1 1.25 1.5	
Compressors	With open compressor building With completely closed compressor building	2.0 per 1000 bhp 2.5 per 1000 bhp	

Table 5.2.2b: Davis' Risk Index for Offshore Production Facilities (continued)

Quality of Concern	Evaluation Criteria	Penalty Points/Multipliers	Multiplier (if applicable)
Oil/Condensate/Diesel Inventory		2 points per 1000 barrels of storage	
Hydrocarbon Production		1 point per 1000 barrels (equivalent)	
Pipelines		1 point per 5000 feet of length (oil or gas)	
Gas Liquid Recovery Plant		5 points per 10K gallons of NGLs recovered + 1 point per pressure vessel	
Gas Treating Plant		5 points + 1 point per pressure vessel	
Distance from Location for Emergency Assistance	less than 2 miles 2 to 5 miles 5 to 10 miles 10 to 20 miles Greater than 20 miles	1.0 1.1 1.2 1.3 1.4	Multiply by the sum total of penalties and credits

Table 5.2.2b: Davis' Risk Index for Offshore Production Facilities (continued)

Quality of Concern	Evaluation Criteria	Penalty Points/Multipliers	Multiplier (if applicable)
Location	Within 3 miles of designated shipping fairway	1.1	Multiply by the sum total number of penalties and credits
	Within 2 miles of designated shipping fairway	1.2	
	Within 1 mile of designated shipping fairway	1.3	
	Within zone 1 of UBC seismic Risk Map	1.0	
	Within zone 2 of UBC seismic Risk Map	1.1	
	Within zone 3 of UBC seismic Risk Map	1.2	
	Within zone 4 of UBC seismic Risk Map	1.3	
Remaining Life of Platform	Less than 5 years	1.0	Multiply by the sum total of penalties and credits
	5 to 10 years	1.1	
	11 to 15 years	1.2	
	Greater than 15 years	1.3	

Table 5.2.2b: Davis' Risk Index for Offshore Production Facilities (continued)

Quality of Concern	Credit Points
Well Bay Deluge System	0.25 per well
Firewater System	1 point per 1000 gpm
Gas Detection System	0.30 points per detector
Smoke Detection System	0.10 points per detector
Fire Detection Systems (fusible links do not count)	0.10 points per detector
Completely Automatic Platform Shutdown Systems	1.5 times number of detector system points
Full-Time Standby Boats	0.5 points per average number of persons quartered

Other Penalties, Credits and Factors:
(not specifically apportioned points in scheme)

Unusual operational features could be evaluated to determine other penalties, credits or factors to properly assess relative risks.

For example:

Poor bottom conditions
Crowded or generous layouts
Very high operating pressures or temperatures
High evacuation times

Minimal structural safety factors
High sand production
History of operating problems
Excellent or poor conditions of facilities

Other Methods

Other methods considered in developing the physical qualities criteria include MMS database materials, the US Coast Guard Foreign Vessel Matrix, and the California State Lands Priority Determination Scheme. These materials are not provided here but are generally available from the respective agencies.

5.2.3 Physical Qualities Assessment Methodology

Regardless of the type of facility to be indexed (offshore platform or marine terminal), the general method for conducting a MAST physical qualities assessment consists of the following steps:

1. An assessor would request information about physical aspects and properties of a facility from facility personnel prior to visit. Requests would also be made for a contact for physical information and for any necessary supporting documentation.

2. The assessor would collate information about the physical aspects and properties of a facility and answer questions in the Physical Qualities Checklist before any visits to the offices or the facility. Gaps in information would be identified to allow efficient use of time and resources during visits.

3. An assessor would visit the shore base or corporate offices for a facility to validate any conclusions from offsite work. Time in the office would also be used to gather data on missing index answers.

4. The offshore platform or marine terminal visit would include a walk-around inspection of the facility. This visit would provide an opportunity to verify the physical qualities information.

5. The assessor would return to the shore or corporate offices for data confirmation and reduction. This visit would allow assessors to clarify any outstanding concerns and gather any additional information.

6. The data analysis would be finalized after all visits were complete, and scores would be computed for a facility physical qualities index. A report of the findings could then be created.

5.3 SAFETY MANAGEMENT SYSTEMS ASSESSMENT

MAST's safety management system evaluation uses the Minimal Basic Question set discussed in Section 3 as the entry point for the assessor and also provides detailed questions to allow more in-depth analysis of safety and human/organizational factors. The following material relates to the development of safety management systems evaluation, criteria, and assessment methodologies for this project.

5.3.1 Guidelines for Question Development

The development of the MAST safety management systems evaluation followed certain guidelines. The first guideline was that the Minimal Basic Question set would serve as the initial mechanism for evaluating safety management systems and human and organizational factors. In this sense, the information contained in the Minimal Basic Question set provides the general questions for a safety management and human/organizational factors evaluation. This approach required that the question set be reviewed and that any gaps or deficiencies be eliminated before detailed evaluation questions could be finalized.

Another guideline was that detailed questions be developed to provide further information to assessors regarding the human and organizational attributes that are considered important to meeting the intent of the general questions. This arrangement would allow assessors to rely on written guidance when making determinations about a facility's safety management system instead of requiring that assessors have in-depth knowledge in the fields of process safety management and human or organizational factors.

Lastly, sponsors of the SAMS project requested that all sources of information used to establish detailed questions be publicly available through the open literature. Special care was taken to ensure that all referenced sources for detailed questions were readily available and not taken from confidential reports or proprietary sources.

5.3.2 Goals for the Safety Management Systems Evaluation

Once the guidelines for developing general and detailed questions were established, the objectives for safety management systems evaluation were outlined. The following five goals were identified:

- *Initial identification of strengths and weaknesses* - Using the Minimal Basic Questions, an assessor would examine the written guidance for a company's safety management system. This step would allow the initial development of impressions about the strengths, weaknesses, and suspected deficiencies within a company's program. Deficiencies in the safety management program would also point to possible human and organizational concerns since the success of safety management lies within the development, administration and application of policies, programs and procedures. The results of the Minimal Basic Question evaluation would determine the focus of further investigations in safety management and human and organizational factors.

- *Detailed identification of safety management strengths and weaknesses and human and organizational factors concerns* - Once the Minimal Basic Question set (i.e., general question set) has been evaluated, an assessor could fine-tune the conclusions about a company's approach to safety by reviewing current systems with regard to human and organizational factors. This review would move beyond the company's safety management system's written guidance and check for different individuals' knowledge and actual implementation of the programs. The detailed questions were provided to allow assessors to determine where a company meets regulatory requirements and where the level of practice exceeds compliance. Areas of weakness can also be identified and scrutinized.

- *Determination of the nature of deficiencies* - Where weaknesses were identified, the assessors would need to determine the nature of the problem. Applying the detailed questions while utilizing a variety of assessment techniques (e.g., document reviews, interviews, observations, etc.) would determine if the deficiency was due to the lack of written guidance, poor organizational communication, inconsistent practice or lack of information/knowledge of those expected to implement the safety practice.

- *Generation of a graphic representation of a facility's compliance* - Upon completion of an evaluation using the Minimal Basic Question set, an initial idea about compliance could be formed by an assessor. However, a further assessment using the detailed questions could be utilized to modify the initial scores. At this point, a profile of the results could be generated. Such a profile would provide graphic indications identifying which process safety areas have high scores and which have low scores.

- *Tying of results to standards and guidelines or research* - As described in Section 3's discussion of the Minimal Basic Question set, results could be referenced or tied back to standards and guidelines. In addition, an assessor could cite particular research studies which support good practices or stress the importance of certain human and organizational factors. For each concern within a category, information on the literature basis is available.

5.3.3 Source Material

The Minimal Basic Question set's questions were synthesized from different standards, guidelines, company policies, and research. These sources are listed in Section 3.2.3, Source Material.

The reference sources for outlining the detailed questions are listed in Section 7.1, Safety and Human/Organizational Factors References. A listing of additional references for process safety management and human and organizational factors that were discovered during the literature search but not directly used is included in Section 7.2, Bibliography from Literature Search.

5.3.4 Safety Management Systems Assessment Methodology

The MAST safety management systems evaluation involves the use of general and detailed questions relating to nine process safety categories. Each category contains a series of general questions (Minimal Basic Questions). Detailed questions related to each general question are also included. Based on the answers to the general and detailed questions, Each Minimal Basic Question area is scored from 1 to 7 based on the assessor's judgment of the company's compliance with safety management and human and organizational factors criteria.

The process for completing a safety management systems evaluation is as follows:

1. An assessor visits the shore base or corporate offices for a facility to evaluate policies, procedures and guidelines in light of the questions written in the Minimal Basic Question set. Identification of strengths and deficiencies of written material in light of the questions would begin. Initial estimates for compliance to criteria can be given at this stage.

2. At the offshore platform or the marine terminal, the assessor checks for appropriate documentation concerning policies, programs, procedures and practices and determines whether or not operators and maintenance personnel are familiar with these documents. The assessor also determines how the information is sent from the location back to the shore base or corporate offices and whether platform or terminal personnel think that requests, needs, and orders for modifications are met. Detailed questions are used as part of these evaluations. Notations are made, as appropriate, to assist with future ratings using an assessment or indexing scale. The assessor conducts interviews with appropriate personnel and walk-around inspections of the offshore platform or marine terminal. Where possible, the assessor observes operational and maintenance tasks underway during the visit. The visit provides an opportunity to see the way practices are being applied in real time. Again, the assessor makes notes of any findings or conclusions and updates estimates to reflect knowledge obtained from field observations and interviews.

3. The assessor conducts interviews with appropriate personnel and walk-around inspections of the platform or terminal. Where possible, the assessor observes operational and maintenance tasks underway during the visit. The visit provides an opportunity to see how practices are being applied in real time.

4. The assessor returns to the shore or corporate offices for final data collection. This visit allows assessors to clarify any outstanding concerns and gather any additional information. An exit interview is conducted with appropriate personnel on general findings.

5. After all visits are completed, data analysis is finalized, profiles and scores are computed, and conclusions are drawn. A report of findings is then created. The report should outline a company's level of compliance for a facility and should provide information concerning the strengths and weaknesses of its safety management systems and approach to human and organizational factors. A graphical representation of findings should be included in the report.

5.4 OFFSHORE PLATFORMS

5.4.1 Physical Qualities Assessment

Based on the review of other approaches, SAMS personnel developed the following set of criteria for the assessment of physical qualities on offshore platforms:

- Number of Wells
- Producing Equipment
- Fluid Corrosivity (H_2S or CO_2)
- Type of Construction
- Maximum Source Pressure
- Ease of Evacuation
- Shipping Hazards
- Seismic
- Simultaneous Operations
- Normal Operating Staff
- Remaining Life

5.4.1.1 Offshore Platform Indexing Test

SAMS personnel chose to test the viability of the proposed MAST Physical Quality assessment system by conducting a table-top exercise. The approach was designed as an indexing method that would allow a quick overall assessment of the facility. The test included 19 offshore platforms that were familiar to the personnel. Points were assigned to physical attributes that could be used to evaluate the relative ratings of the platforms. Weighting of the factors was based on Visser's data and estimates by personnel who were familiar with the platforms. The base-case Physical Qualities Rating Worksheet is presented in Figure 5.4.1.1a, Physical Qualities Rating Worksheet (Initial Version).

Figure 5.4.1.1a: Physical Qualities Rating Worksheet (Initial Version)

Quality	Scoring: Attribute	Points	Total
1. Number of Wells	Active oil and gas wells	1 per well	
2. Maximum Shut-In Pressure	0 - 1,480 psi	0	
	1,480 - 5,000 psi	1	
	5,000 - 10,000 psi	2	
	10,000+ psi	3	
3. Solids Production	Possible with failure of sand control	3 per well	
4. Producing Equipment	Primary Separation	1	
	Emulsion Treating	1	
	Hydrocarbon Storage >500 Bbl	4	
	Compression:		
	Reciprocating	4 each	
	Centrifugal	2 each	
	Gas Dehydration	1	
	Acid Gas Treating	2	
	Gas Liquid Recovery	4	
	Produced Water Treating	1	
	Water Injection	1	
	Hydrocarbon Pumps >250 hp:		
	Reciprocating	4 each	
	Centrifugal	2 each	
	Electrical Generation	3	
	Heat Recovery System	1	
	Fired Heaters	2	
	Pig Launchers and Receivers	1 each	
	Risers	1 each	
	Subtotal Equipment		
	Total Points		

**Figure 5.4.1.1a: Physical Qualities Rating Worksheet (continued)
(Initial Version)**

Quality	Attribute	Multiplier
1. Fluid Corrosivity	Negligible Acid Gas CO_2 with Negligible H_2S H_2S with or without CO_2	1.0 1.1 1.3
2. Type of Construction	Open - Well Ventilated Open - Poor Ventilation Enclosed	1.0 1.1 1.2
3. Ease of Evacuation	Gulf of Mexico-Type Weather Intermediate Northern North Sea-Type Weather	1.0 1.1 1.2
4. Shipping Hazards	Greater than 10 Miles from Fairway Within 10 Miles of Fairway	1.0 1.1
5. Seismic	Zone 1 - 2 Zone 3 Zone 4	1.0 1.1 1.2
6. Simultaneous Operations	One Operation - Drilling or Producing Producing While Drilling with One Rig Producing While Drilling with Two Rigs	1.0 1.2 1.3
7. Remaining Life	Less than 5 Years Greater than 5 Years	1.0 1.1

Final Score = (Total Points) x (Multiplier 1) x (Multiplier 2) x (Multiplier 3) x (Multiplier 4) x (Multiplier 5) x (Multiplier 6) x (Multiplier 7)

The results of the first round were reviewed as a group exercise using a Delphic technique, a scientific method that combines expert opinion and quantitative data analysis. In this review, SAMS engineers interactively evaluated the results of the initial rating system. Adjustments to the scoring and weighting systems were made during the initial stages of the table-top exercise when index estimates did not reflect relative risks as judged by SAMS industry experts. The method was adjusted to remove the solids factor as it overwhelmed the result and was not viewed as increasing the relative risk of the platform. Shut-in tubing pressure was adjusted to be a multiplier based on the Maximum Allowable Working Pressure. Similarly, assigning points based on quarters was revised to involve a multiplier based on staffing levels. These adjustments resulted in ratings that were in line with the judgment of the reviewers. Additional revisions were made to include CO_2 because this factor had been inadvertently omitted from scoring in the first round.

As is standard in using the Delphic technique, revisions to the quantitative analyses were made based on a non-quantitative assessment of the effectiveness of the indexing method. The revised method is presented in Figure 5.4.1.1b, Physical Qualities Rating Worksheet (Revised Version). Results based on using the revised worksheet are shown in Table 5.4.1.1c, Physical Qualities Point Summary for MAST Test and Table 5.4.1.1d, Physical Qualities Multipliers and Final Scores for MAST Test.

One advantage of the MAST Physical Qualities indexing system is the speed of applying the assessment tool. It was estimated that an engineer that was thoroughly familiar with a platform could apply the method in about five minutes. Ease of application is another advantage of the MAST Physical Qualities indexing system. Adjustments were made to physical quality factors to minimize the need for subjective input. The information needed to apply the method can be obtained easily through interviewing of facility personnel and reviewing of facility records.

Figure 5.4.1.1b: Physical Qualities Rating Worksheet (Revised Version)

Quality	Scoring		
	Attribute	**Points**	**Total**
1. Number of Wells	Active Oil and Gas Wells	1 per well	
2. Producing Equipment	Primary Separation	1	
	Emulsion Treating	1	
	Hydrocarbon Storage >500 Bbl	4	
	Compression:		
	Reciprocating	4 each	
	Centrifugal	2 each	
	Gas Dehydration	1	
	Acid Gas Treating	2	
	Gas Liquid Recovery	4	
	Produced Water Treating	1	
	Water Injection	1	
	Hydrocarbon Pumps >250 hp:		
	Reciprocating	4 each	
	Centrifugal	2 each	
	Electrical Generation	3	
	Heat Recovery System	1	
	Fired Heaters	2	
	Pig Launchers and Receivers	1 each	
	Risers	1 each	
	Subtotal Equipment		
	Total Points		

Figure 5.4.1.1b: Physical Qualities Rating Worksheet (Revised Version) (continued)

Quality	Attribute	Multiplier
1. Fluid Corrosivity	H_2S Concentration:	
	0 - 4 ppm	1.0
	4 - 100 ppm	1.3
	> 100 ppm	2.0
	CO_2 Concentration:	
	0 - 9%	1.0
	10+ %	1.1
2. Type of Construction	Open - Well Ventilated	1.0
	Open - Poor Ventilation	1.1
	Enclosed	1.2
3. Maximum Source Pressure	0 - 1480 psi	1.0
	1480 - 5,000 psi	1.1
	5,000 - 10,000 psi	1.2
	10,000+ psi	1.3
4. Ease of Evacuation	Gulf of Mexico-Type Weather	1.0
	Intermediate	1.1
	Northern North Sea-Type Weather	1.2
5. Shipping Hazards	Greater than 10 Miles from Fairway	1.0
	Within 10 Miles of Fairway	1.1
6. Seismic	Zone 1 - 2	1.0
	Zone 3	1.1
	Zone 4	1.2
7. Simultaneous Operations	One Operation - Drilling or Producing	1.0
	Producing While Drilling with One Rig	1.2
	Producing While Drilling with Two Rigs	1.3
8. Normal Operating Staff	Not Normally Staffed	1.0
	1 - 10	1.1
	11 - 20	1.2
	21 - 30	1.3
	Over 30	1.4
9. Remaining Life	Less than 5 Years	1.0
	Greater than 5 Years	1.1

Final Score = (Total Points) x (Multiplier 1) x (Multiplier 2) x (Multiplier 3) x (Multiplier 4) x (Multiplier 5) x (Multiplier 6) x (Multiplier 7) x (Multiplier 8) x (Multiplier 9)

Table 5.4.1.1c: Physical Qualities Point Summary for MAST Test

Facility Description			**Points**		**Total**
I/M	Region	Type	Wells	Equipment	**Points**
M	California	Oil with drilling rig	42	29	71
M	Gulf of Mexico	Oil and gas, complex facility, deepwater	60	33	93
M	Cook Inlet	Oil and gas, with sea water injection	15	17	32
M	California	Oil	24	21	45
M	Cook Inlet	Oil with sea water injection	15	17	32
M	Gulf of Mexico	Oil and gas with drilling rig and sea water injection, deepwater	7	40	47
I	Gulf of Mexico	Oil and gas	18	33	51
I	Gulf of Mexico	Oil and gas	9	39	48
I	Southeast Asia	Oil with gas compressor and oil, satellite	12	21	33
M	Gulf of Mexico	Sour gas	0	13	13
I	West Africa	Oil and gas on jackup rig	0	27	27
M	Gulf of Mexico	Sour gas	0	15	15
M	Gulf of Mexico	Sour gas with gas treating	2	13	15
I	Gulf of Mexico	Sweet gas	3	11	14
M	West Africa	Oil	0	15	15
M	Gulf of Mexico	Gas, slug catcher with metering	0	12	12
I	Gulf of Mexico	Sweet gas with low flow	3	7	10
I	Gulf of Mexico	Oil wells with gas lift manifold, satellite	4	5	9
I	Gulf of Mexico	Gas, satellite	2	3	5

KEY: I = Independent
M = Major

FACILITY DESCRIPTION					
I/M	Region	Type	SCORE (without SIMOPS)	SIMOPS	FINAL SCORE (w/SIMOPS)
M	California	Oil with drilling rig	137.2	1.3	178.4
M	Gulf of Mexico	Oil and gas, complex facility, d	135.0	1.3	175.5
M	Cook Inlet	Oil and gas with sea water inje	109.6	1.2	131.6
M	California	Oil	87.0	1.2	104.4
M	Cook Inlet	Oil with sea water injection	81.0	1.2	97.2
M	Gulf of Mexico	Oil and gas with drilling rig an water injection, deepwater	80.7	1.2	96.8
I	Gulf of Mexico	Oil and gas	74.1	1.0	74.1
I	Gulf of Mexico	Oil and gas	63.9	1.0	63.9
I	Southeast Asia	Oil with gas compressor and oi	58.5	1.2	70.2
M	Gulf of Mexico	Sour gas	44.6	1.0	44.6
I	West Africa	Oil and gas on jackup rig	42.5	1.0	42.5
M	Gulf of Mexico	Sour gas	33.5	1.0	33.5
M	Gulf of Mexico	Sour gas with gas treating	30.7	1.0	30.7
I	Gulf of Mexico	Sweet gas	18.6	1.2	22.4
M	West Africa	Oil	18.2	1.0	18.2
M	Gulf of Mexico	Gas slug catcher with metering	15.8	1.0	15.8
I	Gulf of Mexico	Sweet gas with low flow	13.2	1.0	13.2
I	Gulf of Mexico	Oil wells with gas lift manifol	9.9	1.0	9.9
I	Gulf of Mexico	Gas, satellite	6.1	1.0	6.1

NOTE: Platforms are fixed facilities unless otherwise no

KEY: I = Independent
M = Major
O&G = Oil and Gas

5.4.2 Safety Management Systems Assessment

5.4.2.1 Minimal Basic Question Set

The proposed first step to evaluating an offshore platform's safety management system is the application of general questions provided in the Minimal Basic Questions. Section 3.0, Minimal Basic Question Set, provides the details regarding the way the question set was developed, its contents, and scoring mechanism. As discussed in Section 3.0, all of the questions included in the Minimal Basic Question set are aimed at the overall evaluation of a company's Safety and Environmental Management Program.

During the development of the MAST safety management system evaluation tool, the Minimal Basic Question set was expanded from eight to nine categories of questions. This step was the result of research conducted by SAMS project staff members concerning safety management systems and human and organizational factors. The new category, Management and Organizational Issues, was aimed at capturing perceived deficiencies in the coverage of the Minimal Basic Question set. The impetus for this change resulted from reviewing the Chemical Manufacturers Association's Responsible Care, the Center for Chemical Process Safety's series of guidelines relating to Process Safety Management, Occupational Safety and Health Administration 1910.119, and research documented in books/reports by Frank Bird, Dan Petersen, Scott Geller, Tom Krause, Linda Bellamy, Tim Geyer and Paul Harrison.

The nine safety management categories of questions in the Minimal Basic Question set are:

1. Management and Organizational Issues
2. Hazards Analysis
3. Management of Change
4. Operating Procedures
5. Safe Work Practices
6. Training
7. Mechanical Integrity
8. Emergency Response
9. Investigation and Audit

After adding the new category—Management and Organizational Issues (M&O)—to the Minimal Basic Question set, new general question topics for M&O were agreed upon by SAMS project team members. The general questions statements and appropriate detailed questions were agreed upon, and a final review of all categories and items was undertaken. Deficiencies in the coverage of particular categories were noted during this review. Subsequently, these deficiencies were addressed as follows:

- The Training category was expanded to include selection of personnel concerns.
- Two more additional general questions were added to the Training and Selection category for completeness: one concerning Operator Training and one concerning General Training.

5.4.2.2 Detailed Questions Related to the Minimal Basic Question Set

It was recognized by MAST formulators that each safety management system evaluation category should include both general and detailed questions. The general questions are listed in the Minimal Basic Question set, which is described in Section 3.0 of this report, and also appear in Table 5.4.2.2a. To provide specific safety management systems questions and increase the specific coverage of human and organizational factors, detailed questions were created. Every topic in every safety management category was expanded to provide a listing of additional safety and human and organizational concerns related to the stated general questions as they apply to offshore platforms. A compilation of the general and detailed questions is provided in Table 5.4.2.2a, MAST Safety Management Systems Evaluation - General and Detailed Questions for Offshore Platforms.

The detailed questions were based on research and existing question sets available in literature in the public domain. Proprietary sources and confidential information were avoided in producing the detailed questions. Most sources were identified through a literature search conducted at the University of Houston library in Houston, Texas. Other sources were made available through staff members at Paragon Engineering Services, Inc. A table relating the research basis or support for particular safety management items is provided in Table 5.4.2.2b, Human and Organizational Factors References Relating to Safety Management Concerns. The full reference citations for these sources are provided in Section 7.1, Safety and Human/Organizational Factors References. A listing of additional references for process safety management and human and organizational factors that were discovered during the literature search but not directly used is included in Section 7.2, Bibliography from Literature Search.

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions
Management and Organizational Issues

General Sub-Categories	General Questions	Detailed Questions
1. Safety Policy	Does a written safety policy exist, is this policy endorsed by upper-level management and widely distributed, and are employees generally aware of and follow the policy's contents? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)	• Is the safety policy reviewed and updated? • Are the revisions distributed and employees made aware of the fact that the policy has been revised? • Does this policy include a commitment to Human Factors? • Are safety meetings required and held on a regular basis, and do these meetings address any changes in the contents of the safety policy and Human Factors issues?
2. Safety Culture	Are assessments conducted for safety behaviors, knowledge, and attitudes at all organizational levels, e.g., clerical, management, operations, and any other personnel? (Krause, Hidley & Hodson; Geller; Harrison; SEMP 1.2.2.h)	• Do company audits require an audit of the safety management system? • Is there evidence of a long-standing process safety management program, e.g., documentation?
3. Management Structure Includes Health and Safety Issues	Has the company established a management structure that clearly sets forth responsibilities for health and safety and ensures that people with overall accountability do not have conflicting objectives (e.g., safety versus production)? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.a)	• Is there a Joint Safety Committee in existence with representation from both hourly and management personnel? • Is there an individual who reports to top management regarding health and safety issues? • Are the safety functions independent from the inspection functions? • Are safety objectives set yearly and tracked on an ongoing basis, and is this data made available to all levels of personnel? • Does a training department exist that includes someone directly responsible for training in safety-related issues?
4. Management Responsibilities and Accountability for Safety Concerns	Does each individual manager's performance review include safety issues as a major component of the assessment? (Petersen; Harrison; Bird & Germain; SEMP 4.3)	• Do managers have objectives for safety, and are these managers held accountable for the safety performance of their team?
5. Management Monitoring for Health and Safety Issues	Does the company ensure that periodic audits and reviews occur for safety statistics, measures, and job descriptions; and that the results are discussed at management meetings? (Bird & Germain; Petersen; Harrison; CCPS; Krause, Hidley & Hodson; SEMP 1.2.2.g)	• Do management meeting agendas include discussion of health and safety issues? • Does management review safety studies and statistics? • Does management ensure that job descriptions do not have conflicts between the objectives of the position and the safety requirements of that position? • Is there a formal method for reviewing the effects of organizational changes?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Management and Organizational Issues (continued)

General Sub-Categories	General Questions	Detailed Questions
6. Resources Exist for Health and Safety Issues	Does the company designate safety personnel within the organization and provide funding for such positions and for safety studies, audits, and equipment? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)	• Do safety personnel exist, and do these persons have human and organizational factors expertise? • Are budgets set aside specifically for safety, including resources for programs, studies, staff, equipment, and any additional training required to comply with safety regulations?
7. Defined Communications Channels for Safety Concerns	Has the company established a formal means for personnel to report safety concerns or potential hazards? (Geller; Harrison: SEMP 1.2.2.b)	• Are company personnel informed of who to report safety concerns and ideas, problems, and difficulties to beyond their immediate supervisors? • Are records maintained when safety concerns are reported? • Is there a formal follow-up method to reply to an employee concern and is it documented?
8. Safety Manuals and Information	Do Safety Manuals or handbooks that outline potential hazards and control/mitigation measures exist and are they available at work locations? (SEMP 1.1; CCPS; Harrison)	• Does the company have a safety handbook that employees can put in their pockets for quick reference if field work is part of their job description? • Do the manuals and/or handbooks appear to be used and updated on a regular basis? • Is the content of the safety manual periodically reviewed and updated and endorsed by management, and are the safety manuals updated when changes are made? • Do requirements exist for defining proper basic attire and PPE for offshore personnel and visitors? • Are visitors made aware of the locations of safety manuals and provided with a field safety handbook if it exists?
9. Safety Promotions	Does the company conduct safety promotions (as evidenced by signs or meetings), is the staff aware of these promotions, and is this program's effectiveness periodically evaluated? (Bird & Germain; Harrison)	• Are safety promotions evaluated for their effectiveness? • When new information is available concerning platform and corporate safety performance, is the staff informed, and is the information distributed properly? • Are steps taken to inform staff of risks associated with activities and inventories? • Does a system exist to reward safety performance and does this system provide methods of discipline for unsafe performance related to safety on the job?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Hazards Analysis

General Sub-Categories	General Question	Detailed Questions
1. Policy	Does the company have a general policy statement, either at the corporate or local level, that specifies when a hazards analysis is required and provides guidelines for selecting the study methodology, conducting the analysis, and choosing team members? (SEMP 3.1 & 3.5; API RP14J)	• Does the company have specific guidelines concerning hazards analysis, and is responsibility for the Hazards Analysis program defined? • Do the hazards analysis guidelines address frequency requirements, selection of study methodology, details for conducting the analysis, and choice of team members? • Is funding provided for hazard analysis studies?
2. Policy or Procedure	Does the company specify the objectives of a hazards analysis, including the need to identify the hazards of the process, review past incidents for potential catastrophic consequences, and evaluate the consequences of engineering and administrative controls failures? (SEMP)	• Are objectives for the hazards analysis specified by the company, including the need to identify the hazards of the specific process? • Is hazard identification training required for operators and maintenance personnel? • Are past incidents concerning potential catastrophic consequences and administrative controls failures reviewed and evaluated?
3. Schedule	Does the company have a policy or procedure that defines a rationale, priority order, and schedule for completing hazards analysis for existing facilities (from the most complex system to the simplest, from the systems considered highest-risk to those considered lowest), and does that policy or procedure define time frames for revalidations for hazards analyses? (SEMP 3.3.1, 3.4)	• Are hazards analyses performed prior to simultaneous operations, and are necessary changes implemented prior to simultaneous operations? • Are provisions in scheduling made to allow high-risk activities to be assessed before low-risk activities?
4. Documentation	Does the hazards analysis policy or procedure specify the documentation that is required for the study and the way the study will be documented and does this policy also state that the hazards analyses and supporting materials will be retained for the life of the facility? (SEMP 3.6)	• Does the hazards analysis policy or procedure specify required documentation for the study and a format for this documentation? • Does the policy state that all hazards analyses and supporting data will be retained for the life of the facility?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Hazards Analysis (continued)

General Sub-Categories	General Question	Detailed Questions
5. Methodology	Is the company's current hazards analysis thorough, is the methodology used appropriate (for type, age and complexity of facility) or in compliance with API RP 14J or similar industry standards, and has a review of a typical hazards analysis been made? (SEMP 3.3, 3.4, 3.5, 3.6; PFEER 5; HSEMS 3.4.4, 3.4.1; Company X #2; *Op Team #7)*	• Does the review cover, at a minimum, toxic gases, high and low temperatures and pressures, ambient conditions, flow, level, chemical hazards, relief, spill response equipment and materials, and erosion/corrosion? • Does the review cover operation history, fuel factors, well bay factors, import/export risers, platform design, and accommodations? • Does the review for human factors and ergonomics concerns include operations and maintenance; shift rotations, extended schedules and staffing; communications related to work conducted under work permit system; escape routes and escape craft; etc.? • Does the human factors review cover adequacy and reliability of controls and displays? • Does the human factors review answer alarm system adequacy questions such as: * In high noise areas, are visual indications of critical alarms provided (H_2S, fire, gas, etc.)? * At generators, prime movers, electrical switchgear or MCCs, are both visual and sound alarms initiated before fire suppression systems activate? * Are critical safety and operations alarms discriminable from routine operations alarms? * Are alarm systems designed to prevent defeat or disabling? * Are alarms provided for fire, gas, etc.? * Are means provided in this location to alert personnel to major hazards or emergency events occurring in other parts of the facility?
6. Layout and Configuration	Does the hazards analysis include an evaluation of whether the platform systems were designed and placed within the facility such that the risk of fire and explosion is reduced? (SEMP 2.2, 2.3, 3.2; API RP 14J)	• Is an evaluation performed of the structural integrity of the platform, including any structural damage or weakness that may have occurred due to a functional event? • Are reviews of layout performed for fire compartmentation, location of accommodation module, separation of potential fuel and ignition sources, well bay arrangements, arrangement of process equipment, flare and stack locations, air intakes, emergency shutdown stations and devices, and emergency escape capsules or life craft stations? • Is a review of crane locations provided?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Hazards Analysis (continued)

General Sub-Categories	General Question	Detailed Questions
7. Hazard and Risk Reduction	Has the company addressed and implemented, where appropriate, the conclusions of the hazards analysis? (HSEMS 3.4.2, 3.4.3, 3.4.6; Company X #2)	• Is a tracking system used for addressing and implementing, where appropriate, the conclusions of the hazards analysis?
8. Process Design/Safety Information	Does the following documentation exist: process flow or piping and instrumentation diagrams (which specify acceptable set points and upper and lower limits for temperature, pressure, flow, and composition, as appropriate) and mechanical and facilities design information; and are set points and limits available at the corporate and local levels and current; and does evidence exist that the appropriate process safety, mechanical design and facility design information was used during the hazards analysis? (SEMP 2.2 & 2.3; HSEMS 3.3.7.1.D2; PFEER 21; Company X #6)	• Is the Hazards Analysis information readily available? • Are details regarding materials of construction available? • Are Piping and Instrumentation Diagrams available, updated, and replaced with updated copies? • Does information regarding electrical classification exist? • Is a relief system design and design basis used? • Are design codes and standards employed? • Are all applicable regulations made available and abided by? • Do material and energy balances exist where appropriate? • Are equipment arrangement drawings available? • Does a description of the well control systems exist? • Do equipment and piping specifications exist, and are they updated and distributed in a controlled manner? • Is a corrosion detection and prevention system in place? • Is a description of safety systems and their design in place (e.g., alarms, interlocks, emergency evacuation systems, fire protection systems, fire and gas detection or suppression systems such as fire water, deluge, or halon, etc.)?
9. Communication of Hazards Analysis Results	Is information concerning hazards identified during a hazards analysis and recommended actions for control of hazards communicated to appropriate personnel in a timely manner? (SEMP 3.6)	• Are conclusions of management's decisions for recommendations resulting from Hazards Analysis made available? • Is a reporting mechanism in place for errors relating to hazards and process safety parameters? • Is information on hazards and hazard studies available? • Are records of management's decisions retained and readily available to employees to view upon request?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms General and Detailed Questions (continued)

Management of Change

General Sub-Categories	General Questions	Detailed Questions
1. Policy	Does the company have a general policy statement, both at the corporate and local level, that specifies what constitutes a modification or change with regard to facilities or personnel and outlines required analysis to be completed before the implementation of a change, and does this policy address both permanent and temporary change requirements and state the requirements for maintaining accurate safety and design information? (SEMP 4.1)	• Are specific criteria provided in written material on what constitutes a change? • Are specific criteria in place concerning replacement in kind? • Are specific criteria provided in writing on pre-start-up safety reviews? • Are specific criteria for temporary changes in place? • Is documentation in place regarding what constitutes a major, minor, or temporary change and what the process is for each type of change? • Are a formal initiation and approval policy and defined procedures for change requests in place? • Are responsibilities for follow-up and updating organizational and process documentation, procedures, and training defined?
2. Documentation	Does the policy or procedure specify the documentation that is required for a particular type of change and that which is required in the change packages? (SEMP 4.1)	• Are change forms available? • Is detailed information available for requesting or implementing a change? • Is a change package retained for a specified time period on the platform prior to forwarding to headquarters and are steps taken to ensure that all platform personnel review each package? • Are change packages retained at headquarters for an extended period? • Are change packages available for review by platform personnel for review upon request? • Do any changes or modifications have an impact on the safety management program?
3. Change in Facilities	Does the company ensure that risks are identified, evaluated, and managed when changes in facilities are made? (SEMP 4.2; HSEMS 3.5.4.11; Company X #5; and FLAIM B5.3, B8.4)	• Does a review of changes for human factors and ergonomic concerns occur? • Does a mechanism for engineering review prior to change implementation exist? • Do these change reviews take place when system or equipment functions change? • Are applicable changes or past changes reviewed following an operational event?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Management of Change (continued)

General Sub-Categories	General Questions	Detailed Questions
4. Change in People	Does the company take into account the possible effects of personnel changes and organizational changes in terms of risks and manage these effectively (including the use of contractors)? (SEMP 4.3; HSEMS 3.5.4.I2; ISM 6.3; Company X #5; FLAIM B5.3, B8.4)	• Is a review of changes conducted for necessary communication or reporting modifications? • Are changes in supervision and contacts reviewed?
5. Pre-Start-Up and Environmental Review	Does the company's safety management program require that the commissioning process include a pre-start-up and environmental review for new and modified facilities? (SEMP 9)	• Is detailed information on completing pre-start-up reviews available? • Are checks made for compliance with codes and standards? • Does confirmation exist that any facility or system modifications were built as designed? • Do criteria exist for the amount of time required and the type of hazards analysis needed depending on the type of change? • Before start-up, does verification that all hazard recommendations are resolved occur? • Before start-up, are checks completed for adequacy of procedures for start-up and commissioning, operating, maintenance, and testing (including checks that modifications of existing procedures occurred, if needed)? • Do operator training, pre-start-up checks, and equipment testing take place?
6. Communication and Training	Does the company ensure that changes are accompanied by training and communications, including updating of relevant procedures or practices, before the commissioning of new or modified facilities? (SEMP 4.4, 5.3, 7.4; HSEMS 3.3.6; ISM 6.7)	• Is training provided on identifying process and safety hazards that could occur due to implementing the proposed changes? • Does a method exist to ensure that all relevant personnel are informed of changes?
7. Authorization of Changes	Does a policy or procedure specify the authorization requirements for changes, the people who are qualified to authorize changes, and the requirement that changes cannot occur before authorization, and does such material outline any differences in the authorization process based on whether the change is permanent or temporary? (SEMP 4.4g)	• Are provisions for temporary changes in place? • Before a temporary change can become permanent, does a formal review of the change occur? • Is there an expiration date for temporary changes; how is it enforced?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Management of Change (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Process Safety Information	Does the policy or procedure require the review of process safety information before a change is made and outline the way modifications to process safety information will occur as the result of a change? (SEMP 4.4e)	• Is the level of documentation sufficient on the platform for platform-approved changes (no beach review) (e.g., temporary changes)? • Is a system in place to ensure that the platform has all up-to-date copies of related regulations, standards, and codes?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Operating Procedures

General Sub-Categories	General Questions	Detailed Questions
1. Content of Operating Procedures	Does the company have procedures that address the following operations: start-up, normal operations, temporary operations, simultaneous operations, emergency shutdown and isolation, and normal shutdown? (SEMP 5.2; FLAIM B8.1.2)	• Are process and operating concerns covered in formal procedures? • Is there a standard for the quality of documentation? • Is a formal procedure used for updating and distributing procedures? • When a procedure is created or updated, is it suitable for operators (language, detail matches equipment labels, diagrams, drawings, etc.)? • Are checklists used for routine tasks? • Are responsibility and authority defined for changes to procedures? • Are procedures reviewed by operators prior to issue (procedure verification and validation)?
2. Consequences of Deviations	Are operating limits included in procedures, and are consequences of deviations from limits documented along with steps required to correct or avoid deviations? (SEMP 5.2c)	• Are responsibilities and authority defined for high-consequence operations and maintenance tasks? • Are the contents of warnings, comments, and notes made available and clearly understood by personnel? • Are operational limits defined by numerical values?
3. Temporary Changes	In the general policy statement, is there information that specifies what constitutes a modification or change with regard to temporary procedural changes (or temporary procedures)? Is the policy or statement available to personnel both at the corporate and local level? Is the required analysis for authorizing a temporary change outlined in the policy and is the analysis completed before the implementation of a change?	• Does a method exist for requesting temporary procedure changes? • What time limits exist on temporary procedure changes? • Does documentation of temporary procedure changes occur? • Are responsibilities and authority clearly defined for changes to procedures, both permanent and temporary?
4. Periodic Review	When the company periodically reviews operating procedures in terms of validity for current and actual operating practice, do these reviews ensure that the procedures are written according to the level of experience, understanding, and knowledge of the user and that the procedures are easy to read? (SEMP 5.3; HSEMS 3.5.3)	• What link exists to ensure that all items from the management of change program are appropriately reflected in procedures? • How are procedures reviewed following near misses or incidents? • Prior to re-issue, is a review of procedures by operators conducted (procedure verification and validation)? • After staff reduction, what type of review is required for needed procedural changes? • Is a time period specified for when periodic review must occur of procedures?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Operating Procedures (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Plan Preparation	Does written guidance exist for preparing plans, procedures and instructions, and does this guidance identify the need for assigning qualified personnel to this preparation task? (ISM 7)	• Does a writer's manual exist? • Does the company have a method for requesting changes to procedures? • Before a change is implemented, is it checked against process safety information? (e.g., pressures, temperatures, flows, etc.)
6. Follow-Through	Does the company ensure that operating procedures are understood and followed? (Company X #4; FLAIM B5.2)	• Is a follow-up method defined for requested changes, including time limits for safety items? • When changes to procedures are made, are the changes accompanied by training?
7. Document Control	Does the company have a system for controlling policies, procedures, and plans such that: • These documents are available at relevant locations • Changes are reviewed and authorized before distribution (SEMP 5.3) • Changes are communicated to appropriate personnel (SEMP 5.3) and • Obsolete documents are promptly removed? (ISM 11; HSEMS 3.3.7.2; FLAIM B8.1.2)	• Does an operations manual and emergency/contingency plan exist, and is it kept current with relevant regulations and available to all personnel? • Are materials describing operations and other necessary manuals readily available to any personnel? • How would an employee be able to tell that a procedure is the most current version? • Do distribution lists exist to ensure that all required parties receive information, and is any type of follow-up conducted to ensure that the most current information is in fact in the manual or procedures? • What is the availability of current drawings like process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs) at the platform? • Are warnings, comments, and notes explained to relevant personnel, contractors, and visitors? • Are operational limits defined by numerical values?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Safe Work Practices

General Sub-Categories	General Questions	Detailed Questions

1. Safe Conduct of Work Activities	Regarding Safe Conduct of Work Activities, do the company's safe work practices apply to all modes of operation, including maintenance and modification activities as well as simultaneous operations, and do these practices meet current regulatory requirements and consider and manage hazards and risks during the following activities:
	• Opening of equipment or piping
	• Lockout and tagout of electrical and mechanical energy sources
	• Hot work and other work involving ignition sources
	• Confined space entry and
	• Crane operations?
	(SEMP 6.2; FLAIM B5.1, B8.1.2)
		• Does the Safe Work Practice Manual cover isolation (electrical, mechanical, pneumatic, hydraulic), opening pressurized process or utility equipment or piping, bypassing safety equipment, over-water work, work at heights, and radiation?
		• Does documentation specify safety-critical items and special requirements for taking equipment out of service (e.g., fire and gas detectors, emergency isolation valves, shutdowns, pressure and temperature switches, relief valves)?
		• Does a policy on control of access to the platform for contractors, visitors, and corporate personnel exist?
		• Does a mechanism exist for allowing or preventing bypass of detector or safety interlocks? Are decisions documented when bypasses are permitted? Is there a mechanism for ensuring that bypasses do not become permanent by default?
		• Does modification of Safe Work Practices occur for simultaneous operations?
		• What type of formal mechanism (logs) exists for transfer of information between shifts?
		• What type of formal mechanism (logs) exists for transfer of information between crews?
		  * operations to maintenance including contractors
		  * maintenance to maintenance or contractors
		• What type of formal mechanism (logs) exists for transfer of information between supervisors?
		• Are personnel held accountable for maintaining logs?
		• Does the crew change on a different day than the supervisor?
		• Are inspections of work areas planned and conducted or random?
		• Is a system in place for log-keeping for specific safety-related and critical operational parameters?
		• Are logs kept for routine information?
		• Is room provided in logs for narratives concerning shift operations and maintenance?
		• Is equipment labeled?
		• Does a clear policy exist on illness, substance abuse, etc.?
		• Is refusal to work for safety reasons allowable?

General Sub-Categories	General Questions	Detailed Questions
2. Work Permit or Authorization	Is a work authorization system used in conjunction with specific work practices to ensure adequate communications during work activities, and does the work authorization system address steps to be taken for providing information concerning unfinished work at shift change or crew change? (SEMP 6.2)	• Is a log kept on active work permits? • Does a policy exist regarding frequency of renewal of work permits? • Are work permits visible in a central area and at a local area while a permit is open? • Are all permits either logged or sent to a shore base for retention? • Are inspections performed before and after maintenance by operations personnel? • What, if any, personal protective equipment (PPE) and other safety requirements for maintenance are specified on permits? • Does the supervisor or designee check that all permit requirements are met prior to starting work?
3. Control of Inventories and Material	Do written materials outline what inventories exist? Do these specify what special precautions to be taken by personnel to avoid environmental damage and personnel exposure to toxic or hazardous materials? Are these written materials available at the local level? (SEMP 5.2d, 6.3)	• Do documentation and procedures exist for monitoring, tracking, and replenishing inventory? • Is a system in place for labeling and/or sign posting for hazardous material? • Are reactive chemicals separated and segregated appropriately? • Are flammables stored away from sources of heat and ignition?
4. Hazard Communications	Does the company have a hazardous communications program for providing information regarding hazards to personnel, such as: • Making Material Safety Data Sheets (MSDSs) available • Marking containers or equipment containing hazardous materials • Providing signs in areas where hazards may be present • Designating on safe work permits the personal protective equipment that is needed for hazards? (SEMP 6.3)	• Where hazards may be present, are signs posted? • Are bulk chemicals and their containers and other additives labeled according to hazardous potential? • Is equipment containing hazardous materials labeled accordingly?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms General and Detailed Questions (continued)

Safe Work Practices (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Contractor Selection	Does the company obtain and evaluate information regarding a contractor's accident record and training program and use this information in contractor selection? (SEMP 6.4; HSEMS 3.3.5; Company X #8)	• Is training in work practices and safety rules provided for contracted tasks? • Is a formal orientation required on applicable parts of emergency and response plans? (including routing, routes, alarm sounds, etc.) • Is an orientation on platform-specific emergency response features provided? (e.g., shutdown switches, phones, muster/assembly points, etc.) • Is there an expiration date assigned to training to prompt periodic refresher training? • What type of provision is made for discipline where non-compliance with safety rules exists?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection

General Sub-Categories	General Questions	Detailed Questions
1. Initial Training	Does the company ensure that the following initial training takes place as appropriate and that this training is documented: • All personnel receive orientation training per API RP T-1 before being transported offshore for the first time. (SEMP 7.2.1) • All personnel regularly assigned offshore receive training in non-operating emergencies in accordance with API RP T-4, rescue of persons per API RP T-7, and fire fighting per API RP 14G? (SEMP 7.2.1)	• Do defined training requirements and progression for new hires exist at all levels (operators, maintainers, managers)? • Does a method exist for assigning jobs to persons with prior experience based on demonstration of required skills and knowledge (operators, maintainers, managers)? • What types of basic safety training (e.g., orientation to emergency systems, evacuation, reporting hazards, safety policy, etc.) are provided prior to arrival and beginning work at the platform? • Is first aid training required as appropriate prior to arrival and beginning work at the platform?
2. Operator Training	Has the company established a formal training program for operations staff that includes clear definition of required skills and knowledge for each position, and does this program also require that operators are assessed for competence and periodically receive refresher training?	• Do job descriptions exist? • Is basic skills training provided specifically by job category? • Are critical tasks per job identified? • Is a Task Analysis maintained for critical tasks? • What types of safety training (e.g., production shutdowns, emergency response, evacuation, etc.) are provided at the platform? • How are skills and knowledge identified per job? • What learning objectives are identified for each training module? • Are these learning objectives tied to critical tasks, skills, and knowledge? • Is each operator trained in diagnostic skills? • How is competence assessed? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for completing tasks? • When training is provided, is assessment of the sufficiency of the training by the trainee a part of the training course (feedback from courses)? • How is training documented? • What type of refresher training program, if any, exists?
3. Operating Instructions	Do personnel and contractors receive training in implementing operating instructions pertaining to their job assignments? (SEMP 7.1, 7.5)	• Is there an assessment of understanding of training material either through oral or written examination or hand on demonstration? • Are minimum "pass" criteria set for assessment of understanding?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
4. Hazards Training	Is training in the hazards of the process before undertaking work in the facility required for all personnel and contractors, and is training concerning simultaneous operations and hazard communications to appropriate personnel provided? (SEMP 7.1, 7.5, 8.5)	• Does training include process basics training that covers possible process hazards for operators and maintenance personnel? • Are all personnel trained in hazard identification skills as they apply to the platform or local work area? • Is formal training in safety issues required by a regulatory agency, and if so, has this training been conducted? • How is an assessment for understanding determined? Are tests given either through oral or written examination or hand on demonstration? • Are minimum "pass" criteria required for understanding of training material?
5. Safe Work Practices	Do all personnel and contractors receive training in safe work practices pertaining to their job assignments? (SEMP 7.2.1c, 7.5, 8.5)	• Is all training completed and documented for various safe work practices before the work starts? • Are short courses for training experienced personnel or refresher training provided (including pre-assessment of knowledge)? • Is there a method for assessment of understanding? • Are minimum "pass" criteria for understanding required?
6. Emergency Response and Evacuation	Are all personnel, including contractors, required to receive training in emergency response and evacuation? (SEMP 7.1, 7.5, 10.4)	• Is there a method for establishing competence on emergency response tasks of a general nature (e.g., use of fire extinguishers, rescue, etc.)? • Is orientation training documented for platform-specific emergency response and evacuation procedures, including individuals' roles and reporting status? • Is training provided for designated members of emergency management teams?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
7. Maintenance and Mechanical Integrity	What mechanism does the company have in place to verify that the personnel and contractors who are responsible for maintenance tasks and/or mechanical integrity inspections and testing have received appropriate craft training - and, where appropriate, hold required certifications - before conducting such tasks? (SEMP 7.2.1, 7.5, 8.5)	• Do job descriptions exist? • Is basic skills training identified by job category? • Is identification of special training or certifications required? • How are critical tasks per job identified? • Is there a Task Analysis of critical tasks? • How are skills and knowledge per job identified? • Are learning objectives identified for each training module? • Are these learning objectives tied to critical tasks, skills, and knowledge? • Is the maintenance personnel trained in diagnostic skills? • How is an assessment for competence conducted? Is there criteria or testing established to determine when someone has the skills or knowledge sufficient for completing tasks? • How are contractor and vendor personnel performance monitored? • What criteria exist for evaluating acceptable performance of contractors and vendors? • Does a method exist for documenting and reporting deficient performance? • What type of record-keeping is provided for contractor, vendor and supplier performance?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Topic-Specific Training	Do personnel and contractors receive specific training where appropriate in: • Safety and anti-pollution devices? (API RP T-2; 30 CFR 250.214; HSEMS 3.3.4.2g; FLAIM B8.3) • Crane operations and maintenance? (API RP 2D; 30 CFR 250.20; HSEMS 3.3.4.2I; FLAIM B8.3) • Non-operating (general) emergencies (e.g., personnel overboard, loss of power, security emergencies, etc.? (API RP T-4; FLAIM B8.3) • Well control? (API RP T-6, RP 59, if hydrogen sulfide, API RP 49, 55, 30 CFR 250.210; HSEMS 3.3.4.2h; FLAIM B8.3) • Hydrogen sulfide, if applicable? (30 CFR 250.67; HSEMS 3.3.4.2e) • Environmental protection and pollution control? (30 CFR 250.43; guideline UKOOA "Environmental Training Position Paper"; HSEMS 3.3.4.2f, g, h) • Spill or release reporting and containment including knowledge of contingency plans? (33 CFR 154.710) • Welding, cutting, and burning? (30 CFR 250.52) (SEMP 7.2.2; 7.5; 30 CFR 250 Subpart O; HSEMS 3.3.4.2e, f, g, h; FLAIM B8.3)	• When personnel are transported by boat and helicopter, is specific training provided for escape, evacuation, and survival? • What requirements exist for platform-specific safety training? • Is special training required for simultaneous operations? • Is a method in place for incident reporting and investigation? • How is staff polled for their training needs?
9. Hazardous Materials	Do personnel and contractors receive training on handling hazardous materials in accordance with Material and Safety Data Sheets (MSDSs) information? (SEMP 6.3; 7.5)	• Is training provided for specific hazardous materials and their handling including, as appropriate: hydrogen sulfide, benzene, MTBE, toluene, etc.? • Is an assessment performed for competence? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for completing tasks?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
10. Personal Protective Equipment (PPE)	Is training provided on the proper use of personal protective equipment to appropriate personnel? (SEMP 6.3; 7.5)	• How is competence assessed? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for properly fitting and using their personal protective equipment?
11. Procedures	Does the company ensure that personnel and contractors receive training on procedures and changes in procedures, as appropriate? (SEMP 7.4, 7.5; HSEMS 3.3.6; ISM 6.7)	• Is training and orientation provided to visitors, including emergency response, muster/assembly, and alarms for platform specifics? • Is a review performed of safety rules and work practices for contractors and visitors on the platform? • What type of documentation provides evidence that contractors and visitors have received and understood orientation briefing? • When staff reductions are necessary, is retraining provided? • How are contractor concerns handled (e.g., method for identifying training deficiencies)?
12. Training Documentation and Refresher Training	Is all training documented, and is appropriate refresher training scheduled and conducted? (SEMP 7.3, 7.5)	• Is training and orientation provided to visitors? Is it documented, and are records retained? • Are results of incident investigations and audits fed back to the training department? • Are updates of training based on feedback, audits, and incidents? • Do the refresher training programs emphasize critical tasks and operations?
13. Management Training	Does the company ensure that facility management personnel has been formally trained on safe work practices and emergency and contingency plans for hazard prevention and response? (ISM 5, 6.1, 6.2, 6.4, 6.5, 6.6)	• Are management training programs in place on leadership, communications, personnel management, and process safety? • Do supervisory personnel receive supervisory training, including conflict management? • Is there formal training in communication procedures for normal and emergency conditions? • Are training needs identified by the supervisor in yearly performance reviews?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
14. General Training and Selection	Has the company established a formal training and selection program for all categories of personnel, and does the program clearly define requirements for positions and the need for assessment for competence?	• Does a matrix or document exist with overviews of types of training and training needs by category? • Is a listing of job categories available? • Do job descriptions exist? • What is the formal selection process for personnel? • Is there a formal method for determining staffing levels? Is a workload assessment conducted as a means for determining minimum staffing levels? • When staff reductions are necessary, is an assessment conducted for minimal staffing requirements? Is retraining provided for remaining personnel after reductions with regard to new responsibilities or tasks? • Do staff rotations, shift rotation, shift schedules, and rules for extended work-hour limits exist? • For all formal and on-the-job training, is assessment of the sufficiency of the training by trainee part of the training course (feedback from courses)? • Are special programs designed to ensure that training personnel are knowledgeable about training techniques themselves and have necessary knowledge of skills for topics that are provided?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Mechanical Integrity

General Sub-Categories	General Questions	Detailed Questions
1. Quality Assurance Strategy	Does the company have a program that assures that critical equipment is procured, fabricated, and installed in accordance with appropriate quality standards and specifications? (SEMP 8; ISM 10; PFEER 19; HSEMS 3.5.2; Company X #3)	• Does a listing of safety-critical equipment/parts exist? • What criteria exist for acceptance or rejection of received parts or equipment? • Is there a listing of equipment and components received and inspected, and does the list indicate the results of those inspections? • Is there a system for supplier and vendor qualification criteria or specifications? • Are lists maintained for qualified vendors, service companies, and personnel? • Are checks made against the results of inspections for quality and vendor/supplier performance? • How are deficiencies monitored, and is there a method for reporting deficiencies to vendors/suppliers? • What criteria exist for disqualifying a vendor or supplier due to poor performance? • Are code and standard compliance records available? • Are equipment specifications, with reference to standards and codes, used for design and selection? • Are procedures in place for ordering, purchasing, receiving, and completing inventories for equipment and parts? • Do purchasing specifications exist that refer to safety-related issues for critical products, equipment, materials, and services?
2. Policy	Does the company have a policy that requires that a list of critical equipment be established? Does it state that reviews will be conducted to assess ongoing mechanical reliability, remaining life, and suitability of critical equipment and facilities, depending on service? Does this policy also state that methods, intervals, criteria, and limits be established for testing and inspection? (SEMP 8.5, 8.6)	• Are management reviews of maintenance backlogs required and do they occur? What process is in place to ensure that action is taken to reduce or eliminate maintenance backlogs? In particular, are such reviews required and conducted for the inspection of safety-critical items? • Are maintenance procedures issues addressed (e.g., content, availability, language, expectations, etc.)? • Does a listing of safety-critical equipment exist? • Are maintenance/inspection histories reviewed for trends by management? Are inspection schedules modified based on historical data? • Are requirements defined for outside maintenance contractor qualifications?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
3. Mechanical Reliability - Containment	Does the company regularly assess, test, and inspect equipment containing hydrocarbons and other hazardous material to assure integrity, and do these efforts include testing material compatibility and reviewing wall thickness for service conditions, including erosion and corrosion? (SEMP 8.5; API 510; ISM 10.3, 10.4; PFEER 19.4; FLAIM B2.5, B3)	• Does a listing of safety-critical equipment exist? • Do criteria exist for acceptable limits for equipment? • Are equipment specifications with reference to standards and codes available and used for design and selection? • Are records of equipment installation kept and maintained? • Do specifications for installation exist? • Are manufacturer/supplier documents readily available to personnel?
4. Mechanical Reliability - Rotating Equipment	Does the company have a preventative and/or predictive maintenance program for rotating equipment in critical service? (SEMP 8.5)	• What criteria exist regarding acceptable operating limits for rotating equipment integrity? • Are records of installation, testing, and inspection kept and maintained? • Are manufacturer/supplier documents readily available to personnel?
5. Mechanical Reliability - Pressure Relief	Does the company regularly assess, test, and inspect equipment related to pressure relief to ensure that relief can occur when necessary? (SEMP 8.5)	• Are there equipment specifications with reference to design basis and standards and codes used for design and selection (including documentation of relief and vent calculations)? • What criteria exist for acceptable limits for equipment? • Does a listing of relief and vent equipment exist? • Are records of installation, testing, calibration, cleaning, and repair kept and maintained? • Are manufacturer/supplier documents readily available to personnel?
6. Mechanical Reliability - Shutdown Systems, both Emergency and Process	Does the company regularly assess, test, and inspect shutdown systems to ensure reliability? (SEMP 8.5)	• Do acceptance criteria exist for shutdown devices, including listings of set points and operating limits? • Are there specifications with reference to standards and codes used for design and selection? • Does a listing of safety-critical devices exist? • Does the schedule for testing and calibration reflect safety priorities? • Are records kept of installation, testing, calibration, adjustments, and periods when equipment is taken out of service or not functioning? • Are manufacturer/supplier documents readily available to personnel?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
7. Mechanical Reliability - Emergency Response Systems	Does the company regularly assess, test, and inspect fire fighting, spill control, and other equipment used for emergency response? (SEMP 8.5)	• Are there equipment specifications with reference to standards and codes and regulations used for design and selection? • Does a listing of safety-critical equipment exist? • Are there periodic documented checks of Emergency Response Systems such as alarms, emergency lighting, life rings, boats, spill equipment, communications devices, etc.? • Are records of installation maintained? • Are manufacturer/supplier documents kept available for personnel?
8. Reliability - Life Saving and Evacuation Devices	Does the company regularly assess, test, and inspect mechanical components and equipment associated with evacuation devices including life rafts, personal floating devices, etc.? (SEMP 8.5)	• Are equipment specifications with reference to standards and codes and regulations used for design and selection? • Does criteria exist for acceptable limits for equipment? • Does a listing of safety-critical equipment exist? • Are there periodic documented checks of life saving and emergency devices such as nets, stairwells, life jackets, boats, etc.? • Are records of installation maintained?
9. Spare Parts	Has the company identified critical spare parts and included these on an inventory, and does the company ensure that these parts are available within acceptable time limits? (Organization #8)	• Are spare parts readily accessible to operations and maintenance personnel? • Do criteria exist for acceptance or rejection of parts? • Is an inventory control system in place? • How is ordering/inventory monitored to identify possible deficiencies in the inventory list or availability of spare parts? • Are procedures in place for ordering, purchasing and receiving spare parts? • Does a listing of safety-critical equipment/parts exist? • Is there a list of approved vendors and suppliers? • Are manufacturer/supplier documents, including manuals, readily accessible to personnel?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
10. Documentation	Is documentation concerning assessment methods and procedures, acceptance criteria, and the results of tests and inspections kept; and is information concerning replacement of equipment, instruments, and components documented and retained for a minimum of two years? (SEMP 8.6)	• Are maintenance procedures in place, including preventative maintenance plans, testing and inspection procedures and records, fire protection maintenance records, deficiency correction records, and installation instructions or specifications? • Are records kept on outside maintenance contractor qualifications? • Are records kept of maintenance, testing, and inspection personnel? • Are there records of compliance with appropriate standards and codes? • Are equipment histories maintained? • Do schedules for inspection and testing exist? • Are piping system records kept? • Is control system information readily available? • Are relief and vent records maintained? • Are an instrument index and specifications kept and maintained?
11. Deficiencies	If equipment deficiencies are judged to be outside limits (as defined in the process safety information), are these deficiencies corrected before further use or corrected in a safe and timely manner after necessary steps to assure safe operations have been taken? (SEMP 8.6)	• Are there acceptance criteria for critical equipment and parts? • Does a noncompliance/deficiency documentation method exist? • Are there corrective action procedures? • Are records of corrective actions taken? • Are maintenance-related schedules revised based on inspection and test results? • Does a method exist for tagging and logging out of service items when deficiencies are found?
12. Review and Authorization of Changes	What system for reviewing and authorizing changes in procedures, tests, and inspections exists, and is it aimed at managing hazards and risks? (SEMP 8.5)	• Does the change package refer to standards and codes? • Does management review backlogs of maintenance or inspection for safety-critical items?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Emergency Response

General Sub-Categories	General Questions	Detailed Questions
1. Emergency Response and Evacuation Plans	Does the company have emergency response and contingency plans in place for losses of containment, including releases, fires and explosions, and spills? Do these plans or policies outline the company's philosophy and the components of appropriate responses (e.g., for fire: whether to stand and fight, evacuate, etc.)? (SEMP 10.1; ISM 1.4.5; PFEER 6,12; *Organization #4*; FLAIM B8.2)	• What are the requirements for ensuring competence of individuals in emergency response and checking familiarity with plans? • Do emergency plans include instruction for various types of emergencies, including spills? • What are the contents of the Emergency Plans (organizational chart, maps, possible hazards, resources for assistance, necessary phone numbers, etc.)? • Are the Emergency Response and Evacuation Plans accessible and up-to-date? • What are the steps for spill response and escape and abandonment procedures and routes? • What procedures exist for accounting for personnel at assembly points? • Is there any requirement for protocol or training for communications in reporting or managing emergencies? • Are there contingencies in the Emergency Plan for first aid responders (minimum per facility, their role in emergency, reporting station, etc.)?
2. Emergency and Contingency Response Equipment	Do the emergency response and contingency plans identify emergency equipment that should be available for use during response?	• Are signs posted or marked for evacuation routes? • Are signs posted and markings maintained for emergency equipment (extinguishers, stretchers, hoses, escape packs, personal breathing apparatus, etc.)? • Are the number of emergency shutdown locations sufficient and are they readily accessible? Are emergency shutdown locations sufficiently marked? • Does emergency lighting for evacuation routes exist?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Emergency Response (continued)

General Sub-Categories	General Questions	Detailed Questions
3. Emergency Management Authority and Compliance with Regulations	Do the emergency or contingency plans assign authority to appropriate qualified person(s) and address emergency reporting and response, complying with the most current revision of one or more of the following regulations (as applicable): • Emergency evacuation plans? (USCG-33; CFR 146.140) • Oil, gas and sulfur operations in the OCS? (MMS-30; CFR parts 250, 256) • Oil spill contingency plan? (USCG) • Pipeline emergency plans? (USDOT-49; CFR 192, 195; SEMP 10.2; ISM 8; FLAIM B6.2, B8.3)	• Does the Emergency Plan clearly identify individual responsibilities in an emergency, including those of people who actively manage situations, operators of critical equipment, and first aid responders? • Is technical support available and designated, if needed, during an emergency?
4. Emergency Control Center or Incident Command Center	Has a Center been designated for each facility, and does the Center include the following: • Emergency Action Plan • Oil Spill Contingency Plan • Safety and Environmental Information? (SEMP 10.3)	• Are Emergency Response and Evacuation Plans accessible and up-to-date? • Is the Center designated and equipped with safety information (MSDSs, communications equipment, copies of emergency and environmental response plans)?
5. Revision Process for Plans	Are the actual persons who will respond to loss-of-containment situations (including releases, fires, explosions, spills and other contingencies) included in the review of plans for such events, and does a mechanism exist for these personnel to provide comments regarding such plans to management? (PFEER 8)	• Is there a periodic review of the Emergency Plan? • Is a mechanism for requesting changes in place and understood by all personnel affected? • Are records of corrective actions from drills or audits provided for revision of the Emergency Plan? Is there evidence of revisions based on suggested corrective actions? • Does the designee for endorsing the evacuation plan ensure that the plan is current with regulations and practices? • Is feedback provided on acceptance/rejection of requested changes?
6. Drills	Does the company have drills that are effective in regard to testing plans and correcting weaknesses? (SEMP 10.4; PFEER 8)	• What is the minimum requirement for drill frequency, and what types of drills are held by year? • Does documentation of results of drills exist? • Are drill results evaluated? • Are corrective actions following drills implemented and documented? • Does management review drill results?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Emergency Response (continued)

General Sub-Categories	General Questions	Detailed Questions
7. Communications	Are emergency warnings for fires and explosions in the facility audible and, where appropriate, visual? (PFEER 11) (PFEER 11.2 - types of visual and acoustic warning signals)	• Does emergency plan documentation of contacts and phone numbers exist, and is it accessible to personnel? • Does the plan address alternatives if certain contacts are unavailable? (Note: Phone trees may be used to assign contact responsibilities.) • Is there a protocol or training provided on communications for reporting or managing an emergency?
8. Emergency Equipment and Systems	Has the company evaluated fire and life protection systems and provided adequate protection? (FLAIM B7)	• Is there periodic inspection and necessary calibration or repairs for the following systems: * Platform fire water systems * Fire water distribution systems * Fire water hose stations, hydrants, and monitors * Fixed fire water spray/deluge systems and sprinkler systems * Fire fighting foam systems * Fixed and portable chemical fire suppression systems - including liquids, gaseous agents, and powders * Dry chemical agents * Fire detection systems * Combustible gas detection systems * Alarm and communication systems * Emergency power and lighting * Emergency shutdown (ESD) systems * Pressure relief and vapor depressuring (blowdown) systems * Liquid spill control provision (e.g., absorbent pads, sawdust, etc.) * Thermal robustness and passive fire protection systems * Design for explosion protection * Personal protective and safety equipment (e.g., personal breathing apparatus, protective clothing, fire blankets, etc.) * Communications equipment? • Is there documentation on inspections and are expiration dates assigned to the inspected equipment?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms General and Detailed Questions (continued)

Investigation and Audit

General Sub-Categories	General Questions	Detailed Questions
1. Investigation Policy	Does the company have procedures in place to promptly investigate, document, and report all accidents and incidents with qualified personnel to help prevent similar occurrences? (SEMP 11.1; ISM 1.4.3, ISM 1.4.4, ISM 9; HSEMS 3.6.5; Company X #9; HSEMS 3.6.4)	• What are the requirements for investigators to receive training on investigation methods? • Does a mixed-discipline team investigate? • Is there a system in place for near-miss reporting? • Do confidential reporting schemes exist? • Are time limits defined to report, investigate, and follow-up on accidents and incidents?
2. Investigation	Do company investigations address the following: • The nature of the accident or incident • The factors that contributed to the accident or incident and the mitigation actions that should be taken to prevent or minimize the effects of a recurrence • Recommended actions identified as a result of the investigation? (SEMP 11.2)	• Is an investigation procedure/form available? • Are reporting requirements defined? • Are root causes defined via a formalized method? • Is suggested corrective action documented?
3. Investigation Follow-Up	Does the company distribute findings of an accident or incident investigation to appropriate personnel and similar facilities, and are procedures in place to ensure that corrective actions are completed? (SEMP 11.3; HSEMS 3.6.6)	• Are patterns and statistics monitored and reviewed? • Do the results go to a Joint Safety Committee? • Are results of incidents, conclusions, and corrective actions distributed to all levels? • Are incidents and suggested corrective actions reviewed by management? • Are unresolved incident reports reviewed at management meetings? • Is implementation of corrective actions monitored?
4. Investigation Record Retention	Does the company ensure that accident and incident investigation documentation is retained for a minimum of two years? (SEMP 11.3)	• Are appropriate records retained on accidents and incident investigations for at least the previous two years?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms
General and Detailed Questions (continued)
Investigation and Audit (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Auditing System	Does the company have a system in place to ensure that periodic audits of the safety and environmental management system are conducted, including reviews of hazards analysis, management of change, mechanical integrity, operating procedures, training, safe work practices, emergency response, and investigation systems? (SEMP 12.1)	• Does the audit policy and procedure define: * the team for the audit * the required training for the team * the extent of the audit * the documentation that is required * other important requirements (including the audit schedule)?
6. Auditing Personnel	Are audits conducted by personnel who are independent of the areas being audited? (SEMP 12.1; ISM 1.4.6, ISM 12; HSEMS 3.6.2, 3.7.1; FLAIM B8.1.1, B8.1.3 [Safety Assurance Program])	• Is a multi-disciplinary team responsible for auditing?
7. Audit Reporting	Does the company have procedures in place to ensure that audit findings are provided to appropriate personnel, that actions are taken to resolve inadequacies, and that audit reports are retained until the completion of the next audit? (SEMP 12.2; HSEMS 3.6.3)	• Do audit findings include strengths and noncompliances? • Are corrective actions documented? • Are audit findings tracked?
8. Schedule	Was an initial audit conducted within two years of the initial implementation of the process safety management program, and is the interval between audits less than four years? (SEMP 12.1)	• Is there a method for tracking for compliance with the auditing schedule?
9. Reviewing	Does the company's senior management, at appropriate levels, review audit results to ensure that findings and resolutions are satisfactory in terms of managing hazards and risks, and are similar reviews given for company policies? (SEMP 12.2; HSEMS 3.7.2)	• Are the results of an audit, including strengths, noncompliances, and suggested corrective actions, reviewed by management?

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms General and Detailed Questions (continued)
Reference Codes and Sources

Code	Description
API	American Petroleum Institute
API RP	American Petroleum Institute Recommended Practice
API RP 14J	American Petroleum Institute Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities
Bird & Germain	Bird, Frank E., Jr., and George L. Germain, *Practical Loss Control Leadership.* Loganville, Georgia: DNV Loss Control Management. 1985.
CCPS	Center for Chemical Process Safety of the American Institute of Chemical Engineers. *Guidelines for Auditing Process Safety Management Systems.* New York: American Institute of Chemical Engineers, 1993.
CFR	Code of Federal Regulations
Company X	A major oil company's safety management systems audit
FLAIM	Gale, W.E., Jr., Bea, R.G., and Williamson, R.B. "FLAIM, Fire and Life Safety Assessment and Indexing Methodology, Final Report to the US Department of the Interior, Minerals Management Service, Technology Assessment and Research Branch." Department of Civil Engineering, University of California, Berkeley, 1994.
Geller	Geller, E. Scott. *Working Safe: How to Help People Actively Care for Health and Safety.* Radnor, PA: Chilton Book Company, 1996.
Harrison	Harrison, P.I. *Organizational, Management and Human Factors in Quantified Risk Assessment (Report 2).* Sudbury, Suffolk, England: Health & Safety Executive Research Report No. 34/1992.
HSEMS	International Organization for Standardization. *International Standard for the Development of Safety, Health and Environmental Management for Oil and Gas Production Operation and Facilities* (ISO/CD 14 690). New York: International Organization for Standardization.
ISM	International Maritime Organization. *International Management Code for the Safe Operation of Ships and for Pollution Prevention:* International Safety Management Code, Resolution A.741 (18). London, England, 1993.
Krause, Hidley & Hodson	Krause, T.R., J.H. Hidley, and S.J. Hodson. *The Behavioral Based Safety Process: Managing Involvement for an Injury-Free Culture.* New York: Van Nostrand Reinhold, 1990.
Op Team & Organization	Research including • Libuser, Carolyn B., and Karlene H. Roberts. "The Development of a Conceptual Model for Risk Mitigation." Thesis, University of California, Berkeley, 1995. • Bea, R.G., and K.H. Roberts. "Human and Organization Factors (HOF) in Design, Construction, and Operation of Offshore Platforms" (OTC 7738). Paper presented at the 27th Annual Offshore Technology Conference, Houston, Texas, 1-4 May 1995. • Boniface, D.E. "An Analytical Methodology to Assess the Risks and Countermeasures for Human and Organizational Error in the Marine Industry." Thesis submitted in partial satisfaction of the requirements of the degree of Master of Engineering, Department of Naval Architecture and Offshore Engineering, University of California, Berkeley, 1996.

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Offshore Platforms General and Detailed Questions (continued)
Reference Codes and Sources (continued)

Code	Description
Petersen	Petersen, Dan. *Human-Error Reduction and Safety Management.* New York: Garland STPM Press, 1982.
PFEER	Health and Safety Commission. *Prevention of Fire and Explosion, and Emergency Response on Offshore Installations.* Sudbury, Suffolk, England: HSE Books, 1995.
SEMP	American Petroleum Institute. *Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities* (API RP 75). Washington, DC: American Petroleum Institute, 1993.
UKOOA	United Kingdom Offshore Operators Association
USCG	United States Coast Guard
USDOT	United States Department of Transportation

5.4.2.3 Scoring

The nine categories, which are encompassed by the Minimal Basic Question set (i.e., general questions), and the detailed questions provide the framework for completing a platform's MAST safety management systems assessment. During an initial evaluation, each question in the Minimal Basic Question set would be investigated for supportive written guidance in the company's policies, program descriptions and procedures. An initial score on a 1 to 7 scale would be given and recorded. The assessment scale is the same as that presented in Table 3.4.2, SAMS Minimal Basic Question Set Assessment Scale Anchor Points. The table is replicated on the next page for the reader's convenience.

For all general questions listed in the Minimal Basic Question set, the assessor would investigate whether practices meet the company's written requirements. This step would determine whether or not true implementation was occurring for a particular offshore platform. It would also show if, in some cases, practice in the field actually meets good practices as defined by the assessment criteria, but deficiencies exist in written guidance. This step would require investigations beyond written policies, procedures, and manuals and would involve checking records, forms, and reports and interviewing personnel at different levels of the organization.

Table 5.4.2.3a: SAMS Minimal Basic Question Set Assessment Scale Anchor Points

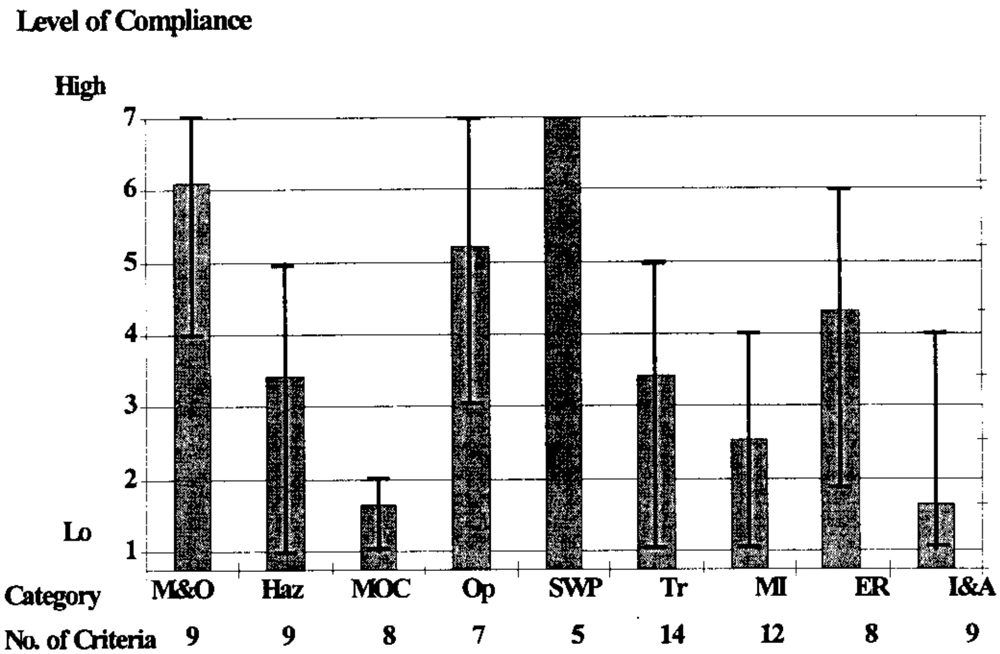
Score (Level of Compliance)	Anchor Point Description
7 (Complete compliance and additional risk or safety studies)	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization. • In addition, the company has taken further measures in this area such as conducting studies or training sessions. • Studies may involve risk assessment, human factors analyses, or integrated risk, safety, environment, quality and loss control programs.
6	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization.
5	• The company addresses this concern in writing and in practice, and implementation is occurring fully at most levels of the organization although minor deficiencies were noted during the assessment process.
4	• The company addresses this concern in writing, but evidence of practice at all levels of the organization is incomplete. • Still, implementation is under way and at an advanced stage.
3	• The company addresses this concern in writing, but evidence of practice at all levels of the organization does not exist. • Implementation is under way and in the initial stages.
2	• Some written guidance exists. • Steps are being taken to meet this criterion in practice. • A schedule for finalizing written guidance and for beginning implementation exists.
1 (Little or no compliance)	• Little or no written guidance exists. • Practice is inconsistent, and no implementation is occurring.

For areas where the assessor requires more complete information or where initial investigations show weak evidence of written guidance or actual practice, the assessor could use the detailed questions to determine the exact nature of deficiencies. The detailed questions could also be used to point to good practices above and beyond the strict interpretation of the questions in the Minimal Basic Question set and identify areas of excellence. All document reviews, investigations and interviews of personnel would be used to determine an offshore platform's level of compliance. These activities would occur both at the corporate offices and in the field, i.e., at the offshore platform.

To reiterate, the purpose of the detailed questions is to assist the assessor in evaluating compliance and to determine where strengths and weaknesses exist in the organization's treatment of process safety, human factors and organizational concerns. Detailed questions are also provided to assist assessors in decision-making about meeting and exceeding general question requirements. These details provide guidance on factors related to good practices for strong treatment of process safety management and human and organizational factors. Based on the document reviews, visits to the corporate offices, and interviews with personnel in various parts of the organization, assessors would weigh the evidence and modify initial scores. It should also be noted that the assessor should make notations concerning observations on questions. The assessor could also use these notes when deciding final scores for questions.

Upon finishing MAST safety management system assessment activities, the assessor would be able to look at compliance within and across safety management assessment categories. For each category, an average score would be calculated. The scores across categories would be plotted on a bar chart to provide a visual indication of overall compliance. Ranges of scores within a category would also be provided so that the basis for an average score could be evident. Assessors could use this bar chart in a report provided to the facility following an evaluation. An example of such a bar chart is provided in Figure 5.4.2.3, Example Graphic Representation of Evaluation Results.

Figure 5.4.2.3: Example Graphic Representation of Evaluation Results



Key: M&O - Management & Organizational Issues, Haz - Hazards Analysis, MOC - Management of Change, Op - Operating Procedures, SWP - Safe Work Practices, Tr - Training and Selection, MI - Mechanical Integrity, ER - EmergencyResponse, I&A - Investigation and Audit

5.5 MARINE TERMINALS

5.5.1 Physical Qualities Assessment

An initial set of criteria was developed for marine terminals by John Stiff at Noble Denton based on his expert opinion and experience in the marine industry. The criteria were presented to participants at a SAMS meeting on October 15, 1996.

For terminals, initial criteria included the following:

- Ship construction, single- or double-hull
- Type of vessel loaded or unloaded (Ships, barges etc.)
- Number of spots for simultaneous unloading and loading
- Physical aspects of terminal (tides, currents)
- Density of other traffic in area
- Type of facilities used (pilot facilities, tug facilities)

The criteria were created to stimulate ideas regarding the sorts of items that might be considered for a physical indexing scheme. The criteria were never intended to represent a final set.

Personnel from the State of California, State Lands Commission, Marine Facilities Division (California State Lands) conducted a brainstorming session to further develop the physical qualities list for marine terminals. The list is considered a point of departure, based on the perceptions of field and headquarters personnel. For California State Lands, the essential question is, "What physical qualities of a marine terminal affect the risk of an oil spill?" In response to this question, California State Lands personnel developed the criteria in Table 5.5.1.1, California State Lands Physical Qualities List for Marine Terminals.

Table 5.5.1.1: California State Lands Physical Qualities List for Marine Terminals

A. Most Critical (listed in order of priority)	**B. Critical (listed alphabetically, not prioritized)**	**C. Least Critical (listed alphabetically, not prioritized)**
1. Number, frequency, and rate of transfer	1. Dock material	1. Booming equipment
2. Maintenance standards	2. Electrical and mechanical equipment	2. Lack of resources
3. Terminal age and physical condition	3. Environmental factors	3. Location of isolation valves
4. Location, design criteria and marine terminal size	4. Fire protection equipment	4. Structural protection (fenders)
5. Safety devices and emergency shutdown system	5. Location of control center	5. Type of oil
6. Communications equipment	6. Method of transfer: loading arms or hoses	6. Time of transfer: day or night
7. Automation level	7. Mooring arrangement	7. Vapor control system and its location
8. Size, number, and location of pipelines	8. Sump capacity, discharge and drain system	8. Vehicle access
	9. Vessel traffic density in vicinity	9. Vessel flag and type

5.5.1.1 Final Product

Building on the initial list and the list developed by California State Lands, a third exercise was completed to develop a set of scoring criteria for marine terminals. This exercise included assembling a team of marine terminal experts, in this case from Paragon Engineering Services, Inc. to further develop the physical quality assessment criteria. The inputs to this activity included the following:

- Initial criteria listed in Section 5.5.1 above
- Criteria provided in Table 5.5.1.1, California State Lands Physical Qualities List for Marine Terminals
- USCG Foreign Vessel Targeting Matrix
- Facility and Vessel Priority Determination developed by California State Lands Commission Marine Facilities Division
- MAST Physical Qualities Indexing System for Offshore Platforms

Armed with the prior sets of criteria, the materials from the California State Land Commission, and the US Coast Guard, as well as the Offshore Platforms Physical Qualities criteria, the team undertook an exercise to define categories applicable to marine terminals physical qualities, define criteria within these categories, and finally establish a method of scoring. The team took the perspective that evaluation categories should match the natural divisions which comprise a terminal.

These divisions, and thus evaluation categories were as follows:

- Vessel criteria
- Terminal criteria
- Tank farm criteria

Within these categories, the team then suggested criteria that would outline the characteristics of the particular part of the marine terminal that related to the category. The candidate criteria were then discussed and decisions were made concerning what factors were desirable or undesirable with the context of either increasing or decreasing the probability of a loss of containment incident. The categories and the criteria were documented and comparisons were made of these to proprietary products used for evaluating marine terminal safety and to descriptions of marine terminal operating and safety equipment.

Points were assigned to physical attributes that could be used to evaluate the relative ratings of the marine terminals. Multipliers used were based on California State Lands Commission data and estimates by personnel who were familiar with the marine terminals. The base-case physical qualities index is presented in Figure 5.5.1.2a, Physical Qualities Rating Worksheet (Initial Version).

Once the new set of criteria was assembled, a table-top exercise was conducted to test the validity of the method. California State Lands Marine Division plans to conduct field testing of the method in September 1997.

5.5.1.2 Marine Terminals Indexing Test

NOTE: RESULTS OF TABLE-TOP EXERCISE AND SEPTEMBER FIELD TESTING ARE PENDING.

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version)

Terminal Name: ______________ Operator: ____________________

VESSEL-RELATED CRITERIA

Quality	Scoring: Attribute	Points	Total
1. Type of Product	Explosion Hazard:		
	Crude Oil	1	
	Refined Products	2	
	LPG	6	
	LNG	10	
2. Size & Type of Vessel	Under keel clearance <10 ft	1	
	>80,000 Dry Weight Tons	1	
3. Vessel Flag and Type	Priority 1 Rating by Coast Guard		
4. Measurement of Compartments	Remote (level gauges)	0	
	Remote Alarms for High/Low	1	
	Manual	2	
5. Pumping System/Capacity	Discharge Rate	1 per 25,000 BBLS/HR	
6. Connecting System	Automatic Self-Sealing	0	
	Manual Flange	1	
7. Vessel Integrity Inspection Frequency	0 - <5 yrs	0	
	5 - < 10 yrs	1	
	10+ yrs	2	
8. Communication with Terminal	No common language w/terminal personnel	1	
	No communication equipment on vessels or not intrinsically safe	1	
9. Flue Gas Blankets	None Present	1	
10. Fire Protection	Deluge	0	
	Pump	1	
	Subtotal Vessel Criteria		

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

MULTIPLIERS FOR VESSELS

Quality	Attribute	Multiplier
1. Number of Transfers per year	30+	1.0
	17 - 30	1.3
	6 - 16	1.6
	<6	2.0
2. Containment	Spill rail on deck	1.0
	No spill rail on deck	1.2
3. McKenzie Rating	Tank Barge	N/A
	5	1.0
	4	1.2
	3	1.4
	2	1.6
	1	1.8
	Subtotal Vessel Points	
	Vessel Final Score	

Final Score = (Total Points) x (Multiplier 1) x (Multiplier 2) x (Multiplier 3)

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TERMINAL CRITERIA

Quality	Scoring		
	Attribute	**Points**	**Total**
Port Criteria			
1. Tugs	Only 1	1	
2. Width/Depth of Port	Width < 400 ft Depth < 40 ft	1 1	
3. Traffic (Density)	No. of vessels on berth X No. of vessels in transit nearby	1 per vessel X No. in transit nearby	
4. Control of Traffic	Not under control of USCG or other port authority	1	
	Subtotal Terminal Criteria		

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TERMINAL CRITERIA (continued)

Quality	Scoring		
	Attribute	**Points**	**Total**
Dock Criteria			
1. Normal Operating Staff	Staff: No. of normal operating personnel Shift >8 hrs. Add 1 pt for every hour over 8 hrs. Add 5 pts for non-regular staff	0.5 for each Add 1 pt for every hour over 8 hrs. 5	
2. Terminal Materials of Construction	Concrete/steel in good condition Concrete/steel, but corroded Wood	0 1 2	
3. Dock Mooring Facilities	No. of Berths	2 ea	
4. Fender System	None Installed	1	
5. Pipelines	No. of Pipelines X Length of P/L over H_2O /100'	1 ea X L (over H_2O)/100'	
6. Exposed Piping	Mechanical Hazards	1	
7. Corrosion Protection	No Cathodic Protection	2	
8. Transfer Equipment	Loading Arms Hoses Liquified gas service	1 ea 1 ea 5	
9. Visibility	Low visibility due to fog, low lighting, night time	1	
10. Metering	No monitoring during transfers No spill control provided for metering	1 1	
11. Pumping	No monitoring during transfers No spill control provided for pump stations	1 1	

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TERMINAL CRITERIA (continued)

Quality	Scoring		
	Attribute	**Points**	**Total**
Dock Criteria			
12. Vapor Control/Recovery System	Volatiles loaded w/o vapor recovery system Poor condition or non-functional	1 1	
13. Valve Systems	No Isolation Valves No Automated Valves	1 1	
14. Shutdown and Emergency Shutdown Devices	>10 3 - <10 1 - 3	0 2 3	
15. Detection Systems	Inadequate Fire Detectors Hydrocarbon Detectors	2 2	
16. Communications	Communications equipment in place, functional and intrinsically safe No communication equipment or equipment non-functional No secondary communications	0 1 1	
17. Location of Control Center	View of vessel No visual contact with vessel No control center	0 1 2	
18. Electrical/Mechanical Equipment	Generators on dock Cranes: Inadequate number of cranes Inadequate size for loads managed Poor condition	1 ea 2 2 4	

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TERMINAL CRITERIA (continued)

Quality	Scoring		
	Attribute	**Points**	**Total**
Dock Criteria (continued)			
19. Fire Protection Systems	Fire Water System- none or inadequate Pressure <80 psig at point of usage Pressure at 80 psig+ at point of usage Foam System	5 2 1 0	
20. Security	Uncontrolled Access	5	
21. Vehicle Access to Dock	Vehicles allowed on dock Not accessible to outside firefighting equipment	1 2	
22. Area Classification	Class 1, Division 1 Class 1, Division 1 compromised by vehicles or other ignition sources	0 2	
23. Incinerators/Flares or other sources of ignition	Distance from transfers <500 ft	5	
24. Static Electricity Protection	Vessel/Dock has poor or no grounding systems	5	
25. Gangway	Secured and safety net present Poor condition or no net Supplied by vessel	0 1 1	
26. Slop Tankage	Remote Slop Tankage Slop Tankage @ Dock or over water No Slop Tankage	0 1 2	
27. Oily Water Storage/Treatment Systems	No Oily Water Storage/Treatment System Available for receiving ballast water	1	

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TERMINAL CRITERIA (continued)

Quality	Scoring		
	Attribute	**Points**	**Total**
Dock Criteria (continued)			
28. Spill Containment	Dock Area: Curbed Concrete Grating Wood Pipelines: No spill containment on pipelines Containment volume not sufficient to handle spills and fire water run off	 0 1 1 1 1	
29. Sumps and Drainage	Manually Operated Sumps Sumps in Poor Condition No Hose Drain-Up Facility	1 2 1	
30. Booming Facilities	Spill Boom Available Fire Boom Only None Available	0 1 2	
31. Spill Boats	None onsite Onsite, but not accessible, poorly located of non-functional	2 1	
32. Escape Equipment	Rope only None available	1 2	
33. Spill Cleanup Equipment	Minimal equipment onsite. (No vacuum equipment)	1	
34. Spill Response Contractor	No record of authorized Oil Spill Response Organization (OSRO)	1	
	Subtotal Terminal Criteria		

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

MULTIPLIERS FOR TERMINALS

Quality	Attribute	Multiplier
1. Type of Terminal	Fixed, onshore	1.0
	Fixed, but on jetty or offshore	1.1
	Mobile or floating	1.2
2. Type of Product	Crude Oil	1.0
	Refined Products	1.2
	LPG	1.4
	LNG	1.6
3. Structural Condition	Good	1.0
	Poor	1.2
4. Proximity to Hazards	No nearby hazards	1.0
	Adjacent to potential hazards	1.1
5. Spill/Reportable Incidents (for previous 2 years)	No reportable incidents	1.0
	At least one reportable incident	1.1
	>1 reportable incident	1.2
6. Loading/Unloading	No. of transfers per year:	
	100+	1.0
	12 - 20	1.3
	20 - 100	1.6
	<12	2.0
	Simultaneous, multi-compartment loading/unloading from same vessel	1.1
	Simultaneous, multi-vessel loading/unloading	1.1
7. Maximum Operating Pressure	Up to 285 psi	1.0
	> 285 psi	1.1
8. Seismic	Zone 1 - 2	1.0
	Zone 3	1.1
	Zone 4	1.2

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

MULTIPLIERS FOR TERMINALS (continued)

Quality	Attribute	Multiplier
9. Type of Environment	Corrosive Environment	1.2
	Subject to Flooding	1.2
	Weather:	
	Moderate (West Coast)	1.0
	Moderate to Difficult (Squalls in area)	1.1
	Arctic Type Weather	1.3
	Tides:	
	Non-factor	1.0
	High variance	1.1
	Currents:	
	Non-factor	1.0
	High velocity	1.5
	Off-shore	2.0
10. Communications	Communication equipment in place, rated intrinsically safe & no language barrier with vessel crew	1.0
	Poor communication with vessel due to lack of equipment	1.1
	Poor communication with vessel due to language barriers	1.1
11. Inspection Frequency	0 - <5 years	1.0
	5 - <10 years	1.1
	10 + years	1.2
	Subtotal Points Terminal Criteria	
	Final Score Terminal	

Final Score = (Total Points) x (Multiplier 1) x (Multiplier 2) x (Multiplier 3) x (Multiplier 4) x (Multiplier 5) x (Multiplier 6) x (Multiplier 7) x (Multiplier 8) x (Multiplier 9) x (Multiplier 10) x (Multiplier 11)

May be revised after Cal State Lands review/field test.

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TANK FARM CRITERIA

Quality	Scoring		
	Attribute	Points	Total
Tankage Criteria			
1. Type of Product	Explosion Hazard: Crude Oil Refined Products LPG LNG	 1 2 6 10	
2. Proximity to Water	Bulk storage tanks located within 500 ft of water	3	
3. Depth to Groundwater	<10 ft	1	
4. Bulk Storage Tanks	No. of Tanks Capacity of Largest >500 BBLS Overall Capacity >1MM BBLS Overall Capacity >10MM BBLS	1 ea 2 5 10	
5. Spacing	Multi-dike arrangement with dike around each tank (wide spacing) Single-dike arrangement with dike around overall facility (high tank density)	0 4	
6. Tank Construction	Roofs: Floating Roof Cone Bottoms: Single	 0 1 1	
7. Containment	Rain water or spills are not directed to treatment facilities Secondary Containment <100% Poor Condition	1 1 2	
8. Drains	No retention or treatment provided for drainage		

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

TANK FARM CRITERIA (continued)

Quality	Scoring		
	Attribute	**Points**	**Total**
Tankage Criteria			
9. Metering	No monitoring during transfers No spill control provided for metering	1 1	
10. Pumping	No monitoring during transfers No spill control provided for pump stations	1 1	
11. Vapor Control/Recovery System	Poor condition or non-functional No Vapor Control/Recovery System	1 2	
12. Valve Systems	No Isolation Valves No Automated Valves	1 1	
13. Shutdown and Emergency Shutdown Devices	1 - 3 3 - <10 >10	1 3 1	
14. Detection Systems	Inadequate Fire Detectors Hydrocarbon Detectors	2 2	
15. Area Classification	Class 1, Division 1 Class 1, Division 1 compromised by vehicles or other ignition sources	0 2	
	Subtotal Tank Farm Criteria		

Table 5.5.1.2a: Physical Qualities Rating Worksheet (Initial Version) (continued)

Terminal Name: ______________ Operator: ____________________

MULTIPLIERS FOR TANK FARM TOTAL POINTS

Quality	Attribute	Multiplier
1. Structural Condition	Good Poor	1.0 1.1
2. Proximity to Hazards	No nearby hazards Adjacent to potential hazards	1.0 1.1
3. Age of Tank Farm	0 - <10 yrs 10 - <20 yrs >20 yrs	1.0 1.1 1.2
4. Spill/Reportable Incidents (for previous 2 years)	No reportable incidents 1 reportable incident >1 reportable incident	1.0 1.1 1.2
5. Grounding	Not in place or in poor condition	1.2
6. Seismic	Zone 1 - 2 Zone 3 Zone 4	1.0 1.1 1.2
7. Type of Environment	Weather: Moderate (West Coast) Moderate to Difficult (Squalls) Arctic-Type Weather Corrosive Environment Subject to Flooding	 1.0 1.1 1.3 1.2 1.2
8. Fluid Corrosivity	H_2S Concentration: 0 - 4 ppm 4 - 100 ppm > 100 ppm CO_2 Concentration: 0 - 9% 10+ %	 1.0 1.3 2.0 1.0 1.1
9. Inspection Frequency (Tank Integrity)	0 - <5 years 5 - <10 years 10 + years	1.0 1.1 1.2
	Subtotal Points Tank Farm Criteria	
	Final Score Tank Farm	

Final Score = (Total Points) x (Multiplier 1) x (Multiplier 2) x (Multiplier 3) x (Multiplier 4) x (Multiplier 5) x (Multiplier 6) x (Multiplier 7) x (Multiplier 8) x (Multiplier 9)

5.5.2 Safety Management Systems Assessment

A modified version of the Minimal Basic Question Set described in Section 3.0 and the Offshore Platforms Question Set in Section 5.4.2.1 is used to evaluate a marine terminal's Safety and Environmental Program. The same nine categories of questions developed for offshore platforms are used for this assessment. These are:

1. Management and Organizational Issues
2. Hazards Analysis
3. Management of Change
4. Operating Procedures
5. Safe Work Practices
6. Training and Selection
7. Mechanical Integrity
8. Emergency Response
9. Investigation and Audit

The offshore platform model of the general question set shown in Figure 5.4.2.2a was used as a basis to create a marine terminal version of the Safety Management Systems Assessment. The general categories stayed the same; however, concerns fundamental to the operational and environmental aspects of a marine terminal required some addition or changes in the detailed questions. An environmental consultant who has participated as an assessor of oil and gas facilities was put to use to provide a quality check on this first phase of the model.

Once the candidate set of criteria specific to marine terminals was established, a group of marine terminal and safety experts from California State Lands Commission and Paragon Engineering Services, Inc. reviewed, expanded upon, and finalized the SMS materials. This exercise occurred in May 1997. After the final review from this group and an additional quality check in July 1997, this model was finalized and ready for coverage and assessment of the Safety and Environmental Program of a marine terminal. A compilation of the general and detailed questions developed for marine terminals is shown in Table 5.5.2.2a.

The history of the question set development is presented in Section 5.4.2.1, Minimal Basic Question Set, and Section 5.4.2.2, Detailed Quests Related to the Minimal Basic Question Set.

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions
Management and Organizational Issues

General Sub-Categories	General Questions	Detailed Questions
1. Safety & Environmental Policies	Do both a written safety policy and a written environmental policy exist, are these policies endorsed by upper-level management and widely distributed, and are employees generally aware of and follow the policies' contents? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)	• Are the safety and environmental policies reviewed and updated? • Are the revisions distributed and employees made aware of the fact that the policies have been revised? • Does the environmental policy include a commitment to environmental loss control and environmental protection, and is it reviewed annually? • Do these policies include a commitment to Human Factors? • Are safety meetings required and held on a regular basis, and do these meetings address any changes in the contents of the policies, environmental issues, and Human Factors issues?
2. Safety & Environmental Culture	Are assessments conducted for safety behaviors, environmental knowledge, and attitudes at all organizational levels, e.g., clerical, management, operations, and any other personnel? (Krause, Hidley & Hodson; Geller; Harrison; SEMP 1.2.2.h)	• Do company audits require an audit of the safety and environmental management systems? • Is there evidence of a long-standing process safety and an environmental loss control management program, e.g., documentation?
3. Management Structure Includes Health, Safety and Environmental Issues	Has the company established a management structure that clearly sets forth responsibilities for health, safety, and environmental issues and ensures that people with overall accountability do not have conflicting objectives (e.g., safety or environmental versus production)? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.a)	• Is there a Joint Safety Committee in existence with representation from both hourly and management personnel? In addition, does this committee review environmental issues? • Is there an individual who reports to top management regarding health, safety, and environmental issues? • Are the safety and environmental functions independent from the inspection functions? • Are safety and environmental objectives set yearly and tracked on an ongoing basis, and is this data made available to all levels of personnel? • Does a training department exist that includes someone directly responsible for training in safety and environmental-related issues?
4. Management Responsibilities and Accountability for Safety and Environmental Concerns	Does each individual manager's performance review include safety, environmental and loss control issues as a major component of the assessment? (Petersen; Harrison; Bird & Germain; SEMP 4.3)	• Do managers have objectives for safety, environmental issues, and loss control; and are these managers held accountable for the safety performance, environmental issues and loss control, and conformance to safety and environmental regulations of their team?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Management and Organizational Issues (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Management Monitoring for Health, Safety, and Environmental Issues	Does the company ensure that periodic audits and reviews occur for safety and environmental statistics, measures, and job descriptions; and that the results are discussed at management meetings? (Bird & Germain; Petersen; Harrison; CCPS; Krause, Hidley & Hodson; SEMP 1.2.2.g)	• Do management meeting agendas include a discussion of health, safety, and environmental issues? • Does management review both safety and environmental studies and statistics? • Does management ensure that job descriptions do not have conflicts between the objectives of the position and the safety and environmental requirements of that position? • Is there a formal method for reviewing the effects of organizational changes?
6. Resources Exist for Health, Safety, and Environmental Issues	Does the company designate safety and environmental personnel within the organization and provide funding for such positions and for both safety and environmental studies, audits, and equipment? (Bird & Germain; Petersen; Harrison; SEMP 1.2.2.b)	• Do safety and environmental personnel exist, and do these persons have human and organizational factors expertise and knowledge of environmental issues and loss control? • Are budgets set aside specifically for safety and environmental conformance, including resources for programs, studies, staff, equipment, and any additional training required to comply with safety and environmental regulations?
7. Defined Communications Channels for Safety and Environmental Concerns	Has the company established a formal means for personnel to report safety concerns or potential safety or environmental hazards? (Geller; Harrison: SEMP 1.2.2.b)	• Are company personnel informed of who to report either safety or environmental concerns and ideas, problems, and difficulties to beyond their immediate supervisors? • Are records maintained when safety or environmental concerns are reported? • Is there a formal follow-up method to reply to an employee concern and is it documented?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Management and Organizational Issues (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Safety Manuals and Environmental Information	Do Safety Manuals or handbooks that outline potential safety and environmental hazards and loss control/mitigation measures exist and are they available at work locations? (SEMP 1.1; CCPS; Harrison)	• Does the company have a safety and environmental handbook that employees can put in their pockets for quick reference if field work is part of their job description? • Do the manuals and/or handbooks appear to be used and updated on a regular basis. • Is the content of the safety manual periodically reviewed and updated and endorsed by management, and are the safety manuals updated when changes are made? • Does an environmental loss control reference manual exist, and if so, is it reviewed annually, updated, and endorsed by management? • Do requirements exist for defining proper basic attire and PPE for personnel and visitors? • Are visitors made aware of the locations of safety manuals, environmental loss control reference manuals, and provided with a field safety handbook if it exists? • Are visitors made aware of any environmental hazards that may exist?
9. Safety and Environmental Promotions	Does the company conduct safety and environmental awareness promotions (as evidenced by signs or meetings), is the staff aware of these promotions, and are these programs' effectiveness periodically evaluated? (Bird & Germain; Harrison)	• Are safety and environmental promotions evaluated for their effectiveness? • When new information is available concerning the worksite and corporate safety performance, is the staff informed, and is the information distributed properly? • Are steps taken to inform staff of risks (both environmental and safety related) associated with activities and inventories? • Does a system exist to reward safety performance or environmental awareness and does this system provide methods of discipline for unsafe performance, either related to safety on the job or neglect of potential environmental loss control issues?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Hazards Analysis

General Sub-Categories	General Question	Detailed Questions
1. Policy	Does the company have a general policy statement, either at the corporate or local level, that specifies when a hazards analysis is required and provides guidelines for selecting the study methodology, conducting the analysis, and choosing team members? (SEMP 3.1 & 3.5; API RP14J)	• Does the company have specific guidelines concerning hazards analysis, and is responsibility for the Hazards Analysis program defined? • Do the hazards analysis guidelines address frequency requirements, selection of study methodology, details for conducting the analysis, and choice of team members? • Is funding provided for hazard analysis studies?
2. Policy or Procedure	Does the company specify the objectives of a hazards analysis, including the need to identify the hazards of the process, review past incidents for potential catastrophic consequences, and evaluate the consequences of engineering and administrative controls failures? (SEMP)	• Are objectives for the hazards analysis specified by the company, including the need to identify the hazards of the specific process? • Is hazard identification training required for operators and maintenance personnel? • Are past incidents concerning potential catastrophic consequences and administrative controls failures reviewed and evaluated?
3. Schedule	Does the company have a policy or procedure that defines a rationale, priority order, and schedule for completing hazards analysis for existing facilities (from the most complex system to the simplest, from the systems considered highest-risk to those considered lowest), and does that policy or procedure define time frames for revalidations for hazards analyses? (SEMP 3.3.1, 3.4)	• Are hazards analyses performed prior to simultaneous operations, and are necessary changes implemented prior to simultaneous operations? • Are provisions in scheduling made to allow high-risk activities to be assessed before low-risk activities?
4. Documentation	Does the hazards analysis policy or procedure specify the documentation that is required for the study and the way the study will be documented, and does this policy also state that the hazards analyses and supporting materials will be retained for the life of the facility? (SEMP 3.6)	• Does the hazards analysis policy or procedure specify required documentation for the study and a format for this documentation? • Does the policy state that all hazards analyses and supporting data will be retained for the life of the facility?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation -Marine Terminals
General and Detailed Questions (continued)
Hazards Analysis (continued)

General Sub-Categories	General Question	Detailed Questions
5. Methodology	Is the company's current hazards analysis thorough, is the methodology used appropriate (for type, age and complexity of facility) or in compliance with API RP 14J or similar industry standards, and has a review of a typical hazards analysis been made? (SEMP 3.3, 3.4, 3.5, 3.6; PFEER 5; HSEMS 3.4.4, 3.4.1; Company X #2; *Op Team #7)*	• Does the review cover, at a minimum, toxic gases, high and low temperatures and pressures, ambient conditions, flow, level, chemical hazards, relief, spill response equipment and materials, and erosion/corrosion? • Does the review cover operational history and fuel inventory type and volumes history? • Does the review for human factors and ergonomics concerns include operations and maintenance; shift rotations, extended schedules and staffing; communications related to work conducted under work permit system; and escape routes? • Does the human factors review cover adequacy and reliability of controls and displays? • Does the human factors review answer alarm system adequacy questions such as: * In high noise areas, are visual indications of critical alarms provided (H_2S, fire, gas, etc.)? * Are critical safety and operations alarms discriminable from routine operations alarms? * Are alarm systems designed to prevent defeat or disabling? * Are alarms provided for fire, gas, etc.? * Are means provided in this location to alert personnel to major hazards or emergency events occurring in other parts of the facility?
6. Layout and Configuration	Does the hazards analysis include an evaluation of whether the terminal was designed such that the risk of fire and explosion is reduced? (SEMP 2.2, 2.3, 3.2; API RP 14J)	• Is an evaluation performed of the structural integrity of the terminal, including any structural damage or weakness that may have occurred due to a functional or environmental event? • Are reviews of layout performed for fire compartmentation, location of personnel shelters/refuges, separation of potential fuel and ignition sources, and emergency escape routes?
7. Hazard and Risk Reduction	Has the company addressed and implemented, where appropriate, the conclusions of the hazards analysis? (HSEMS 3.4.2, 3.4.3, 3.4.6; Company X #2)	• Is a tracking system used for addressing and implementing, where appropriate, the conclusions of the hazards analysis?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation -Marine Terminals
General and Detailed Questions (continued)
Hazards Analysis (continued)

General Sub-Categories	General Question	Detailed Questions
8. Process Design/Safety Information	Does the following documentation exist: piping and instrumentation diagrams (which specify acceptable set points and upper and lower limits for temperature and pressure, as appropriate) and mechanical and facilities design information; and are set points and limits available at the corporate and local levels and current; and does evidence exist that the appropriate mechanical design and facility design information was used during the hazards analysis? (SEMP 2.2 & 2.3; HSEMS 3.3.7.1.D2; PFEER 21; Company X #6)	• Is the Hazards Analysis information readily available? • Are details regarding materials of construction available? • Are Piping and Instrumentation Diagrams available, updated, and replaced with updated copies? • Does information regarding electrical classification exist? • Are design codes and standards employed? • Are all applicable regulations made available and abided by? • Do material and energy balances exist where appropriate? • Are equipment arrangement drawings available? • Do equipment specifications exist, and are they updated and distributed in a controlled manner? • Is a corrosion detection and prevention system in place? • Is a description of safety systems and their design in place (e.g., alarms, interlocks, emergency evacuation routes, fire protection systems, fire and gas detection or suppression systems such as fire water, deluge, or halon, etc.)? • Are materials regarding potential environmental hazards available, updated, and used in conjunction with the Hazards Analysis?
9. Communication of Hazards Analysis Results	Is information concerning hazards identified during a hazards analysis, and are recommended actions for control of hazards communicated to appropriate personnel in a timely manner? (SEMP 3.6)	• Are conclusions of management's decisions for recommendations resulting from Hazards Analysis made available? • Is a reporting mechanism in place for errors relating to environmental hazards? • Is information on hazards and hazard studies available? • Are records of management's decisions retained and readily available to employees to view upon request?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Management of Change

General Sub-Categories	General Questions	Detailed Questions
1. Policy	Does the company have a general policy statement, both at the corporate and local level, that specifies what constitutes a modification or change with regard to facilities or personnel and outlines required analysis to be completed before the implementation of a change, and does this policy address both permanent and temporary change requirements and state the requirements for maintaining accurate safety, environmental, and design information? (SEMP 4.1)	• Are specific criteria provided in written material on what constitutes a change? • Are specific criteria in place concerning replacement in kind? • Are specific criteria provided in writing on safety and environmental reviews? • Are specific criteria for temporary changes in place? • Is documentation in place regarding what constitutes a major, minor, or temporary change and what the process is for each type of change? • Are a formal initiation and approval policy and defined procedures for change requests in place? • Are responsibilities for follow-up and updating organizational documentation, procedures, and training defined?
2. Documentation	Does the policy or procedure specify the documentation that is required for a particular type of change and that which is required in the change packages? (SEMP 4.1)	• Are change forms available? • Is detailed information available for requesting or implementing a change? • Is a change package retained for a specified time period at the terminal prior to forwarding to headquarters and are steps taken to ensure that all terminal personnel review each package? • Are change packages retained at headquarters for an extended period? • Are change packages available for review by terminal personnel for review upon request? • Do any changes or modifications have an impact on the loss control program?
3. Change in Facilities	Does the company ensure that risks are identified, evaluated, and managed when changes in facilities are made? (SEMP 4.2; HSEMS 3.5.4.11; Company X #5; and FLAIM B5.3, B8.4)	• Does a review of changes for human factors and ergonomic concerns occur? • Does a mechanism for engineering review prior to change implementation exist? • Do these change reviews take place when system or equipment functions change? • Are applicable changes or past changes reviewed following operational or environmental events?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Management of Change (continued)

General Sub-Categories	General Questions	Detailed Questions
4. Change in People	Does the company take into account the possible effects of personnel changes and organizational changes in terms of risks and manage these effectively (including the use of contractors)? (SEMP 4.3; HSEMS 3.5.4.I2; ISM 6.3; Company X #5; FLAIM B5.3, B8.4)	• Is a review of changes conducted for necessary communication or reporting modifications? • Are changes in supervision and contacts reviewed?
5. Environmental Review	Does the company's safety and environmental management program require that the commissioning process include an environmental review for new and modified facilities? (SEMP 9)	• Is detailed information on completing environmental reviews available? • Are checks made for compliance with codes and standards? • Does confirmation exist that any facility or system modifications were built as designed? • Do criteria exist for the amount of time required and the type of hazards analysis needed depending on the type of change? • Before start-up, does verification that all hazard recommendations are resolved occur? • Before start-up, are checks completed for adequacy of procedures for start-up and commissioning, operating, maintenance, and testing (including checks that modifications of existing procedures or the loss control manual occurred, if needed)? • Do operator training, environmental checks, and equipment testing take place?
6. Communication and Training	Does the company ensure that changes are accompanied by training and communications, including updating of relevant procedures or practices, before the commissioning of new or modified facilities? (SEMP 4.4, 5.3, 7.4; HSEMS 3.3.6; ISM 6.7)	• Is training provided on identifying process, safety and environmental hazards that could occur due to implementing the proposed changes? • Does a method exist to ensure that all relevant personnel are informed of changes?
7. Authorization of Changes	Does a policy or procedure specify the authorization requirements for changes, the people who are qualified to authorize changes, and the requirement that changes cannot occur before authorization, and does such material outline any differences in the authorization process based on whether the change is permanent or temporary? (SEMP 4.4g)	• Are provisions for temporary changes in place? • Before a temporary change can become permanent, does a formal review of the change occur? • Is there an expiration date for temporary changes; how is it enforced?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Management of Change (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Safety & Environmental Information	Does the policy or procedure require the review of safety and environmental information before a change is made and outline the way modifications to this information will occur as the result of a change? (SEMP 4.4e)	• Is the level of documentation sufficient on the terminal for terminal-approved changes (e.g., temporary changes)? • Is a system in place to ensure that the terminal has all up-to-date copies of related regulations, standards, and codes?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Operating Procedures

General Sub-Categories	General Questions	Detailed Questions
1. Content of Operating Procedures	Does the company have procedures that address the following operations: start-up, normal operations, temporary operations, emergency shutdown and isolation, and normal shutdown? Are procedures available for simultaneous operations such as combinations of cargo loading, discharging, transfers, bunkering, or operations involving multiple products? (SEMP 5.2; FLAIM B8.1.2)	• Are environmental and operating concerns covered in formal procedures? • Is there a standard for the quality of documentation? • Is a formal procedure used for updating and distributing procedures? • When a procedure is created or updated, is it suitable for operators (language, detail matches equipment labels, diagrams, drawings, etc.)? • Are checklists used for routine tasks? • Are responsibility and authority defined for changes to procedures? • Are procedures reviewed by operators prior to issue (procedure verification and validation)?
2. Consequences of Deviations	Are operating limits for environmental concerns included in procedures, and are consequences of deviations from limits documented along with steps required to correct or avoid deviations? (SEMP 5.2c)	• Are responsibilities and authority defined for high-consequence operations and maintenance tasks? • Are the contents of environmental warnings, comments, and notes made available and clearly understood by personnel? • Are operating limits for environmental concerns defined by numerical values? • Does the definition of environmental issues include spills and release concerns as well as wind, weather and current limits?
3. Temporary Changes	In the general policy statement, is there information that specifies what constitutes a modification or change with regard to temporary procedural changes (or temporary procedures)? Is the policy or statement available to personnel both at the corporate and local level? Is the required analysis for authorizing a temporary change outlined in the policy and is the analysis completed before the implementation of a change?	• Does a method exist for requesting temporary procedure changes? • What time limits exist on temporary procedure changes? • Does documentation of temporary procedure changes occur? • Are responsibilities and authority clearly defined for changes to procedures, both permanent and temporary?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Operating Procedures (continued)

General Sub-Categories	General Questions	Detailed Questions
4. Periodic Review	When the company periodically reviews operating procedures in terms of validity for current and actual operating practice, do these reviews ensure that the procedures are written according to the level of experience, understanding, and knowledge of the user and that the procedures are easy to read? (SEMP 5.3; HSEMS 3.5.3)	• What link exists to ensure that all items from the management of change program are appropriately reflected in procedures? • How are procedures reviewed following near misses or incidents? • Prior to re-issue, is a review of procedures by operators conducted (procedure verification and validation)? • After staff reduction, what type of review is required for needed procedural changes? • Is a time period specified for when periodic review must occur of procedures?
5. Plan Preparation	Does written guidance exist for preparing plans, procedures and instructions, and does this guidance identify the need for assigning qualified personnel to this preparation task? (ISM 7)	• Does a writer's manual exist? • Does the company have a method for requesting changes to procedures? • Before a change is implemented, is it checked against process safety information? (e.g., metallurgy, pressures, temperatures, flows, etc.)
6. Follow-Through	Does the company ensure that operating procedures are understood and followed? (Company X #4; FLAIM B5.2)	• Is a follow-up method defined for requested changes, including time limits for safety and environmental items? • When changes to procedures are made, are the changes accompanied by training?
7. Document Control	Does the company have a system for controlling policies, procedures, and plans such that: • These documents are available at relevant locations • Changes are reviewed and authorized before distribution (SEMP 5.3) • Changes are communicated to appropriate personnel (SEMP 5.3) and • Obsolete documents are promptly removed? (ISM 11; HSEMS 3.3.7.2; FLAIM B8.1.2)	• Does an operations manual and emergency/contingency plan exist, and is it kept current with relevant regulations and available to all personnel? • Are materials describing operations and other necessary manuals readily available to any personnel? • How would an employee be able to tell that a procedure is the most current version? • Do distribution lists exist to ensure that all required parties receive information, and is any type of follow-up conducted to ensure that the most current information is in fact in the manual or procedures? • What is the availability of current drawings like process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs) at the terminal? • Are warnings, comments, and notes explained to relevant personnel, contractors, and visitors?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Safe Work Practices

General Sub-Categories	General Questions	Detailed Questions

1. Safe Conduct of Work Activities	Regarding Safe Conduct of Work Activities, do the company's safe work practices apply to all modes of operation, including maintenance and modification activities as well as simultaneous operations, and do these practices meet current regulatory requirements and consider and manage hazards and risks during the following activities:
	• Opening of equipment or piping
	• Lockout and tagout of electrical and mechanical energy sources
	• Hot work and other work involving ignition sources and
	• Confined space entry?
	(SEMP 6.2; FLAIM B5.1, B8.1.2)
		• Do the Safe Work Practice procedures cover isolation (electrical, mechanical, pneumatic, hydraulic), opening pressurized process or utility equipment or piping, bypassing safety equipment, and environmental issues?
		• Does documentation specify safety-critical and environmentally critical items and special requirements for taking equipment out of service (e.g., fire and gas detectors, emergency isolation valves, shutdowns, pressure and temperature switches, relief valves)?
		• Does a policy on control of access to the terminal for contractors, visitors, and corporate personnel exist?
		• Does a mechanism exist for allowing or preventing bypass of detector or safety interlocks? Are decisions documented when bypasses are permitted? Is there a mechanism for ensuring that bypasses do not become permanent by default?
		• Does modification of Safe Work Practices occur for simultaneous operations?
		• What type of formal mechanism (logs) exists for transfer of information between shifts?
		• What type of formal mechanism (logs) exists for transfer of information between crews?
		  * operations to maintenance including contractors
		  * maintenance to maintenance or contractors
		  * terminal to vessel
		• What type of formal mechanism (logs) exists for transfer of information between supervisors?
		• Are personnel held accountable for maintaining logs?
		• Does the crew change on a different day than the supervisor?
		• Are inspections of work areas planned and conducted?
		• Is a system in place for log-keeping for specific safety-related, environmentally-related, and critical operational parameters?
		• Are logs kept for routine information?
		• Is room provided in logs for narratives concerning shift operations and maintenance?
		• Is equipment labeled?
		• Does a clear policy exist on illness, substance abuse, etc.?
		• Is refusal to work for safety reasons or environmental concerns allowable?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Safe Work Practices (continued)

General Sub-Categories	General Questions	Detailed Questions
2. Work Permit or Authorization	Is a work authorization system used in conjunction with specific work practices to ensure adequate communications during work activities, and does the work authorization system address steps to be taken for providing information concerning unfinished work at shift change or crew change? (SEMP 6.2)	• Is a log kept on active work permits? • Does a policy exist regarding frequency of renewal of work permits? • Are work permits visible in a central area and at a local area while a permit is open? • Are all permits logged for retention? • Are inspections performed before and after maintenance by operations personnel? • What, if any, personal protective equipment (PPE) and other safety requirements for maintenance are specified on permits? • Are environmental concerns covered prior to issuing or renewal of work permits? • Does the supervisor or designee check that all permit requirements are met prior to starting work?
3. Control of Inventories and Material	Do written materials outline what inventories exist? Do these specify what special precautions to be taken by personnel to avoid environmental damage and personnel exposure to toxic or hazardous materials? Are these written materials available at the local level? (SEMP 5.2d, 6.3)	• Do documentation and procedures exist for monitoring, tracking, and replenishing inventory? • Is a system in place for labeling and/or sign posting for hazardous materials? • Are reactive chemicals separated and segregated appropriately? • Are flammables stored away from sources of heat and ignition?
4. Hazard Communications	Does the company have a hazardous communications program for providing information regarding hazards to personnel, such as: • Making Material Safety Data Sheets (MSDSs) available • Marking containers or equipment containing hazardous materials • Providing signs in areas where hazards may be present • Designating on safe work permits the personal protective equipment that is needed for hazards? (SEMP 6.3)	• Where hazards may be present, are signs posted? • Are bulk chemicals and their containers and other additives labeled according to hazardous potential? • Is equipment containing hazardous materials labeled accordingly?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Safe Work Practices (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Contractor Selection	Does the company obtain and evaluate information regarding a contractor's accident record and training program and use this information in contractor selection? (SEMP 6.4; HSEMS 3.3.5; Company X #8)	• Is training in work practices, safety rules, and environmental hazards provided for contracted tasks? • Is a formal orientation required on applicable parts of emergency and response plans? (including reporting, routes, alarm sounds, etc.) • Is an orientation on terminal-specific emergency response features provided? (e.g., shutdown switches, phones, muster/assembly points, etc.) • Is there an expiration date assigned to training to prompt periodic refresher training? • What type of provision is made for discipline where non-compliance with safety rules exists? • Are contractors required to demonstrate compliance with environmental regulatory requirements?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Training & Selection

General Sub-Categories	General Questions	Detailed Questions
1. Initial Training	Does the company ensure that initial training takes place as appropriate and that this training is documented? (SEMP 7.2.1)	• Do defined training requirements and progression for new hires exist at all levels (operators, maintainers, managers)? • Does a method exist for assigning jobs to persons with prior experience based on demonstration of required skills and knowledge (operators, maintainers, managers)? • What types of basic safety and environmental training (e.g., orientation to emergency systems, evacuation, reporting hazards, safety policy, etc.) are provided prior to beginning work at the terminal? • Is first aid training required as appropriate prior to beginning work at the terminal? • Is basic firefighting training required as appropriate prior to beginning work at the terminal?
2. Operator Training	Has the company established a formal training program for operations staff that includes clear definition of required skills and knowledge for each position, and does this program also require that operators are assessed for competence and periodically receive refresher training?	• Do job descriptions exist? • Is basic skills training provided specifically by job category? • Are critical tasks per job identified? • Is a Task Analysis maintained for critical tasks? • What types of safety and environmental training (e.g., production shutdowns, emergency response, evacuation, etc.) are provided at the terminal? • How are required skills and knowledge identified per job? • What learning objectives are identified for each training module? • Are these learning objectives tied to critical tasks, skills, and knowledge? • Is each operator trained in diagnostic skills? • How is competence assessed? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for completing tasks? • When training is provided, is assessment of the sufficiency of the training by the trainee a part of the training course (feedback from courses)? • How is training documented?
3. Operating Instructions	Do personnel and contractors receive training in implementing operating instructions pertaining to their job assignments? (SEMP 7.1, 7.5)	• Is there an assessment of understanding of training material either through oral or written examination or hand on demonstration? • Are minimum "pass" criteria set for assessment of understanding?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
4. Hazards Training	Is training in the hazards of the process before undertaking work in the facility required for all personnel and contractors, and is training concerning simultaneous operations and hazard communications to appropriate personnel provided? (SEMP 7.1, 7.5, 8.5)	• Does training include process basics training that covers possible process and environmental hazards for operators and maintenance personnel? • Are all personnel trained in hazard identification skills as they apply to the terminal work area? • Is formal training in safety and environmental issues required by a regulatory agency, and if so, has this training been conducted? • How is an assessment for understanding determined? Are tests given either through oral or written examination or hand on demonstration? • Are minimum "pass" criteria required for understanding of training material?
5. Safe Work Practices	Do all personnel and contractors receive training in safe work practices pertaining to their job assignments? (SEMP 7.2.1c, 7.5, 8.5)	• Is all training completed and documented for various safe work practices before the work starts? • Are short courses for training experienced personnel or refresher training provided (including pre-assessment of knowledge)? • Is there a method for assessment of understanding? • Are minimum "pass" criteria for understanding required?
6. Emergency Response and Evacuation	Are all personnel, including contractors, required to receive training in emergency response and evacuation? (SEMP 7.1, 7.5, 10.4)	• Is there a method for establishing competence on emergency response tasks of a general nature (e.g., use of fire extinguishers, rescue, etc.)? • Is orientation training documented for terminal-specific emergency response and evacuation procedures, including individuals' roles and reporting status? • Is training provided for designated members of emergency management teams?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)

Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
7. Maintenance and Mechanical Integrity	What mechanism does the company have in place to verify that the personnel and contractors who are responsible for maintenance tasks and/or mechanical integrity inspections and testing have received appropriate craft training - and, where appropriate, hold required certifications - before conducting such tasks? (SEMP 7.2.1, 7.5, 8.5)	• Do job descriptions exist? • Is basic skills training identified by job category? • Is identification of special training or certifications required? • How are critical tasks per job identified? • Is there a Task Analysis of critical tasks? • How are skills and knowledge per job identified? • Are learning objectives identified for each training module? • Are these learning objectives tied to critical tasks, skills, and knowledge? • Is the maintenance personnel trained in diagnostic skills? • How is an assessment for competence conducted? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for completing tasks? • How are contractor and vendor personnel performance monitored? • What criteria exist for evaluating acceptable performance of contractors and vendors? • Does a method exist for documenting and reporting deficient performance? • What type of record-keeping is provided for contractor, vendor and supplier performance?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Topic-Specific Training	Do personnel and contractors receive specific training where appropriate in: • Safety and anti-pollution devices? (33 CFR 154.735 and 310, HSEMS 3.3.4.2g; FLAIM B8.3) • Fixed crane operations and maintenance? (API RP 2D; 30 CFR 250.20; HSEMS 3.3.4.2I; FLAIM B8.3) • Moveable cranes (e.g., cherry pickers) and forklift operations and maintenance? • General (non-operating) emergencies (e.g., personnel overboard, loss of power, security emergencies, etc.? (FLAIM B8.3) • Environmental protection and pollution control including booming? (33 CFR 154.310; HSEMS 3.3.4.2f, g, h) • Spill or release reporting and containment including knowledge of contingency plans? (33 CFR 154.710) • Welding, cutting, and burning? (30 CFR 250.52) (SEMP 7.2.2; 7.5; 30 CFR 250 Subpart O; HSEMS 3.3.4.2e, f, g, h; FLAIM B8.3)	• Is specific training provided for escape, evacuation, and survival? • What requirements exist for terminal-specific safety training? • Is special training required for simultaneous operations including cargo loading, discharging, transfers, bunkering, or operations involving multiple products? • Is a method in place for incident reporting and investigation? • How is staff polled for their training needs?
9. Hazardous Materials	Do personnel and contractors receive training on handling hazardous materials in accordance with Material and Safety Data Sheets (MSDSs) information? (SEMP 6.3; 7.5)	• Is training provided for specific hazardous materials and their handling including, as appropriate: hydrogen sulfide, benzene, MTBE, toluene, etc.? • Is an assessment performed for competence? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for completing tasks?
10. Personal Protective Equipment (PPE)	Is training provided on the proper use of personal protective equipment to appropriate personnel? (SEMP 6.3; 7.5)	• How is competence assessed? Is there criteria or testing established to determine when someone has the skills and knowledge sufficient for properly fitting and using their personal protective equipment?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
11. Procedures	Does the company ensure that personnel and contractors receive training on procedures and changes in procedures, as appropriate? (SEMP 7.4, 7.5; HSEMS 3.3.6; ISM 6.7)	• Is training and orientation provided to visitors, including emergency response, muster/assembly, and alarms for terminal specifics? • Is a review performed of safety rules and work practices for contractors and visitors at the terminal? • What type of documentation provides evidence that contractors and visitors have received and understood orientation briefing? • How are contractor concerns handled (e.g., method for identifying training deficiencies)?
12. Training Documentation and Refresher Training	Is all training documented, and is appropriate refresher training scheduled and conducted? (SEMP 7.3, 7.5)	• Is training and orientation provided to visitors? Is it documented, and are records retained? • Are the results of incident investigations and audits fed back to the training department? • Are updates of training based on feedback, audits, and incidents? • Do the refresher training programs emphasize critical tasks and operations?
13. Management Training	Does the company ensure that facility management personnel has been formally trained on safe work practices and emergency and contingency plans for hazard prevention and response? (ISM 5, 6.1, 6.2, 6.4, 6.5, 6.6)	• Are management training programs in place on leadership, communications, personnel management, process safety, and environmental management? • Do supervisory personnel receive supervisory training, including conflict management? • Is there formal training in communication procedures for normal and emergency conditions? • Are training needs identified by the supervisor in yearly performance reviews?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Training & Selection (continued)

General Sub-Categories	General Questions	Detailed Questions
14. General Training and Selection	Has the company established a formal training and selection program for all categories of personnel, and does the program clearly define requirements for positions and the need for assessment for competence?	• Does a matrix or document exist with overviews of types of training and training needs by category? • Is a listing of job categories available? • Do job descriptions exist? • What is the formal selection process for personnel? • Is there a formal method for determining staffing levels? Is a workload assessment conducted as a means for determining minimum staffing levels? • When staff reductions are necessary, is an assessment conducted for minimal staffing requirements? Is retraining provided for remaining personnel after reductions with regard to new responsibilities or tasks? • Do staff rotations, shift rotation, shift schedules, and rules for extended work-hour limits exist? • For all formal and on-the-job training, is assessment of the sufficiency of the training by trainee part of the training course (feedback from courses)? • Are special programs designed to ensure that training personnel are knowledgeable about training techniques themselves and have necessary knowledge of skills for topics that are provided?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)

Mechanical Integrity

General Sub-Categories	General Questions	Detailed Questions
1. Quality Assurance Strategy	Does the company have a program that assures that critical equipment is procured, fabricated, and installed in accordance with appropriate quality standards and specifications? (SEMP 8; ISM 10; PFEER 19; HSEMS 3.5.2; Company X #3)	• Does a listing of safety-critical equipment/parts exist? • What criteria exist for acceptance or rejection of received parts or equipment? • Is there a listing of equipment and components received and inspected, and does the list indicate the results of those inspections? • Is there a system for supplier and vendor qualification criteria or specifications? • Are lists maintained for qualified vendors, service companies, and personnel? • Are checks made against the results of inspections for quality and vendor/supplier performance? • How are deficiencies monitored, and is there a method for reporting deficiencies to vendors/suppliers? • What criteria exist for disqualifying a vendor or supplier due to poor performance? • Are code and standard compliance records available? • Are equipment specifications, with reference to standards and codes, used for design and selection? • Are procedures in place for ordering, purchasing, receiving, and completing inventories for equipment and parts? • Do purchasing specifications exist that refer to safety, environmental, or loss-control related issues for critical products, equipment, materials, and services?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)

Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
2. Policy	Does the company have a policy that requires that a list of critical equipment be established? Does it state that reviews will be conducted to assess ongoing mechanical reliability, remaining life, and suitability of critical equipment and facilities, depending on service? Does this policy also state that methods, intervals, criteria, and limits be established for testing and inspection? (SEMP 8.5, 8.6)	• Are management reviews of maintenance backlogs required and do they occur? What process is in place to ensure that action is taken to reduce or eliminate maintenance backlogs? In particular, are such reviews required and conducted for the inspection of safety-critical and potential environmental loss-control related items? • Are maintenance procedures issues addressed (e.g., content, availability, language, expectations, etc.)? • Does a listing of safety-critical equipment exist? • Does a listing of potential safety, environmental, and loss-control related equipment exist? • Are maintenance/inspection histories reviewed for trends by management? Are inspection schedules modified based on historical data? • Are requirements defined for outside maintenance contractor qualifications?
3. Mechanical Reliability - Containment	Does the company regularly assess, test, and inspect equipment containing hydrocarbons and other hazardous material to assure integrity, and do these efforts include testing material compatibility and reviewing wall thickness for service conditions, including erosion and corrosion? (SEMP 8.5; API 510; ISM 10.3, 10.4; PFEER 19.4; FLAIM B2.5, B3)	• Does a listing of safety-critical equipment exist? • Does a listing of potential safety, environmental and loss-control related equipment exist? • Is a vapor control system in place, and if so, is it designed, installed, operated and being maintained in accordance with appropriate regulations and codes? • Are precautions taken during maintenance and operations for systems where pyrophoric iron sulfide may accumulate? • Do criteria exist for acceptable limits for equipment? • Are equipment specifications with reference to standards and codes available and used for design and selection? • Are records of equipment installation kept and maintained? • Do specifications for installation exist? • Are manufacturer/supplier documents readily available to personnel?
4. Mechanical Reliability - Rotating Equipment	Does the company have a preventative and/or predictive maintenance program for rotating equipment in critical service? (SEMP 8.5)	• What criteria exist regarding acceptable operating limits for rotating equipment integrity? • Are records of installation, testing, and inspection kept and maintained? • Are manufacturer/supplier documents readily available to personnel?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Mechanical Reliability - Pressure Relief	Does the company regularly assess, test, and inspect equipment related to pressure relief to ensure that relief can occur when necessary? (SEMP 8.5)	• Are there equipment specifications with reference to design basis and standards and codes used for design and selection (including documentation of relief and vent calculations)? • What criteria exist for acceptable limits for equipment? • Does a listing of relief and vent equipment exist? • Are records of installation, testing, calibration, cleaning, and repair kept and maintained? • Are manufacturer/supplier documents readily available to personnel?
6. Mechanical Reliability - Shutdown Systems, both Emergency and Process	Does the company regularly assess, test, and inspect shutdown systems to ensure reliability? (SEMP 8.5)	• Do acceptance criteria exist for shutdown devices, including listings of set points and operating limits? • Are there specifications with reference to standards and codes used for design and selection? • Does a listing of safety-critical devices exist? • Does a listing of potential environmental and loss-control related equipment exist? • Does the schedule for testing and calibration reflect safety and environmental priorities? • Are records kept of installation, testing, calibration, adjustments, and periods when equipment is taken out of service or not functioning? • Are manufacturer/supplier documents readily available to personnel?
7. Mechanical Reliability - Emergency Response Systems	Does the company regularly assess, test, and inspect fire fighting, spill control/containment vessels, and other equipment used for emergency response? (SEMP 8.5)	• Are there equipment specifications with reference to standards and codes and regulations used for design and selection? • Does a listing of safety-critical equipment exist? • Does a listing of potential environmental and loss-control related equipment exist? • Are there periodic documented checks of Emergency Response Systems such as alarms, emergency lighting, spill equipment, communications devices, etc.? • Are records of installation maintained? • Are manufacturer/supplier documents kept available for personnel?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
8. Reliability - Life Saving and Evacuation Devices	Does the company regularly assess, test, and inspect equipment associated with evacuation devices including life rafts, personal floating devices, etc.? (SEMP 8.5)	• Are equipment specifications with reference to standards and codes and regulations used for design and selection? • Does criteria exist for acceptable limits for equipment? • Does a listing of safety-critical equipment exist? • Are there periodic documented checks of life saving and emergency devices?
9. Spare Parts	Has the company identified critical spare parts and included these on an inventory, and does the company ensure that these parts are available within acceptable time limits? (*Organization #8*)	• Are spare parts readily accessible to operations and maintenance personnel? • Do criteria exist for acceptance or rejection of parts? • Is an inventory control system in place? • How is ordering/inventory monitored to identify possible deficiencies in the inventory list or availability of spare parts? • Are procedures in place for ordering, purchasing and receiving spare parts? • Does a listing of safety-critical equipment/parts exist? • Does a listing of potential environmental and loss-control equipment/parts exist? • Is there a list of approved vendors and suppliers? • Are manufacturer/supplier documents, including manuals, readily accessible to personnel?
10. Documentation	Is documentation concerning assessment methods and procedures, acceptance criteria, and the results of tests and inspections kept; and is information concerning replacement of equipment, instruments, and components documented and retained for a minimum of two years? (SEMP 8.6)	• Are maintenance procedures in place, including preventative maintenance plans, testing and inspection procedures and records, fire protection maintenance records, deficiency correction records, and installation instructions or specifications? • Are records kept on outside maintenance contractor qualifications? • Are records kept of maintenance, testing and inspection personnel? • Are there records of compliance with appropriate standards and codes? • Are equipment histories maintained? • Do schedules for inspection and testing exist? • Are piping system records kept? • Is control system information readily available? • Are relief and vent records maintained? • Are an instrument index and specifications kept and maintained?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Mechanical Integrity (continued)

General Sub-Categories	General Questions	Detailed Questions
11. Deficiencies	If equipment deficiencies are judged to be outside limits (as defined in the process safety or environmental information), are these deficiencies corrected before further use or corrected in a safe and timely manner after necessary steps to assure safe operations have been taken? (SEMP 8.6)	• Are there acceptance criteria for critical equipment and parts? • Does a noncompliance/deficiency documentation method exist? • Are there corrective action procedures? • Are records of corrective actions taken? • Are there records of deficiencies available that were identified by regulatory agencies? Is there evidence of corrective actions? • Are maintenance-related schedules revised based on inspection and test results? • Does a method exist for tagging and logging out of service items when deficiencies are found?
12. Review and Authorization of Changes	What system for reviewing and authorizing changes in procedures, tests, and inspections exists, and is it aimed at managing hazards and risks? (SEMP 8.5)	• Does the change package refer to standards and codes? • Does management review backlogs of maintenance or inspection for safety-critical or environmentally critical items?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Emergency Response

General Sub-Categories	General Questions	Detailed Questions
1. Emergency Response and Evacuation Plans	Does the company have emergency response and contingency plans in place for losses of containment, including releases, fires and explosions, and spills? Do these plans or policies outline the company's philosophy and the components of appropriate responses (e.g., for fire: whether to stand and fight, evacuate, etc.)? (SEMP 10.1; ISM 1.4.5; PFEER 6,12; *Organization #4*; FLAIM B8.2)	• What are the requirements for ensuring competence of individuals in emergency response and checking familiarity with plans? • Do emergency plans include instruction for various types of emergencies, including spills? • What are the contents of the Emergency Plans (organizational chart, maps, possible hazards, resources for assistance, necessary phone numbers, etc.)? • Are the Emergency Response and Evacuation Plans accessible and up-to-date? • What are the steps for spill response and escape and abandonment procedures and routes? • What procedures exist for accounting for personnel at assembly points? • Is there any requirement for protocol or training for communications in reporting or managing emergencies? • Are there contingencies in the Emergency Plan for first aid responders (minimum per facility, their role in emergency, reporting station, etc.)?
2. Emergency and Contingency Response Equipment	Do the emergency response and contingency plans identify emergency equipment that should be available for use during response?	• Are signs posted or marked for evacuation routes? • Are signs posted and markings maintained for emergency equipment (extinguishers, stretchers, hoses, escape packs, personal breathing apparatus, etc.)? • Are the number of emergency shutdown locations sufficient and are they readily accessible? Are emergency shutdown locations sufficiently marked? • Does emergency lighting for evacuation routes exist?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Emergency Response (continued)

General Sub-Categories	General Questions	Detailed Questions
3. Emergency Management Authority and Compliance with Regulations	Do the emergency or contingency plans assign authority to appropriate qualified person(s) and address emergency reporting and response, complying with the most current revision of one or more of the following regulations (as applicable): • Emergency evacuation plans? (USCG-33; CFR 146.140) • Oil spill contingency plan? (USCG) • Pipeline emergency plans? (USDOT-49; CFR 192, 195; SEMP 10.2; ISM 8; FLAIM B6.2, B8.3)	• Does the Emergency Plan clearly identify individual responsibilities in an emergency, including those of people who actively manage situations, operators of critical equipment, and first aid responders? • Is technical support available and designated, if needed, during an emergency?
4. Emergency Control Center or Incident Command Center	Has a Center been designated for each facility, and does the Center include the following: • Emergency Action Plan • Oil Spill Contingency Plan • Safety and Environmental Information? (SEMP 10.3)	• Are Emergency Response and Evacuation Plans accessible and up-to-date? • Is the Center designated and equipped with safety and environmental information (MSDSs, communications equipment, copies of emergency and environmental response plans)?
5. Revision Process for Plans	Are the actual persons who will respond to loss-of-containment situations (including releases, fires, explosions, spills and other contingencies) included in the review of plans for such events, and does a mechanism exist for these personnel to provide comments regarding such plans to management? (PFEER 8)	• Is there a periodic review of the Emergency Plan? • Is a mechanism for requesting changes in place and understood by all personnel affected? • Are records of corrective actions from drills or audits provided for revision of the Emergency Plan? Is there evidence of revisions based on suggested corrective actions? • Does the designee for endorsing the evacuation plan ensure that the plan is current with regulations and practices? • Is feedback provided on acceptance/rejection of requested changes?
6. Drills	Does the company have drills that are effective in regard to testing plans and correcting weaknesses? (SEMP 10.4; PFEER 8)	• What is the minimum requirement for drill frequency, and what types of drills are held by year? • Does documentation of results of drills exist? • Are drill results evaluated? • Are corrective actions following drills implemented and documented? • Does management review drill results?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)

Emergency Response (continued)

General Sub-Categories	General Questions	Detailed Questions
7. Communications	Are emergency warnings for fires and explosions in the facility audible and, where appropriate, visual? (PFEER 11) (PFEER 11.2 - types of visual and acoustic warning signals)	• Does emergency plan documentation of contacts and phone numbers exist, and is it accessible to personnel? • Does the plan address alternatives if certain contacts are unavailable? (Note: Phone trees may be used to assign contact responsibilities.) • Is there a protocol or training provided on communications for reporting or managing an emergency? • Is appropriate agency notification included in communications reporting requirements?
8. Emergency Equipment and Systems	Has the company evaluated fire and life protection systems and provided adequate protection? (FLAIM B7)	• Is there periodic inspection and necessary calibration or repairs for the following systems: * Fire water distribution systems * Fire water hose stations, hydrants, and monitors * Fixed fire water spray/deluge systems and sprinkler systems * Fire fighting foam systems * Fixed and portable chemical fire suppression systems - including liquids, gaseous agents, and powders * Dry chemical agents * Fire detection systems * Combustible gas detection systems * Alarm and communication systems * Emergency power and lighting * Emergency shutdown (ESD) systems * Pressure relief and vapor depressuring (blowdown) systems * Oil spill control provisions (e.g., absorbent pads, sawdust, etc.) * Thermal robustness and passive fire protection systems * Design for explosion protection * Personal protective and safety equipment (e.g., personal breathing apparatus, protective clothing, fire blankets, etc.) * Communications equipment? • Is there documentation on inspections and are expiration dates assigned to the inspected equipment?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Investigation and Audit

General Sub-Categories	General Questions	Detailed Questions
1. Investigation Policy	Does the company have procedures in place to promptly investigate, document, and report all accidents and incidents with qualified personnel to help prevent similar occurrences? (SEMP 11.1; ISM 1.4.3, ISM 1.4.4, ISM 9; HSEMS 3.6.5; Company X #9; HSEMS 3.6.4)	• What are the requirements for personnel to receive training on investigation methods? • Is a representative from a regulatory agency invited to participate in any investigations? • Does a mixed-discipline team investigate? • Is there a system in place for near-miss reporting? • Are undesired environmental events formally reported and investigated? • Do confidential reporting procedures exist? • Are time limits defined to report, investigate, and follow-up on accidents and incidents?
2. Investigation	Do company investigations address the following: • The nature of the accident or incident • The factors that contributed to the accident or incident and the mitigation actions that should be taken to prevent or minimize the effects of a recurrence • Recommended actions identified as a result of the investigation? (SEMP 11.2)	• Is an investigation procedure/form available? • Are reporting requirements defined? • Are root causes defined via a formalized method? • Is suggested corrective action documented?
3. Investigation Follow-Up	Does the company distribute findings of an accident or incident investigation to appropriate personnel and similar facilities, and are procedures in place to ensure that corrective actions are completed? (SEMP 11.3; HSEMS 3.6.6)	• Are patterns and statistics monitored and reviewed? • Do the results go to a Joint Safety Committee? • Are results of incidents, conclusions, and corrective actions distributed to all levels? • Are incidents and suggested corrective actions reviewed by management? • Are unresolved incident reports reviewed at management meetings? • Is implementation of corrective actions monitored?
4. Investigation Record Retention	Does the company ensure that accident and incident investigation documentation is retained for a minimum of two years? (SEMP 11.3)	• Are appropriate records retained on accidents and incident investigations for at least the previous two years?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals
General and Detailed Questions (continued)
Investigation and Audit (continued)

General Sub-Categories	General Questions	Detailed Questions
5. Auditing System	Does the company have a system in place to ensure that periodic audits of the safety and environmental management system are conducted, including reviews of hazards analysis, management of change, mechanical integrity, operating procedures, training, safe work practices, emergency response, and investigation systems? (SEMP 12.1)	• Does the audit policy and procedure define: * the team for the audit * the required training for the team * the extent of the audit * the documentation that is required * other important requirements (including the audit schedule)?
6. Auditing Personnel	Are audits conducted by personnel who are independent of the areas being audited? (SEMP 12.1; ISM 1.4.6, ISM 12; HSEMS 3.6.2, 3.7.1; FLAIM B8.1.1, B8.1.3 [Safety Assurance Program])	• Is a multi-disciplinary team responsible for auditing? • Is a representative from a regulatory agency invited to participate in any or all audits? • Do the auditors have a working knowledge of risk assessment principles?
7. Audit Reporting	Does the company have procedures in place to ensure that audit findings are provided to appropriate personnel, that actions are taken to resolve inadequacies, and that audit reports are retained until the completion of the next audit? (SEMP 12.2; HSEMS 3.6.3)	• Do audit findings include strengths and noncompliances? • Are corrective actions documented? • Are audit findings tracked?
8. Schedule	Was an initial audit conducted within two years of the initial implementation of the process safety management program, and is the interval between audits less than four years? (SEMP 12.1)	• Is there a method for tracking for compliance with the auditing schedule?
9. Reviewing	Does the company's senior management, at appropriate levels, review audit results to ensure that findings and resolutions are satisfactory in terms of managing hazards and risks, and are similar reviews given for company policies? (SEMP 12.2; HSEMS 3.7.2)	• Are the results of an audit, including strengths, noncompliances, and suggested corrective actions, reviewed by management?

Table 5.5.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)

Reference Codes and Sources

Code	Description
API RP	American Petroleum Institute Recommended Practice
API RP 14J	American Petroleum Institute Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities
Bird & Germain	Bird, Frank E., Jr., and George L. Germain, *Practical Loss Control Leadership.* Loganville, Georgia: DNV Loss Control Management. 1985.
CCPS	Center for Chemical Process Safety of the American Institute of Chemical Engineers. *Guidelines for Auditing Process Safety Management Systems.* New York: American Institute of Chemical Engineers, 1993.
CFR	Code of Federal Regulations
Company X	A major oil company's safety management systems audit
FLAIM	Gale, W.E., Jr., Bea, R.G., and Williamson, R.B. "FLAIM, Fire and Life Safety Assessment and Indexing Methodology, Final Report to the US Department of the Interior, Minerals Management Service, Technology Assessment and Research Branch." Department of Civil Engineering, University of California, Berkeley, 1994.
Geller	Geller, E. Scott. *Working Safe: How to Help People Actively Care for Health and Safety.* Radnor, PA: Chilton Book Company, 1996.
Harrison	Harrison, P.I. *Organizational, Management and Human Factors in Quantified Risk Assessment (Report 2).* Sudbury, Suffolk, England: Health & Safety Executive Research Report No. 34/1992.
HSEMS	International Organization for Standardization. *International Standard for the Development of Safety, Health and Environmental Management for Oil and Gas Production Operation and Facilities* (ISO/CD 14 690). New York: International Organization for Standardization.
ISM	International Maritime Organization. *International Management Code for the Safe Operation of Ships and for Pollution Prevention:* International Safety Management Code, Resolution A.741 (18). London, England, 1993.
Krause, Hidley & Hodson	Krause, T.R., J.H. Hidley, and S.J. Hodson. *The Behavioral Based Safety Process: Managing Involvement for an Injury-Free Culture.* New York: Van Nostrand Reinhold, 1990.
Op Team & Organization	Research including • Libuser, Carolyn B., and Karlene H. Roberts. "The Development of a Conceptual Model for Risk Mitigation." Thesis, University of California, Berkeley, 1995. • Bea, R.G., and K.H. Roberts. "Human and Organization Factors (HOF) in Design, Construction, and Operation of Offshore Platforms" (OTC 7738). Paper presented at the 27th Annual Offshore Technology Conference, Houston, Texas, 1-4 May 1995. • Boniface, D.E. "An Analytical Methodology to Assess the Risks and Countermeasures for Human and Organizational Error in the Marine Industry." Thesis submitted in partial satisfaction of the requirements of the degree of Master of Engineering, Department of Naval Architecture and Offshore Engineering, University of California, Berkeley, 1996.

Table 5.4.2.2a, MAST Safety Management Systems Evaluation - Marine Terminals General and Detailed Questions (continued)
Reference Codes and Sources (continued)

Code	Description
Petersen	Petersen, Dan. *Human-Error Reduction and Safety Management*. New York: Garland STPM Press, 1982.
PFEER	Health and Safety Commission. *Prevention of Fire and Explosion, and Emergency Response on Offshore Installations*. Sudbury, Suffolk, England: HSE Books, 1995.
SEMP	American Petroleum Institute. *Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities* (API RP 75). Washington, DC: American Petroleum Institute, 1993.
USCG	United States Coast Guard
USDOT	United States Department of Transportation

5.5.3 Scoring

The nine categories, which are encompassed by the Minimal Basic Question set (i.e., general questions), and the detailed questions provide the framework for completing a marine terminal's MAST safety management systems assessment. During an initial evaluation, each question in the Minimal Basic Question set would be investigated for supportive written guidance in the company's policies, program descriptions and procedures. An initial score on a 1 to 7 scale would be given and recorded. The assessment scale is the same as that presented in Table 3.4.2, SAMS Minimal Basic Question Set Assessment Scale Anchor Points. The table is replicated on the next page (Table 5.3.3a) for the reader's convenience.

For all general questions listed in the Minimal Basic Question set, the assessor would investigate whether practices meet the company's written requirements. This step would determine whether or not true implementation was occurring for a particular marine terminal. It would also show if, in some cases, practice in the field actually meets good practices as defined by the assessment criteria, but deficiencies exist in written guidance. This step would require investigations beyond written policies, procedures, and manuals and would involve checking records, forms, and reports and interviewing personnel at different levels of the organization.

Table 5.5.3a: SAMS Minimal Basic Question Set
Assessment Scale Anchor Points

Score (Level of Compliance)	**Anchor Point Description**
7 (Complete compliance and additional risk or safety studies)	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization. • In addition, the company has taken further measures in this area such as conducting studies or training sessions. • Studies may involve risk assessment, human factors analyses, or integrated risk, safety, environment, quality and loss control programs.
6	• The company addresses this concern in writing and in practice, and implementation is occurring fully at all levels of the organization.
5	• The company addresses this concern in writing and in practice, and implementation is occurring fully at most levels of the organization although minor deficiencies were noted during the assessment process.
4	• The company addresses this concern in writing, but evidence of practice at all levels of the organization is incomplete. • Still, implementation is under way and at an advanced stage.
3	• The company addresses this concern in writing, but evidence of practice at all levels of the organization does not exist. • Implementation is under way and in the initial stages.
2	• Some written guidance exists. • Steps are being taken to meet this criterion in practice. • A schedule for finalizing written guidance and for beginning implementation exists.
1 (Little or no compliance)	• Little or no written guidance exists. • Practice is inconsistent, and no implementation is occurring.

For areas where the assessor requires more complete information or where initial investigations show weak evidence of written guidance or actual practice, the assessor could use the detailed questions to determine the exact nature of deficiencies. The detailed questions could also be used to point to good practices above and beyond the strict interpretation of the questions in the Minimal Basic Question set and identify areas of excellence. All document reviews, investigations and interviews of personnel would be used to determine a marine terminal's level of compliance. These activities would occur both at the shore base and in the field, i.e., the marine terminal

To reiterate, the purpose of the detailed questions is to assist the assessor in evaluating compliance and to determine where strengths and weaknesses exist in the organization's treatment of process safety, human factors and organizational concerns. Detailed questions are also provided to assist assessors in decision-making about meeting and exceeding general question requirements. These details provide guidance on factors related to good practices for strong treatment of process safety management and human and organizational factors. Based on the document reviews, visits to the shore base, and interviews with personnel in various parts of the organization, assessors would weigh the evidence and modify initial scores. It should also be noted that the assessor should make notations concerning observations on questions. The assessor could also incorporate these notes when deciding final scores for questions.

Upon finishing the MAST safety management system assessment activities, the assessor would be able to look at compliance within and across safety management assessment categories. For each category, an average score would be calculated. The scores across categories would be plotted on a bar chart to provide a visual indication of overall compliance. Ranges of scores within a category would also be provided so that the basis for an average score could be evident. Assessors could use this bar chart in a report provided to the marine terminal following an evaluation. An example of such a bar chart is provided in Section 5.4.2.3, Figure 5.4.2.3a, Example Graphic Representation of Evaluation Results.

6.0 PROJECT RESULTS AND CONCLUSIONS

6.1 INTRODUCTION

Human and Organizational Factors (HOF) usually are not addressed explicitly in most risk and safety evaluation tools currently used in the marine industry. In some cases, human factors are addressed, but in a limited manner. Organizational factors are seldom addressed by present methods.

The SAMS Joint Industry Project was undertaken with the objective of developing a generic Safety Management Assessment System that could be used by industry and government to assess HOF that can lead to a loss of containment and result in releases, fires and explosions on offshore platforms and marine terminals. A summary of the two methods developed for this project are presented below along with the project findings and conclusions.

6.2 PROJECT RESULTS *(NOTE TO REVIEWERS: Results for MAST method as applied to marine terminals are pending September field testing in California.)*

Both the FOOT and the MAST methods are attempts to structure the way in which an audit team reviews documentation, focuses on important issues, conducts site visits and interviews of operating staff, and analyzes the results to determine whether HOF have been adequately considered and appropriately implemented in the operation of a specific offshore platform or marine terminal. Both techniques also attempt to provide an index of "riskiness" of the installation relative to others evaluated so that an operator or regulatory authority can concentrate on those installations which have the highest risk to safety and the environment, and to provide guidance as to where to focus attention to have the greatest impact on reducing that risk.

It must be explicitly stated that neither of these techniques is proposed as a hazards analysis technique. Both start with the assumption that a hazards analysis has been performed using one of the classic techniques that are well documented in the industry (e.g. HAZOP, FMEA, Checklist, etc.), and thus neither FOOT nor MAST focuses on the hardware. However, as HOF techniques, they both attempt to assess whether or not HOF were adequately considered in the hazards analysis and to evaluate whether or not operating procedures and knowledge are indeed in place, understood and used in practice, and sufficient to assure appropriate levels of safety.

6.2.1 Summary of FOOT and MAST Methods

Both FOOT and MAST start with an evaluation of the Minimal Basic Question (MBQ) set described in Section 3. The MBQ set has 9 categories:

- Management and Organizational Issues (M&O)
- Hazards Analysis (HAZ)
- Management of Change (MOC)
- Operating Procedures (OP)
- Safe Work Practices (SWP)
- Training and Selection (TR)
- Mechanical Integrity (MI)
- Emergency Response (ER)
- Investigation and Audit (I&A)

When the FOOT method was first developed the M&O category had not been added to the MBQ and so the exercise described in Section 4 and Appendix D does not include an evaluation of this category. However, this should not be considered a difference between the two methods. FOOT as currently envisioned would contain as its first step an analysis of the whole revised MBQ set including M&O.

Both methods contemplate an initial evaluation of the MBQs based on documentation available prior to the site visit, as well as a more in-depth probing of the MBQ to take place during the site visit. At this point the two methods diverge.

MAST Approach: MAST takes the position that numerous safety management system guidelines have been written for installations such as marine terminals and offshore platforms. These guidelines all indicate that one of the characteristics of a high reliability organization in this industry is that it addresses the concerns identified in the MBQs. Thus, MAST gives the evaluators a second tier of HOF-related questions to aid them in assessing each of the MBQ categories in more detail.

The basic assumption of MAST is that the eight specific organization factors and eight specific team factors listed in Table 1.5.1 must be addressed in order to have an implemented and functioning SMS which addresses each of the specific nine MBQ categories. The premise of MAST is that if this is true, given the history of evaluation of similar installations to offshore platforms and marine terminals which lead to the understanding of Safety Management Systems incorporated in the MBQs, then no further analysis is needed to identify, either in isolation or as it applies to a specific potential problem (i.e. an area of concern), the specific organization and operating team factors of FOOT listed in Table 1.5.1.

FOOT Approach: FOOT takes a different approach. This method uses the MBQs to identify three to six areas of concern (AOC). AOCs could include, for example, a gas leak in the compressor building due to packing failure, an oil leak at the pump station due to excessive vibration and seal failure, a well blowout due to low mud weight, or an incorrect operation of a sampling valve. Although FOOT grades the MBQs in the same way that MAST does, the focus of the site visit is on the AOC. In the FOOT method the evaluators test each AOC and evaluate it against each of the 16 organization and operating team factors listed in Table 1.5.1.

The FOOT method states that a "manageable number" of AOC (i.e. 3 to 6) should be selected . It is clear that even for a moderately complex offshore platform there will be just too many AOC to evaluate each one. Determining which of the numerous AOC to evaluate is left to the evaluators. The assumption is made that they have sufficient knowledge of the system to select those AOCs which will lead to the most representative understanding of HOF as practiced at a particular installation.

By focusing the evaluator's attention in-depth on the 16 HOF factors for a few selected AOC, a pattern will emerge as to how HOF in general is used in managing safety at a particular facility. Thus, FOOT provides both an analysis of the MBQs and a specific analysis of the 16 organizational and team factors (at least as it applies to the limited number of AOC evaluated).

6.2.2 Risk Index

Both MAST and FOOT use a graphical display of the weighted (or non-weighted) average of the evaluator's score on each of the nine categories of MBQs as well as the range of scores on individual questions which make up that score. MAST, by focusing its second tier of analysis on the MBQs, could be argued to give a more accurate score, but this tier of analysis could easily be incorporated in FOOT if the evaluators found it useful.

MAST Approach: MAST takes the approach that the overall risk index for the installation cannot be determined by evaluating the Safety Management System alone, or by addressing only the organization and operating team factors alone. The MAST method assumes that the physical characteristics of the installation must be taken into account to measure the overall risk represented by an installation. That is, a low pressure, single well, sweet gas well jacket with no quarters and no processing equipment with a poor Safety Management System (score of 1 on every category of MBQ) may be less "risky" (i.e. low chance of loss of life, injury or release to the environment) than a high pressure, sour gas and oil, multi-well platform with quarters which has an excellent Safety Management System (score of 7 on every category of MBQ). For this reason MAST includes a physical qualities assessment with separate checklists for offshore platforms and for marine terminals to determine a physical quality index.

At one point during this project, a matrix was presented to the steering committee which included the overall weighted average of the MBQ score as a measure of "likelihood" and the physical quality index as a measure of "consequence" to determine a single number for a risk index for the installation. There was significant debate on this approach, and due to a lack of consensus, this approach was not evaluated further. It was agreed by the steering committee that this approach would be excluded from this report.

FOOT Approach: The FOOT method presents a series of triangular distributions of consequence for each AOC and a triangular distribution of probability of each of the organization and operating team factors contributing to a problem for that AOC. From these distributions, a relative risk of the importance of each of the 8 operating team factors is calculated and presented for each AOC in a bar graph. A relative risk of the importance of each of the 8 organization factors is calculated and presented in a separate bar graph. In these calculations, a single-consequence triangular distribution is used for each of the 16 factors. Thus, for any installation there is one bar graph for the MBQ categories and two additional bar graphs for each AOC evaluated. No attempt has been made to combine these "scores" and obtain an overall risk index for the installation.

Summary: Since neither MAST nor FOOT provide a single index for the installation, it can be argued that neither provide a technique to determine the relative risk associated with each facility within a group of installations. On the other hand, it could be argued that by looking at the output of each method—the physical qualities index and the bar chart of MBQ average and ranges for MAST, and the MBQ bar chart and the 6 to 12 risk bar charts for the AOCs for FOOT—a group of knowledgeable evaluators could make a qualitative ranking of "riskiness" of a group of installations.

6.2.3 Guidance for Reducing Risk

Both MAST and FOOT result in a score for the various items evaluated and, therefore, have the ability to show how the score can be improved. For example, if there is a low score on a category in the MBQs, clearly this would indicate an area where improvement is needed. In MAST the physical quality index can be improved by changing the process (e.g. removing quarters, adjusting storage requirements, etc.), and in FOOT the risk associated with an AOC can be reduced by improving one of the organization or operating team factors or by revising the design to reduce the consequence.

Since neither MAST nor FOOT provide an overall index of risk, it is difficult to determine if effort applied in one area (e.g. MOC) would pay a better dividend than the same effort applied to another area (e.g. MI). However, it could be argued that a knowledgeable evaluation team could make these assessments and that potential changes in the various bar charts and physical quality index (in the case of MAST) could lead the team to better understand how to allocate resources.

6.3 CONCLUSIONS *(Preliminary For Draft Report)*

Methods currently being used by the marine industry for identifying and evaluating human and organizational error were reviewed and found to have several deficiencies. Some of these deficiencies are as follows:

- The methods rely on sparse data and expert opinion to create HOE probabilities.
- The methods normally require a significant amount of time and resources to apply.
- Low likelihood, high consequence events may be eliminated at the start of the method.
- Human and Organizational Factors (HOF) may not be explicitly addressed.
- The methods may not have associated training programs available for examination.
- Final assessment reports may not be understandable to operators.
- A single list of questions can not always fully address an infinite number of possible accidents. The list must grow after every "once in a lifetime" accident.

It was concluded by the SAMS project team that existing assessment methods for HOF identification and evaluation could benefit from a new approach or method. In response to this conclusion and to address deficiencies in existing methods two different assessment methods were developed: FOOT and MAST.

Although there are differences between the two methods, it could be argued that the differences between FOOT and MAST are unimportant. It is possible that an evaluation team which reviews documentation to answer MBQs before a site visit and is asked to either evaluate MBQs or evaluate selected AOC in more detail on a site visit will in the final analysis reach the same conclusions as far as how HOF are being utilized to enhance safety at the installation being evaluated. It is hard to imagine that the recommendations which come from the FOOT table-top exercise described in Section 4.9 would have been any different if a MAST method were employed. The scoring would be different, but since neither method produces a single score which could be objectively compared to that of another facility, differences in scoring approaches do not appear to be important.

In both the FOOT and MAST methods, the evaluators will make safety-related observations which are not specifically targeted by either method as they are observing and asking questions about the operation. Examples of these types of findings are included in section 4.9.5 (General Findings of the FOOT Table-Top Exercise).

In practice, a combination of the two techniques may prove to be optimal. The AOCs for FOOT may be considered to be the nine MBQ categories. Organization and operating team factors could be defined slightly differently so that they could be applied to each of these AOCs, and an evaluator could test how HOF were employed in developing and implementing each of these nine AOCs for the installation as a whole. A triangular distribution of the weighted score for the probability of each AOC could then be calculated.

Some method of relating the MAST physical qualities index to a consequence score could then be developed leading to a consequence triangle for the facility. With this approach, a risk index could be calculated for each AOC as in FOOT. The final output would be a single bar graph of the relative risk indexes of the nine MBQ categories. A procedure to develop an overall score from this bar graph could be developed which would allow relative ranking of any number of installations.

7.0 REFERENCES

The references cited in Section 7.1 (Safety and Human/Organizational Factors References) are used as a support for the research basis for particular safety management items. Additional references for process safety management and human/organizational factors that were discovered during the literature search but not directly used are cited in Section 7.2.

7.1 SAFETY AND HUMAN/ORGANIZATIONAL FACTORS REFERENCES

American National Standard. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection System* (ANSI N41-4-1976), (IEEE Standard 352-1975, Revision of IEEE Standard 352-1972.) American National Standard, 1975.

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APPENDIX A: GLOSSARY

Administrative Controls	Administrative controls include operating and maintenance procedures, safe work practices (e.g. opening process equipment and piping, hot work permits, lockout/tagout, confined space entry, etc.), contractor safety, and access to the facility by maintenance and laboratory personnel (i.e. non-operating personnel). Administrative controls also include the management of change system as well as emergency response (e.g. evacuation).
Barge	Any vessel that carries oil in commercial quantities as cargo, but is not equipped with a means of self-propulsion. (California State Lands Commission, Nov. 1994)
Basic Minimal Questions	*See* Minimal Basic Questions
Boom	Flotation boom or other effective barrier containment material suitable for containment of oil that is discharged onto the surface of the water. (California State Lands Commission, Nov. 1994)
Change Package	A change package is a set of information which documents any particular change.
Critical Equipment	Refers to equipment and other systems determined to be essential in preventing the occurrence of an uncontrolled release. (API RP75)
Critical Tasks	A job task within an occupation that has been associated with major loss more frequently than others. (Kuhlman)
Discharge	Any release of oil into marine waters which is not authorized by any federal, state, or local government entity. (California State Lands Commission, Nov. 1994)
Fire and Life Safety Assessment and Indexing Methodology (FLAIM)	FLAIM is a safety assessment methodology for safety management of existing oil and gas production platforms in the U.S. Outer Continental Shelf (OCS). This methodology is intended to be a simple and adaptable means of assessing fire and life safety risks and accounting for mechanical systems and management systems safety. This method was developed by Bill Gale.
Formal Review	Requires signature for approval.

Hazards Analysis	The application of one or more methodologies that aid in identifying and evaluating hazards. (API RP75)
Incident	Any undesired event that, under slightly different circumstances, could have resulted in personal harm, property damage, or an undesired environmental event. (DNV Questionnaire)
Interlocks	An interlock is any device in one part of a system that automatically enables or disables the operation of another part of the system.
Joint Safety Committee	Represents hourly and management personnel.
Loss Control	At a minimum, this term covers safety and environmental protection. It may also cover the following scope: providing and improving a safe working environment, establishing and improving safeguards against all identified risks, and continuous improvement of safety and environmental protection management skills of personnel ashore and on board, including preparing for emergencies related to safety and environmental protection. (DNV Questionnaire)
Marine Loading Arms	Marine terminal loading arms consist of a series of swivel connected pipe sections which permit rapid hookup between the tanker and the terminal facility. Basic components of a loading arm include a riser, a swivel connected outboard arm, and a manifold swivel. (Marine Terminal Audit Manual, California State Lands Commission, Feb. 1994)
Marine Terminal	A facility, other than a vessel, located on or adjacent to marine waters in California, used for transferring oil to or from tank vessels or barges. (California State Lands Commission, Nov. 1994)
Material Safety Data Sheets MSDS	A compilation of information required under the OSHA Communication Standard on the identity of hazardous chemicals, health, and physical hazards, exposure limits, and precautions. (Environmental Regulatory Glossary)

Minimal Basic Questions (MBQ)	Minimal Basic Questions (MBQ) is one set of criteria that was developed by the FLAIM project team. The Minimal Basic Question set was established as an initial means for gathering information on facilities and their safety management policies, procedures, and practices. As of January 1997, the Minimal Basic Question set included approximately 80 general assessment questions or criteria.
Offshore Marine Terminal	Any marine terminal at which tank vessels or barges are made fast to a buoy or buoys. (California State Lands Commission, Nov. 1994)
Oil	Any kind of petroleum, liquid hydrocarbons, or petroleum products or any fraction or residues therefrom, including, but not limited to, crude oil, bunker fuel, gasoline, diesel fuel, aviation fuel, oil sludge, oil refuse, oil mixed with waste, and liquid distillates from unprocessed natural gas. (California State Lands Commission, Nov. 1994)
Onshore Marine Terminal	Any marine terminal at which tank vessels or barges are made fast to a buoy or buoys. (California State Lands Commission, Nov. 1994)
Personal Protective Equipment (PPE)	Equipment required to be worn by workers to avoid injurious effects on the body and provide protection to workers in the event of an accident.
Procedure	A step-by-step description of "how to proceed", from start to finish, in performing a task properly. (DNV)
Safety Behaviors	Behaving in a way which minimizes loss and controls accidental loss.
Simultaneous Operations for Offshore Platforms	Include two or more of the following activities: production, drilling, completion, workover, wireline (except routine operations described in 30 CFR 250.91**), and major construction operations. (API RP75)
Simultaneous Operations for Marine Terminals	Combinations of cargo loading, discharging, transfers, bunkering, or any operations involving multiple products. (California State Lands Commission, Nov. 1994)
Spill	Any release of oil into marine waters which is not authorized by any federal, state, or local government entity. (California State Lands Commission, Nov. 1994)

Tank Vessel or Tanker	Any self-propelled, waterborne vessel, constructed or adapted for the carriage of oil in bulk or in commercial quantities as cargo. (California State Lands Commission, Nov. 1994)
Task Analysis	An analytical process that measures behavior on a job against time to determine the physiological and psychological demands of the job on the workers. (Eastman Kodak, 1986)
Terminal	*See* Marine Terminal. (California State Lands Commission, Nov. 1994)
Transfer	Any movement of oil to, from or within any part of the marine terminal or vessel by means of pumping, gravitation, or displacement while oil is moving between the terminal and the vessel. (California State Lands Commission, Nov. 1994)
Vessel	Every description of watercraft or other artificial contrivance, used or capable of being used, as a means of transportation on water and includes, but is not limited to, tank vessels and barges. (California State Lands Commission, Nov. 1994)
Writer's Manual	A guide to assist personnel in the writing of procedures.

Safety Assessment Management Systems (SAMS) Training Program

A one day training course in the fundamentals of assessment and management of human and organizational factors in the safety of offshore platforms

Professor Robert G. Bea
Department of Civil & Environmental Engineering
University of California at Berkeley

9:00 - 10:00: **Lecture 1 - Major Accidents Involving Offshore Platforms**
"Men, Ships, and the Sea: The Human Factor"

10:00 - 10:30: **Discussion of Key Points in Lecture 1**

10:30 - 11:30: **Lecture 2 - Fundamentals of Human and Organizational Factors in Safety of Offshore Platforms**
"Human and Organizational Factors in the Design, Construction, and Operation of Offshore Platforms"

11:30 - 12:00: **Discussion of Key Points in Lecture 2**

12:00 - 1:00: **Lunch**

1:00 - 2:00: **Lecture 3 -Assessments of Human and Organizational Factors in the Safety of Offshore Platforms**
"Quantitative and Qualitative Risk Analyses: The Safety of Offshore Platforms"

2:00 - 2:30: **Discussion of Key Points in Lecture 3**

2:30 - 3:00: **Lecture 4 - Strategies to Improve the Safety of Offshore Platforms**
"Managing Rapidly Developing Crises: Real-Time Prevention of Marine System Accidents"

3:00 - 3:30: **Discussion of Key Points in Lecture 4**

3:30 - 4:30: **Summary and Closure**

Lecture 1
Major Accidents Involving Offshore Platforms

MEN, SHIPS, AND THE SEA: The Human Factor[1]

by
Professor Robert Bea
Department of Civil & Environmental Engineering
University of California at Berkeley

Experience with high consequence - low frequency accidents involving both marine and non-marine systems indicates that approximately 80-percent of these accidents have their root causes in human and organizational factors (HOF). Approximately 80-percent of the HOF caused accidents occur during operations of the systems (Figure 1). These operating accidents may have antecedents in design and construction of the system. If substantial improvements are to be made in the safety of marine systems, the challenges associated with HOF in design, construction, and operation of marine systems must be addressed at least as well has we have learned to address the physical aspects of these systems.

It was eleven o'clock, July 6, 1988, and the night shift had just taken over operations on the Piper Alpha platform. This massive island of steel, installed in the mid 1970's, supported drilling and production equipment, housed up to 250 people, and at its peak produced almost 350,000 barrels of oil per day.

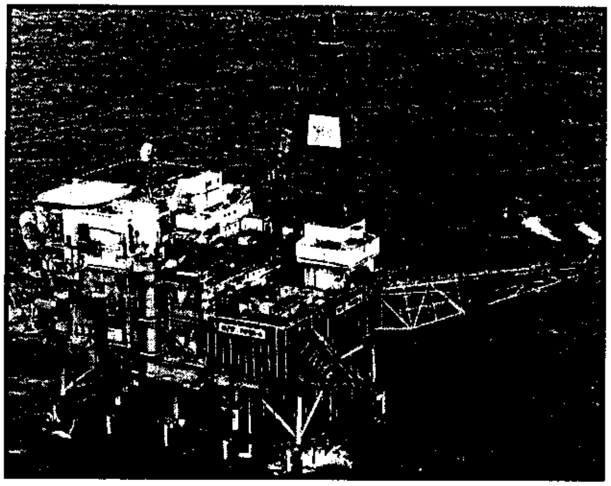

Figure 1 - *Piper Alpha* Platform in North Sea

Earlier in the day, gas being produced from two adjacent platforms and sent via pipeline to Piper Alpha placed the platform on a code red status (maximum production). One of the two condensate (liquids produced from the gas) injection pumps failed, and the other pump was turned on. The spare pump could not inject fluids into the pipeline because it had been taken out of service. It had been blind-flanged for maintenance of an emergency relief valve by the day crew. A gas leak occurred, and the gas ignited with a deafening explosion in the gas compression module.

The crew working on the pump and the production superintendent were killed instantly. The near-by control room was devastated, and the emergency and power systems were knocked out. There was no power to activate emergency shut-in controls. Unprotected fuel storage above the gas compression module was ignited and thick, dense, toxic smoke engulfed the quarters where surviving crew members were being mustered for evacuation in life boats. In the dark and confusion, the crew members were overcome by the smoke and died. The order to evacuate never came. The crew members that were saved did not muster in the quarters. They saved themselves by jumping from the platform decks into the water some 100 feet below where they were picked up by stand-by boats.

Water could not be pumped through the platform fire deluge system (like a fire sprinkler system in a building), because the pumps had been placed on manual control. This precaution had been taken to protect divers under the platform from being sucked into the pump intake. The fire fighting pumps and deluge system could not be activated due to the loss of the production control room. Due to the intensity of the heat and explosions, and confusion in the command

1 Copyright 1995, U. S. Coast Guard, Proceedings of the Marine Safety Council, Washington, DC.

the critical issues were firmly rooted in the undesirable activities of people.

On the night of February 15, 1982, the floating offshore drilling unit Ocean Ranger was conducting drilling operations 166 miles east of St. John's Newfoundland, Canada, in about 260 feet of water (Figure 3). Heavy seas were running with wave heights between 30 and 40 feet. Winds were gusting up to 90 knots. Drilling operations were suspended due to the bad weather.

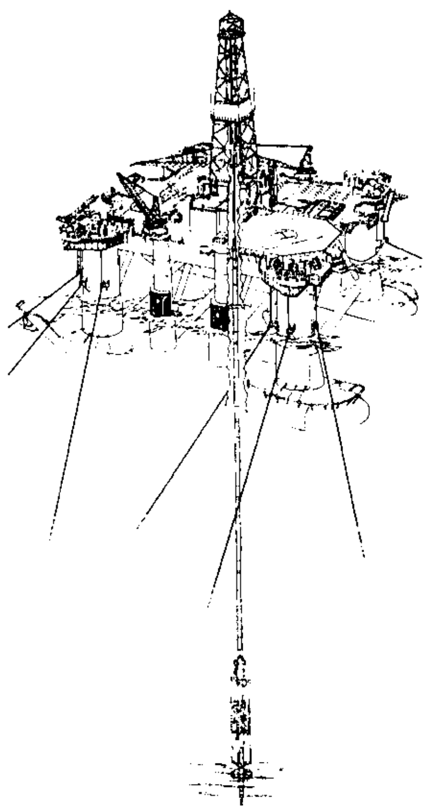

Figure 3 - Floating Drilling Unit
Ocean Ranger

About 7:00 in the evening, spray from a large wave broke a portlight in the ballast control room and caused an electrical malfunction. A 10 to 15 degree list developed due to the forces from the storm and an accidental transferring of liquids in the ballast tanks by the malfunctioning ballast control system.

The master and crew on board the Ocean Ranger apparently did not understand the operation of the complex ballast system, and they were unable to manually correct the increasing list of the unit. The ballast system operations manual did not provide adequate guidance regarding correcting the situation, and the unit slowly continued to turn over.

Although the Ocean Ranger's upper hull was watertight, there were large openings to the chain lockers in each corner column. These chain lockers are used to store the chain used to moor this marine system. As the unit continued to list, the chain lockers were filled by the waves and the Ocean Ranger capsized and began to sink.

About one o'clock in the morning, emergency rescue aircraft and boats were dispatched to the Ocean Ranger. However, due to the severe storm, the aircraft could do little but help direct the rescue boats to the site. The crewmen donned life jackets, but there were no exposure suits for protection against the cold 31° F water. Those that escaped directly into the water were quickly immobilized and died due to hypothermia before they could be picked up by the standby boats.

The one lifeboat that could be launched capsized alongside a rescue boat when water entered a hole in the bow and everyone moved to one side of the lifeboat. The standby vessels did not have adequate equipment for recovering the survivors from the water under the adverse weather conditions.

Nine hours after the portlight had been broken, the Ocean Ranger sank to the bottom of the North Atlantic. All 84 crewmen perished. No one wanted this disaster, but again poor systems interacting with poorly managed people resulted in another catastrophe at sea.

Very similar stories of unexpected and undesirable interactions of people and marine systems background other major marine accidents such as the Torry Canyon, Amoco Cadiz, Exxon Valdez, Braer, Therald of Free Enterprise, and the Estonia.

As these sad pieces of the history of "men, ships, and the sea" testify, the majority of high consequence, low probability marine accidents have one common theme: **a chain of important errors made by people in critical situations involving complex technological and organizational systems.** The errors go beyond the individuals directly involved in the incidents. In a majority of these accidents, there are organizations that provide "cultures" that invite excessive risk taking, demand superhuman performance, or develop complacency that results in reactive safety management. Excessive cost-cutting measures and a focus on short-term results are frequently symptomatic of such cultures. The industry, government, and public all share in providing the encouragements that allow such cultures to develop and persist.

accidents are those that we can anticipate. Once anticipated, we can put measures into place to prevent such accidents and mitigate their effects. An ounce of prevention is worth a ton of cure. Our study of past catastrophic accidents involving a variety of marine and non-marine systems indicates that prevention can only go so far. More safety work should be directed at learning how to better manage catastrophic "abnormal" accidents, and in mitigating the effects of such accidents. The admission that there can be abnormal accidents that represent unrecognized and perhaps unknowable combinations of situations is a major step in the right direction. Our work is clearly indicating that very different measures are required to successfully manage abnormal accidents. This is particularly true when stress is very high (perhaps due to noise, motion, and threat of harm) and the situation is rapidly unfolding.

There are some highly qualified and devoted people attempting to improve the safety of marine systems. However, sometimes it is easy to find inadequately trained and motivated people in these jobs, frequently working without proper resources to really do their jobs. This is a work function that costs money, and if it does its job, does not clearly show a reduction in costs. In most cases, we have not been involving properly qualified and experienced safety personnel in the early design and construction phases. They frequently are presented with an extremely complex system and hazardous situation, and told to manage it without stopping production (like changing the oil in a car going 60 miles per hour). Perhaps it is not surprising that many of those faced with the problems of safety management of marine systems focus on technical fixes, while largely ignoring people fixes.

Those of us that go to sea in ships must learn to be truly proactive at accident prevention (first priority) and accident mitigation (second priority). We must honestly recognize the potential blindness produced by our pride, our enduring trait of wishful thinking (optimism), our limitations (fatigue, boredom, confusion, ignorance), and our reckless ways. The human and organizational elements of our systems must be engineered, built, tested, and revised just as we do physical elements of these systems, and each of these need to compliment the other. We should design our systems to be more forgiving and tolerant of errors and flaws; people tolerant and damage tolerant (fail-safe) systems. We must understand that imperfection is more the rule than perfection. Marine systems must be designed so that they are simpler and more adaptable to what people can or will actually do.

Recognition of the roles of HOF in the safety of marine systems must address the level of the individual; selection, training, testing, motivating, and verifying to a degree commensurate with the job to be performed and the needs for safety in the job. People must be trained how to manage crisis situations in the systems they operate. Reduction in complexity of tasks, improvements in personnel selection procedures, providing for self and external checking, planning and scheduling to reduce time pressures and fatigue effects, and providing positive incentives for high quality performance can all help in reducing the incidence of accidents due to HOF. Our research clearly indicates that high quality crews involved in design, construction, operation, and maintenance of marine systems are much more important than the quality of the marine system itself.

A very critical aspect of improving the safety of marine systems regards the organization aspects. Our work shows that the dominant contributing or underlying cause of most high consequence accidents relates to the organization or organizations that influence the life-cycle of a particular marine system. The same can be said for the compounding causes that allow accident initiators to propagate to catastrophic proportions. We need to understand the heritageís of our corporate cultures, their powers and limitations, their flaws, the incentives they provide, and their capabilities to respond in a positive manner in quickly escalating and potentially catastrophic situations. We need to recognize the extreme importance of effective communications in organizations including information collection, archiving, retrieval, analysis, and dissemination; in particular the potentials for information filtering (things are better than they are) need to be recognized. We need to provide organizations that will maintain constant situation awareness, promote migrating decision making so that decisions can be made by those that have the most information, and provide robustness in the structure of the organization so that defects and deficiencies that can develop in the organization will not be allowed to degrade safety. An equitable system of positive incentives must be provided that will encourage safety of marine systems.

In the end, our research indicates that improving safety at sea basically is not a problem of not knowing what we should do. It is a problem of not doing what we know we should not do.

Discussion of Key Points in Lecture 1
Major Accidents Involving Offshore Platforms

MEN, SHIPS, AND THE SEA: The Human Factor

1. It generally takes a sequence of several (e.g. 5 to 10) errors, events, developments, and influences to develop an accident. In the post-analysis of Piper Alpha, there was a sequence of more than 20 events that lead to the initial explosions and the final destruction of the platform. It is important to recognize that it would have been virtually impossible to have predicted this sequence of events and developments.

2. Experience indicates that for every accident there are 10 to 100 'near misses' and 100 to 1000 'incidents.' This is important for several reasons. First, people regularly are able to interrupt the developing sequences and turn these sequences into incidents and near misses. Second, there are many early warnings that precede an accident. There were many incidents and near-misses onboard Piper Alpha that preceded the 1988 catastrophic accident.

3. Accidents, near-misses, and incidents involve the interactions between seven primary elements: 1) the operators (people directly involved), 2) the organizations (people and influences indirectly involved), 3) the hardware (physical equipment, facilities), 4) the structure (supporting, protecting elements), 5) the procedures (formal, informal, written, not written), 6) the environments (external, internal),and 7) the interfaces between the foregoing. There can be break-downs in each of the six elements and between these elements (the seventh component).

4. In the case of Piper Alpha, 14 systems broke down or were not functional on the night of the catastrophe. There were ample warning signs of the potential disaster. The platform operator had been made well aware of the potential problems. However, wishful thinking (nothing ever happened before) and 'lets think about this some more before we make the investment' resulted in 'an accident waiting to happen.'

5. The Piper Alpha accident had a direct cost to Occidental of approximately $2 billions and an indirect cost of about the same amount. This accident had a major affect on the regulatory system in the UK sector of the North Sea and on the industry.

6. The Piper Alpha accident involved major breakdowns in all seven of the components noted earlier. Most important were the breakdowns in the operating teams and the organizations.

7. Like the Piper Alpha accident, the Ocean Ranger accident represented an almost impossible to predict sequence of events and developments. But, could the accident have been anticipated and prevented? I think that the answer is clearly yes. But, it was not. Why? Fundamentally, because no one really looked. The operating personnel and even the organizations had become 'risk habituated.'

8. An in-depth study of about 600 major accidents involving marine systems clearly indicates that about 80 % of the accidents are due principally to breakdowns in the human components of these systems. About 80 % of the accidents are due to 'exherent' or human causes. The remaining 20 % of the accidents are due to inherent or environmental causes. These are frequently referred to as 'acts of god.'

9. Of the 80 % of accidents that have fundamental roots in human causes, about 80 % of these accidents develop or occur during the operating phase of the platform life. This is reasonable since this represents the longest portion of the life of a platform. Many of the accidents that develop during the operating phase are founded in maintenance and loss of well control (during primary drilling or work-over operations). It is important to recognize that many of the accidents that develop during the operating phase have roots embedded in the design phase and the construction phase. Bad design can lead to bad construction, and these two can lead to a difficult to operate and maintain system.

Lecture 2
Fundamentals of Human and Organizational Factors

Human and Organization Factors in Design, Construction, and Operation of Offshore Platforms[2]

by
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University of California at Berkeley
and
Professor Karlene Roberts
Haas School of Business
University of California at Berkeley

Abstract
This paper addresses Human and Organization Factors (HOF) in the contexts of approaches, assessments, and experiences that are intended to help improve the quality, safety, and reliability of offshore platforms. These elements are intended to primarily address potentially critical situations involving HOF that can develop during design, construction, operation, and maintenance of these facilities.

Introduction
Experience with offshore platforms* has amply demonstrated that the primary hazards to the quality, safety, and reliability of these systems are associated with the actions and inactions of the people that are involved with the design, construction, maintenance, and operations of these systems. Rarely are the primary problems associates with the structures, hardware and equipment. This is clearly a tribute to good engineering, construction, and operations.

Experience clearly shows that roughly 80 % of the major compromises in quality of these systems can be attributed to Human and Organization Factors (HOF).[1,2,3] About 80 % of these compromises occur during operations and maintenance. However, many of these compromises have antecedents firmly embedded in design, and construction.[4] These findings are similar to those found in a wide variety of non-marine systems and communities.

Experience also has amply demonstrated that traditional methods and approaches to help assure that desirable quality, safety, and reliability are developed work in the vast majority of cases.[5] It is the rare, low probability, high consequence situations involving HOF slip through the Quality Assurance and Quality Control (QA / QC) processes and associated management strategies (e.g. Total Quality Management). The contents of this paper are intended to address what is not addressed by traditional quality management activities and strategies. We are focused on prevention and mitigation of high consequence - low probability accidents.

The contents of this paper represent a summary of some of the key results from six years of work that have addressed the life-cycle quality, safety, and reliability aspects of a wide variety of both marine and non-marine system[1-4,6-12] This work has involved field studies in which attempts have been made to apply, verify, and test the results of the research.[4,19-11] The work includes in-depth studies of information contained in major marine systems accident data bases[3,11] It continues to focus on HOF in design, construction, and operation of marine systems including platforms, marine terminals, pipelines, and commercial tankers.

[2] Copyright 1995, Society of Petroleum Engineers, Transactions Paper SPE 30899

maintaining and increasing production; meanwhile the organization hopes for safety (*rewarding 'A' while hoping for 'B'*). The *formal and informal* rewards and incentives provided by an organization have a major influence on the performance of operators and on the reliability of offshore platforms.

One of the most pervasive problems that has resulted in failures of offshore platforms regards organizational communications. In the case of the Piper Alpha platform, the break down in organizational communications was represented by the failure of the permit to work system and the organization's ignoring early warning signals issued by the field operating personnel.[17,18] Due to incentives provided by the organization, there were tendencies to filter information, making the bad seem better than it was. In development of programs to improve management of HOF, careful consideration should be given to information integrity (collection, communications, and learning), particularly as they affect the balancing of several objectives such as costs and reliability.

Several examples of organizational malfunctions recently have developed as a result of efforts to down-size and out-source as a part of *re-engineering* organizations.[19] Loss of corporate memories (leading to repetition of errors), creation of more difficult and intricate communications and organization interfaces, degradation in morale, unwarranted reliance on the expertise of outside contractors, cut-backs in quality assurance and control, and provision of conflicting incentives (e.g. cut costs, yet maintain quality) are examples of activities that have lead to substantial compromises in the intended quality of systems.[19]

Experience indicates that one of the major factors in organizational malfunctions is the culture of the organization.[6-8] Organizational culture is reflected in how action, change, and innovation are viewed; the degree of external focus as contrasted with internal focus; incentives provided for risk taking; the degree of lateral and vertical integration of the organization; the effectiveness and honesty of communications; autonomy, responsibility, authority and decision making; rewards and incentives; and the orientation toward the quality of performance contrasted with the quantity of production. The culture of an organization is embedded in its history.

Hardware Malfunctions. Human malfunctions can be initiated by or exacerbated by poorly engineered systems and procedures that invite errors.[20,21] Such systems are difficult to construct, operate, and maintain. **Table 4** summarizes a classification system for hardware (equipment, structure) related malfunctions.

New technologies compounds the problems of latent system flaws.[22] Complex design, close coupling (failure of one component leads to failure of other components) and severe performance demands on systems increase the difficulty in controlling the impact of human malfunctions even in well operated systems.[22,23]

Emergency displays have been found to give improper signals of the state of the systems. Land based industries can spatially isolate independent subsystems whose joint failure modes would constitute a total system failure. System malfunctions resulting from complex designs and close coupling are more apparent due to spatial constraints aboard offshore platforms. The field of *ergonomics* has largely developed to address the human - machine or system interfaces. Specific guidelines have been developed to facilitate the development of people friendly systems.[21]

The issues of system robustness (defect or damage tolerance),[2,4,24] design for constructablity, and design for IMR (Inspection, Maintenance, Repair)[12] are critical aspects of engineering offshore platforms that will be able to deliver acceptable quality. Design of the structure system to assure robustness is intended to combine the beneficial aspects of redundancy, ductility, and excess capacity (it takes all three). The result is a defect and damage tolerant system that is able to maintain its serviceability characteristics in the face of HOF. This has important ramifications with regard to structural design criteria and guidelines.[4] Design for constructability and IMR have similar objectives.[12]

Software Malfunctions. Table 5 summarizes a classification system for procedure or software malfunctions. These malfunctions can be embedded in engineering design guidelines and computer programs, construction specifications, and operations manuals.[2] They can be embedded in how people are taught to do things. With the advent of computers and their integration into many aspects of the design, construction, and operation of marine structures, software errors are of particular concern because *the computer is the ultimate fool.*

Software errors in which incorrect and inaccurate algorithms were coded into computer programs have been at the root cause of several major failures of marine structures.[2,4] Guidelines have been developed to address the quality of computer software for the performance of finite element analyses. Extensive software testing is required to assure that the software performs as it should and that the documentation is sufficient. Of particular importance is the provision of independent checking procedures that can be used to validate the results from analyses. High quality procedures need to be verifiable based on first principles, results from testing, and field experience.

Given the rapid pace at which significant industrial achieve and assure the desired level of quality in a marine structure. This approach uses *soft linguistic variables* (e.g. high, moderate, low) to describe the quality attributes of systems and procedures. Integration of the evaluations of the attributes generally is subjective.

This approach may or may not involve detailed structuring of systems and the related HOF EDA (Events, Decisions, Actions) that may influence the quality of these systems.[3] Traditional hazard and operability studies (HAZOP) have addressed the hardware and equipment aspects in design guidelines such as API RP 14C.[27] HOF influences have generally not been addressed.[28] Recently HOF have been addressed in development of API RP 75 guidelines for Safety and Environmental Management Programs (SEMP).[5,29]

Quantitative - Objective. The second approach can be termed *objective* or *quantitative*. This approach is generally utilized for higher consequence systems and processes in which undesirable levels of quality have potentially severe ramifications. This approach generally examines in much greater detail the systems and the EDA that influence the quality of these systems.

Numerical analytical models are used to provide quantitative indications of the effects are of changes in the quality management systems and procedures. This approach generally focuses on the critical aspects of systems that have been evaluated using more general qualitative methods. *Hard numerical variables* are used to describe systems and procedures. The analytical probability based models provide for a structured integration of the effects and variables.

The quantitative approach has traditionally been identified as the PRA (Probabilistic Risk Analysis)[17,18,30,31] or QRA (Quantified Risk Analysis) approach.[32,33] It has been highly developed and applied to a wide variety of types of marine and non-marine systems.

Mixed Qualitative - Quantitative. The third approach is a mixed qualitative and quantitative process. *Linguistic variables are translated to numerical variables.* A mathematical process performs analytical integration of the effects and variables. In one form, this approach has been based on the mathematics of *Fuzzy Sets*.[34] Moore and Bea[3] utilized such an approach in developing THESIM (Human Error Safety Index Method) to assist in the quantitative evaluations of HOF in operations of marine systems (ships, offshore platforms). Gale, et al.[35] utilized a similar ranking - index method to evaluate the potentials for fires and explosions onboard offshore platforms. This method has been identified as FLAIM (Fire and Life safety Assessment Indexing Method).[36]

This approach has been termed *soft computing*.[37] The rigid structure of formal probability theory and analytical quantification are surrendered in favor of a more flexible structure. Expert systems (knowledge base systems) and neural networks have been combined with the theory of Fuzzy Sets to provide an evolving approach to the evaluation of systems in which there is either no need or it is not desirable to apply the analytically more demanding hard computing approaches.3[7] This approach is being applied to a wide variety of non-marine systems such as buildings, bridges, dams, and pipeline systems.

Fundamentally this third approach can be developed and applied in the context of the first two approaches. Traditional reliability theory can accommodate this approach if analysts are willing to surrender rigid interpretations applied to probability numerical quantifications and analyses. Conventional probability theory and mathematics can be used to provide the necessary quantifications that provide links with qualitative expressions of likelihoods.

If it is not desirable or possible to develop detailed models of the systems and processes, then other approaches can be used to develop the assessments, e.g., the Analytic Hierarchy Process.[38] The AHP structures problems as a hierarchy or priority formulation of the key considerations associated with a system, elicits judgments concerning the interactions and magnitudes of these considerations, represents those judgments with numbers, synthesizes the results in a formal mathematical framework, and analyzes the sensitivity of the results with plausible changes in the judgments. The AHP has been applied in studies to improve the quality of a wide variety of complex technological systems and the decision making processes associated with these systems.[38]

High Reliability Organizations

Even though it may be the most important, the organization aspects of platform design, construction, operations, and maintenance quality are perhaps the most difficult to define, evaluate, and modify.[22] Because of their pervasive importance in determining the quality achieved in offshore platforms, some critical aspects of quality in organizations will be addressed in this section. Organizations that are oriented toward achieving high quality and operate relatively free of malfunctions are termed *High Reliability Organizations* (HRO).[6]

The life-cycle of an offshore platform should be viewed in the context of the multiplicity of organizations that influence the quality of that process. The organizations and their activities form a *mega-*

combination of these factors have a high potential for compromises in the intended quality the platform structure. It should be a primary objective of QA / QC design measures to first prevent the occurrence of these factors and second to place checks in the primary parts of the design process to verify that they are not developing an undesirable compromise in the quality of the structure.

It is desirable that QA / QC are very stringent for the error intolerant elements that comprise a structure system.[2,4] Also, it is desirable to configure or design the element or component so that it can be error tolerant for the highly likely types of design, construction, and / or operations malfunctions. The design of damage or defect tolerant (*robust*) structures is very desirable. The sensitivities of various parts of a particular structure and various parts of a particular design process can be studied beforehand to determine the most error intolerant parts. Re-design and QA /QC efforts can thus be directed at those elements and aspects with the highest criticality. Constant attention needs to be given to these elements during construction, operation, and maintenance.[12] Inspections can help confirm the quality and condition of the elements most important to the integrity of the platform and most intolerant of low quality factors.

Table 7 addresses four key questions associated with design QA / QC: *what, when , how, and who to check.4*[2] High consequence of error parts are those aspects of the design process that are error intolerant. These are a high priority for QA / QC measures. Our research on design malfunctions indicates that at the present time much QA / QC effort is devoted to low probability and low consequence malfunctions. Implementation of a more structured QA / QC effort directed at high probability and consequence malfunctions can lead to reductions in QA / QC costs and increase in its effectiveness.[42,43]

Checking can be internal to the design team or external. Studies of design checking indicate that internal checking is relatively effective at detecting and correcting computational errors. Internal checking is relatively ineffective at catching major errors in concepts, particularly those embedded in traditional assumptions and procedures.[42,44] Announced external audits with effective mechanisms for checking detect these errors so they can be kept to an acceptable level. The timing of these audits is best scheduled before the design starts (to detect and correct critical flaws in the proposed approaches), during the critical parts of the design (to detect and correct major malfunctions of commission and omission), and after the design documentation has been completed (to detect major errors in the plans and specifications to be used for construction).[44,45]

The hows of checking are particularly important (**Table 7**).[4] The use of qualified and experienced engineers provided with sufficient time and information resources is very important. Following the failure of Sleipner A platform, a primary change made in the design process for the replacement platform was a 400 % increase in the resources provided for checking.4[5] Personnel selection and training were revised. Detailed procedures for the performance of the finite element analyses were developed. Physical testing of critical components was undertaken. And, the error intolerant *star cells* and their reinforcement were modified to develop a more robust structure system. All of these measures are excellent examples of QA / QC in the design process to better manage HOF. Detailed qualitative and quantitative evaluations were performed to identify potentially critical aspects of the design and construction.[45] In the wake of the $1+ billion disaster, little expense was spared to assure that the replacement platform would not experience the same or similar embedded flaws in the structure design and construction processes. The Sleipner B platform was installed without incident.

Management of Rapidly Developing Crises

Human malfunctions are magnified and compounded in times of extreme operating pressures associated with incidents such as blowouts, fires, and explosions.[17,18] This is the venue of rapidly developing crises in which the objective of the operators is not to develop and implement an optimum decision to secure the system. The objective is to simply secure the system with minimum losses.

Pressure results from a combination of task complexity, poor training, high task precision, psychological stress, intensity of distractions, and the severity of impairments.[46] Optimal performance levels are realized at an *appropriate level of arousal.* Increases in performance with the level of arousal is due to an expansion of the amount of cognitive resources mobilized for performance. However, there is a marked and rapid decrease in the performance reliability after the optimum pressure has been passed. This a consequence of the effects of pressure on the selectivity of attention; there is a focus on a restricted set of information. This focus can lead to a loss of *situation awareness.* High pressure is more detrimental to complex tasks that require large amounts of cognitive processing than simple tasks. Skill based automatic performance is much more important in high pressure situations. Thinking out all of the possibilities and actions and selecting the best one takes time, and due to the focusing of attention, may not result in adequate performance.

performance criteria, simplified task structure, provision of sufficient time to perform the tasks, providing clear, concise, and timely communications, minimizing the cognitive processing required to perform the tasks, and making the response and documentation system as simple and clear as possible are examples of task difficulty quality management strategies.

We continue to study crisis management in a wide variety of communities including emergency room operations, law enforcement, fire fighting, commercial and military aircraft operations, and nuclear power plant operations.[26] Much can be learned from these other communities that can be of benefit to improve management of rapidly developing crises onboard offshore platforms.[49]

Conclusions

The offshore industry has developed a wide variety of guidelines and procedures to help assure adequate and desirable quality is achieved during the life-cycle of offshore platforms. Experience indicates that these procedures are effective in the vast majority of cases. But, low probability and high consequence situations associated with HOF are slipping through this quality net. The structures and hardware are not the primary source of quality problems. People are.

Key aspects of what we have learned about achieving adequate quality in platform design, better managing crises during operations, and developing High Reliability Organizations have been summarized in this paper. Work on human factors in a variety of communities is continuing to improve this understanding.[49]

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TABLE 1 - CLASSIFICATION OF INDIVIDUAL MALFUNCTIONS
Communications - ineffective transmission of information
Slips - accidental lapses
Violations - intentional infringements or transgressions
Ignorance - unaware, unlearned
Planning & Preparation - lack of sufficient program, procedures, readiness
Selection & Training - not suited, educated, or practiced for the activities
Limitations & Impairment - excessively fatigued, stressed, and having diminished senses
Mistakes - cognitive malfunctions of perception, interpretation, decision, discrimination, diagnosis, and action

TABLE 2 - CLASSIFICATION OF MISTAKES
Perception - unaware, not knowing
Interpretation - improper evaluation and assessment of meaning
Decision - incorrect choice between alternatives
Discrimination - not perceiving the distinguishing features
Diagnosis-incorrect attribution of causes and or effects
Action- improper or incorrect carrying out activities

TABLE 3 - CLASSIFICATION OF ORGANIZATION MALFUNCTIONS
Communications - ineffective transmission of information
Culture - inappropriate goals, incentives, values, and trust
Violations - intentional infringements or transgressions
Ignorance - unaware, unlearned
Planning & Preparation - lack of sufficient program, procedures, readiness
Structure & Organization - ineffective connectedness, interdependence, lateral and vertical integration
Monitoring & Controlling - inappropriate awareness of critical developments and utilization of ineffective corrective measures
Mistakes - cognitive malfunctions of perception, interpretation, decision, discrimination, diagnosis, and action

TABLE 4 - CLASSIFICATION OF HARDWARE MALFUNCTIONS
Serviceability - inability to satisfy purposes for intended conditions
Safety - excessive threat of harm to life and the environment, demands exceed capacities
Durability - occurrence of unexpected maintenance and less than expected useful life
Compatibility - unacceptable and undesirable economic, schedule, and aesthetic characteristics

TABLE 5 - CLASSIFICATION OF SOFTWARE MALFUNCTIONS
Incorrect - faulty
Inaccurate - untrue
Incomplete - lacking the necessary parts
Excessive Complexity - unnecessary intricacy
Poor Organization - dysfunctional structure
Poor Documentation - ineffective information transmission

TABLE 6 - FACTORS INFLUENCING THE OCCURRENCE OF DESIGN MALFUNCTIONS
o new or complex design guidelines and specifications o new or unusual materials o new or unusual types of loadings o new or unusual types of structures o new or complex computer programs o limited qualifications and experience of engineering personnel o poor organization and management of engineering personnel o insufficient research, development and testing background o major extrapolations of past engineering experience o poor financial climate, initial cost cutting o poor quality incentives and quality control procedures o insufficient time, materials, procedures, and hardware

Discussion of Key Points in Lecture 2
Fundamentals of Human and Organizational Factors

Human and Organization Factors in Design, Construction, and Operation of Offshore Platforms

1. Quality is defined as freedom from unanticipated defects. Quality is fitness for purpose. Quality is meeting the requirements of those who own, operate, design, construct, and regulate offshore platforms. These requirements include those of *serviceability, safety, compatibility, and durability*. *Serviceability* is fitness for purpose. *Safety* is freedom from undue exposure to harm. *Compatibility* is the ability of the system to meet economic, schedule, and environmental constraints. *Durability* is freedom from unanticipated maintenance and maintenance related problems.

2. Reliability is closely related to quality. Reliability is defined there as the probability that a given level of quality will be achieved during the design, construction, and operating life-cycle phases of an offshore platform. Reliability is the likelihood that the platform will perform in an acceptable manner. Acceptable performance means that the system has desirable serviceability, safety, compatibility, and durability. The compliment of reliability is the likelihood or probability of unacceptable performance; the probability of failure. Failure is an event that results in an undesirable compromise in quality.

3. Mistakes, errors, and malfunctions are all part of the human condition. They are inevitable. A primary objective of reliability and risk analyses is to learn how to help minimize these malfunctions and to learn how to make the system robust so that it can tolerate these malfunctions without serious loss of its quality.

4. Mistakes, errors, and malfunctions can be defined as actions and / or inactions taken by individuals that can lead an activity to realize a lower quality than intended. Mistakes is a general term that is often used to describe cognitive malfunctions. Cognitive malfunctions arise from how one interprets and applies information. In general, we have tried to avoid use of the term errors because of the implications of blame and shame that are often associated with this term.

5. There are a wide variety of ways to categorize or classify human malfunctions. The classification system that is chosen should match the applications and uses for the system. The way that was developed during this research was based on study of more than major 800 accidents involving marine systems. The system was developed to identify the 'causes' of malfunctions that could be 'fixed' or remedied. The leading cause identified in our study was communications. Information was either not available, was erroneous, or was misunderstood.

6. Organizational malfunctions have been shown to be a primary cause of human malfunctions. Knowingly or unknowingly, the organization introduces influences that are counter to acceptable or desirable quality. The organizational 'culture' has a pervasive influence for either good or bad. The culture of an organization is embedded in its history and in the incentives that it provides for people to conduct high quality operations of their systems. Again, a leading cause of accidents involves communications between the organization and the people that operate a system. Information 'filtering' goes two ways and this filtering can and does frequently lead to accidents.

7. We all know that hardware can malfunction and these malfunctions can lead to accidents or compromises in the intended quality of a system. The hardware malfunctions can have influences or causes rooted in bad design and or bad construction. Hardware malfunctions can develop when there are inappropriate 'interfaces' between the hardware and the people that must use the hardware. Around this problem the field of micro-ergonomics has developed. An objective of micro-ergonomics is to configure and design the system so that it is 'user friendly', 'forgiving', and does not invite malfunctions by its human operators.

and analytical procedures, not calculations. Emphasis should be given to correction measures: providing sufficient resources to adequately correct detected malfunctions.

15. Management of rapidly developing crises addresses the third approach in managing the reliability of offshore platforms: real time management. This approach will be further detailed in a future section of this training course.

Quantitative & Qualitative Risk Analyses: The Safety of Offshore Platforms[3]

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This paper was presented at the 28th Annual OTC in Houston, Texas USA, 6-9 May 1996.

Abstract

Two primary methods have been used in performing safety audits of platforms: 1) qualitative methods such as HazOp (Hazard and operability analyses) and FMEA (Failure Modes and Effects Analyses) and, 2) quantitative methods such as QRA (Quantified Risk Analyses) and PRA (Probabilistic Risk Analyses). A third method, identified in this paper as Safety Indexing Methods (SIM), has been developed and is being applied to offshore platforms. This paper discusses experience with applications of these methods in development of safety audits on offshore platforms. The pros and cons of these alternative methods are discussed.

Results of the experiences summarized in this paper highlight the potential complementary nature of the three assessment methods. These experiences indicate that it is critical that the fundamental objective of the applications of these methods be kept in clear view. It is contended that the fundamental objective of the applications should be to develop improvements in the safety of offshore platform operations and not to produce elegant analytical constructs. The most essential ingredient in such improvements is the integration of the experience, insights, and judgment of those that have direct and daily responsibilities for field operations.

Selection of an assessment and auditing process must take into account the skills and knowledge of these people. Any safety audit process that does not account for implementation in and by the field rarely is beneficial to safety. Whatever method is used should facilitate interactions with the people in the field, and should result in the empowerment of those in the field.

An important objective of this work is to help enhance platform safety while at the same time enhancing the long term profitability of the operation: "Safety can be good business."[1] Experience indicates that some safety related activities should be discarded and more effective and efficient methods adopted. Thus, improvements in how safety is achieved can be realized without increasing costs. Profitability is required because without this profitability the resources will not be available to improve safety. There needs to be an equitable balance between adequate safety and sufficient profitability.

Introduction

Experience has amply demonstrated that the major problems associated with the safety of offshore structures generally are not associated with the structures or the equipment onboard these structures. They are associated with Human and Organization Factors (HOF) that develop during the design, construction, operation, and maintenance of the structures.[2]

Table 1 summarizes observations based on results from a study of several hundred well documented cases involving low-probability, high-consequence (LP/HC) platform accidents.[3] These observations indicate that the primary concerns for platform safety should be centered in equipment and facilities involving interactions with human and organization factors during operations and maintenance that can result in blowouts, explosions, and / or fires. While individuals can be blamed for initiating accidents, the prevalent contributing and compounding factors associated with

[3] Copyright 1996, Society of Petroleum Engineers, Proceedings of Offshore Technology Conference, Paper No. 8037

and with a variety of metrics. Monetary costs are one metric to measure and express consequences. Time (schedule, availability), injuries to humans, and injuries to the environment are other ways to express and measure consequences.

Some consequences can be proactively managed or controlled (hazard mitigation measures). Some consequences can not be proactively managed or controlled. Some consequences can be evaluated objectively and quantitatively and some consequences can not be evaluated objectively and quantitatively.

Generally, there are significant uncertainties associated with the results of evaluations of consequences. This is particularly so as one projects the consequences of insufficient or unacceptable quality far into the future.

Evaluations of consequences are difficult to make and express. Evaluations of consequences are very susceptible to the values, views, and biases of the assessors (Table 3).[2]

Some consequences are essentially static. Other consequences are very dynamic in that they change markedly with time.

An identified risk is an engineering and management problem. A faulty or bad definition of a risk can result in additional risk and result in bad management of safety. A risk management framework should be based on intelligent and perceptive risk identification, classification, analysis, evaluation, and response. Risk management attacks both the likelihoods of compromises in quality and the consequences associated with these compromises.

Risks have sources, are translated to reality with events, and are felt with effects. There are initiating events (direct causes), contributing events (background causes), and compounding events (propagating or escalating or arresting causes). *Risk management attempts to identify and remedy causes, detect potential and evolving events and bring them under control, and minimize undesirable effects.*

Risks are independent and dependent. Risks can have partial dependence. If the occurrence of one risk does not influence the occurrence of another risk, then it is independent. If the magnitude of one risk is related to the magnitude of another risk then these two risks are correlated. Independence and correlation are critical issues in risk analysis, evaluation, and management.

Risks are controllable and uncontrollable.[11] Controllable risks are those that are within the direct control of those that own, operate, design, classify, regulate, and build offshore platforms. Uncontrollable risks are those that are not within the direct control of these groups. Proactive risk management is concerned primarily with predictable and controllable risks.[5] Real-time risk management is concerned primarily with unpredictable risks. Inherent risk and uncontrollable risk must be recognized, evaluated, and managed in the process of making decisions regarding the activities and ventures associated with offshore platforms.

A risk management system should be practical, realistic, and must be cost effective. Risk management need not be complicated nor require the collection of vast amounts of data.[11,12] *Excellent risk management results from a combination of uncommon common sense, qualified experience, judgment, knowledge, wisdom, intuition, and integrity.* Mostly it is a willingness to operate in a caring and disciplined manner in approaching the critical features of any activity in which risk can be generated. *Risk management is largely a problem of doing what we know we should do and not doing what we know we should not do.*

The purpose of a risk management system should be to enable and empower those that have direct responsibilities for the designing, building, maintaining, and operating offshore platforms. The engineer can play a vital role in this empowerment. If technology is not used wisely, scarce resources and attention can be diverted from the true factors that determine the safety of an offshore platform, and less safe systems developed. The purpose of a risk management system should be to assist the front line operators to take the right (sensible) risks and to achieve acceptable safety. To try to completely eliminate risk is futile. To help manage risks and make appropriate use of technology should be one of the key objectives of offshore engineering and management.

There are three fundamental HOF risk management approaches: *1) reduce the incidence and severity of HOF, 2) reduce the effects of HOF, and 3) increase the detection and remediation of HOF.* Experience indicates that a good risk management program will employ all three approaches in a balanced way.

Incidence and Severity Reduction. The first approach is very difficult. It requires fundamental changes in how operators are selected, trained, audited, and evaluated. Current experience with major accidents on offshore platforms indicates that in the majority of cases, the particular set of circumstances and breakdowns that resulted in the accident could not have been predicted. Who could have predicted the sequence of events and simultaneous breakdown of 13 critical systems on Piper Alpha that night in 1988?[13] While not lessening the importance of and necessity for proactive management of safety, this recognition highlights the necessity for 'real time' management of crises.

As a result of a study of how different professional level of safety even though they are subjected to normal abuse.

Detection and Remediation. The third approach is focused on internal and external assessments and auditing. Quality Assurance and Quality Control (QA/QC) measures have traditionally addressed detection and remediation of hazards and flaws. QA are those practices and procedures that are designed to help assure that an acceptable degree of quality (safety, durability, serviceability, compatibility) is obtained. QA is focused on prevention of errors. QC is associated with the implementation and verification of the QA practices and procedures. Quality control is intended to assure that the desired level of quality is actually achieved. Quality control is focused on reaction, identification of errors, rectification, and correction.[2]

QA/QC measures are intended to assure that a desirable and acceptable reliability of the platform is achieved throughout its life. Quality is initiated with the conception of a platform, defined with design, translated to reality with construction, and maintained with high quality operations. Achieving quality goals is primarily dependent on people. QA/QC efforts are directed fundamentally at assuring that human and system performance is developed and maintained at acceptable levels.

QA/QC strategies include those put in place before the activity (prevention), during the activity (checking), after the activity (inspection), after the manufacture or construction (testing), and after the platform has been put in service (detection). The earlier QA/QC measures are able to detect the lack of acceptable quality, then the more effective can be the remediation.

Of all of the QA/QC measures, the most effective are those associated with prevention. As factors leading to lack of desirable safety are allowed to become more and more embedded in first the design, then the construction, and then the operation of a platform, then the more difficult they are to detect and correct. Personnel selection, training, and verification; the formation of cohesive teams and encouragement of teamwork, and the elimination of unnecessary complexity in procedures and structure - equipment systems are examples of effective QA/QC measures.

Control QA/QC measures consist of procedures and activities that are implemented during activities to assure that desirable quality is achieved. Self-checking, checking by other team members, and verification by activity supervisors are examples of such activities.

Inspection and verification QA/QC measures consist of procedures and activities that are implemented after an activity has been completed.

Detection QA/QC measures consist of procedures and activities that are implemented after the platform has been put in service to assure that desirable and acceptable quality and safety are maintained.

Norwegian offshore safety management system.[23,28]

Mixed. The third approach is a mixed qualitative and quantitative process. It is identified there as a Safety Indexing Method (SIM). Linguistic variables are translated to numerical variables. A mathematical process is provided to perform analytical integration of the effects and variables. Groeneweg utilized this approach in development of the Tripod Delta evaluation process.[11] This process has been used very successfully in identifying critical elements on platforms that need to be addressed to improve safety.[11] Moore and Bea utilized such an approach in development of THESIM (Human Error Safety Index Method) to assist in the quantitative evaluations of HOF in operations of ships and offshore platforms.[3]

Gale, et al utilized a SIM to evaluate the potentials for fires and explosions onboard offshore platforms.[29] This method has been identified as FLAIM (Fire and Life safety Assessment Indexing Method). During the next two years, under the auspices of a joint industry - government - classification society sponsored project,[30] FLAIM will be further developed to incorporate the Mineral Management Service's SEMP (Safety and Environmental Management Programs),[1] the American Petroleum Institute's RP 75 guidelines,[31,32] the Health and Safety Executive's PFEER (Prevention of Fire and Explosion and Emergency Response) regulations,[33] the International Maritime Organization's ISM (International Safety Management) code,[34] and the International Standards Organization guidelines for petroleum facilities.[35] An assessor training protocol will developed and implemented for three teams of assessors. The assessor teams will be comprised of regulatory, owner/operator, classification, and consulting engineering personnel. The FLAIM assessment instrument (a laptop computer program) and assessor training protocol will be field tested on four offshore platforms and two marine terminals.[30]

A SIM has been applied recently by the Nuclear Regulatory Commission in development of regulations for medical radiation facilities.[36,37] Even though PRA have been highly developed by the nuclear power industry, a SIM was used in this instance because of the large number of facilities (more than 2,000), the lack of definitive data on performance characteristics of these facilities, and the over-riding importance of HOF in the safety of these facilities.[36]

The 'gamma knife' approach involved a review of the types of facilities and a characterization of the associated risks, identification of the risk contributors by the practitioners responsible for the operation of the facilities, a preliminary screening of these contributors to identify the potential high risk contributors, development of relative risk profiles, performance of an importance and uncertainty analysis, and a resulting identification of the operator, organization, procedure, and hardware elements that should be the primary targets for safety management.[37] This approach did not involve development of any overall grading of a particular facility and operation. It focused on identification and remediation of the potentially high risk components. Experience since implementation of the approach indicates that it has developed realistic and meaningful evaluations of the risks associated with these facilities.[38]

Strengths and Weaknesses. Each of the three approaches possess strengths and weaknesses.[2,11,12,14] The qualitative approach does not attempt to capture details of the systems and processes. Rather it focuses on a general evaluation of the systems and processes and attempts to identify the critical elements in these systems and how they might be improved. Given the extremely complex and frequently irrational nature of the systems and processes that are involved in offshore platforms, the qualitative approach offers some significant advantages. As for any of the approaches, the quality of the approach depends directly on the experience, skill, and motivations of the assessors.

The quantitative approach is frequently viewed as one that is able to capture the details of systems and processes, and to a certain extent this is true. For well defined and 'behaved' systems and processes, the quantitative approach offers some significant advantages and attractions. However, for ill-defined systems, and particularly those that involve significant and complex HOF interactions, then one might question the reality of the results produced by the quantitative approach.[11,14,39]

Viewed in the context of their life cycle of design, construction, and operations, offshore platforms are extremely complex. Based on recent experience in attempting to apply this approach in the field,[40] it is contended that quantitative approaches generally are not able to sufficiently capture this complexity. Yet, the approach appears to capture the complexity. Added to the poor quality of information and data that is available to provide objective information on HOF,[2,3,41] one is left with a feeling that application of quantitative approaches produces results that have severe limitations.

In addition, multiple PRA/QRA performed on the same system or even a given accident often do not produce reasonably consistent results.[11,14] As systems become more complex, then the PRA/QRA must become more complex. This spiral results in computational and analytical nightmares that almost

PRA analyses that had been developed. Extensive and sophisticated fault tree and event tree analyses had been developed. With the computer analytical models, one could make a change in a piece of equipment on the platform, and instantly determine its effect on the probability of failure. Modifications to the structure and facilities were being studied to determine how best to meet the ALARP (As Low As Reasonably Practical) guidelines.[27] I asked the engineers how HOF were being integrated into the analyses and got the answer that these effects were implicitly included in the equipment and activity failure rates that were input to the computer models. There were no explicit evaluations of HOF.

Several of the contract engineers were veterans of Safety Case studies. Their expertise in performing PRA/QRA was very highly developed and they were rightly proud of this expertise. In the course of reviewing the details of the Safety Case study, one of these engineers said that in his experience, one of the best Safety Case studies that the had ever seen was written by field people, for implementation by field people, and did not contain any numbers. The said that Safety Case studies did not have to be performed using PRA/QRA methods, but that many, if not most owner/operators had chosen to use PRA/QRA in performing their Safety Case studies. I asked why the was so keen on helping perform this very intensive PRA when the had reservations concerning the utility of the analyses. He responded that this is what he had been asked to do and what his company did. His job as a contract engineer depended on performing PRA/QRA.

My meetings with the safety department focused on the safety procedures that had been developed to help guide daily drilling, workover, and production operations on the platform. The safety department was rightly proud of the extensive volumes of safety procedures that had been developed for the platform operations. They occupied one bookcase shelf. In reading through the extensive books of procedures, I developed the feeling that due to their extent, detail, and complexity, that they literally defied human comprehension and performance. Heavy emphasis was given to routine and daily safety processes. Little attention was given to real-time crisis management. It appeared that many of the guidelines had been written following each significant new accident. I encountered these same volumes of procedures and some of the same safety engineers when I visited the regional production office. I got the impression that these volumes rarely were read in any detail or left the book shelves.

Regional Office. At the regional production office, again the preoccupation of many of the personnel was with the reorganization of the company. And again, the effects of down-sizing, out-sourcing, and cost-cutting were clearly evident. On one side of the office, the primary preoccupation was with increasing production on the platform. Recently, new wells had been completed and the gas production rate had been dramatically increased.

On the other side of the office, the primary preoccupation was with the Safety Case study and the requalification of the platform. A team of engineers and contractors were busy supplying information for the head office study. I had extensive meetings with the production managers and engineers and some of the platform operating personnel.

We reviewed the preliminary results from the Safety Case study. I was surprised to learn that the primary hazard to the platform was from vessel collisions. I asked if there had been any previous collisions that had threatened the safety of the platform. They responded that on many occasions they had sighted large vessels, but that there had not been any collisions or even near-misses with the platform or with other platforms in the area. Yes, there had been instances of collisions with supply and stand-by boats, but nothing that threatened the integrity of the platform or near-by platforms. Much effort was being expended on re-examining the analytical models and information that had been used to predict vessel collisions and their effects. In the history of worldwide platform operations, I could locate less than 12 cases in which collisions had severely threatened the integrity of a platform. Depending on how an 'accident' was defined, somewhere between 15 % and 30 % of the accidents involving major platforms were due to collisions. I could only explain this result as being an aberration of the PRA.

As was the case at head office, I was impressed with the very high quality of the personnel and their experience. I was fully briefed and prepared for the third stage of my audit on the platform.

My guide for the platform audit was a OIM (Offshore Installation Manager) from the North Sea. He had worked for 20 years with one of the major operators in the North Sea. He had been responsible for several of the largest production platforms in the North Sea. As we prepared for the helicopter trip to the platform, I was impressed by the extensive nature of the safety related preparations and briefings. A video briefing was given on proper use of PFD's (Personal Flotation Devices) and survival suits. I was issued a hard hat, safety toe boots, and coveralls. The emphasis on daily safety in operations was clearly evident. I loaded my gear onto the helicopter, climbed in behind months. They hoped that they would develop a solution soon and that the necessary work would be authorized and completed before one of the lines fatigued and ruptured. Again, I did not recall any recognition of this potential hazard in the Safety Case study. Perhaps, it had been assumed that it would be fixed.

After lunch, I went with one of the maintenance crews that were pulling gaskets on one of the platform's emergency shut down valves. This required a scheduled shut down of the platform production. After the valve was unbolted, the crew replaced the gaskets. They noticed that the valve operator stem was severely corroded and eroded. They started to replace the valve, and I asked why they were not going to replace the valve stem. They replied that they did not have any replacements on the platform. Due to cost cutting, the inventory of spare parts on the platform had been reduced to a bare minimum. They would have to wait until the part could be ordered and delivered and then replace the part during the next scheduled shut down. I could only wonder what would happen if the valve had to be used in an emergency and the valve stem broke.

As for many platforms, this platform had become very dependent on contract crews. This development was in dramatic contrast with the earlier platform organization in which company personnel had operated and maintained the platform. The contract crews were supervised by company shift foremen. The work was carefully controlled by an effective permit-to-work system. Important maintenance and production work specifications and plans were written up, approved by the facilities engineers, production manager, shift foreman, and OIM. I was told about one work plan that had 53 signatures on it.

The work plans were reviewed with the contract crews before work was begun. The primary concern of the platform supervisory personnel was with the lack of training and experience that generally characterized the contract crews. I learned that these crews were contracted based on a low-bid process. To survive financially, the contractor had to do all possible to keep the costs of the crews as low as possible, and this resulted in the use of marginally trained and experienced personnel. The shift foremen and OIM related several instances in which contract crews had come close to causing a major accident that was narrowly avoided. A shift foreman commented "you do with what you got to keep on production." I wondered how this factor had been integrated into the PRA/QRA for the platform.

The next day, we began checking some of the critical deck structural elements, production piping, equipment, and facilities that were part of the Safety Case model. It was soon evident that there were major discrepancies between what was in the Safety Case model and what was on the platform. The operating personnel said that they had been unable to keep the facilities documentation up to date, and that the Safety Case model had been developed based on the information that was available in head office and in the regional production office.

I asked if the engineers that had been responsible for developing the Safety Case models had verified these models with the platform production personnel. They replied that such verification had not been done, but that it probably would be done soon. They did not know exactly when it would be done. The OIM and shift foremen said that most of the engineers that were performing the Safety Case analyses had never been on the platform. The platform operating personnel were not asked to help with the Safety Case analyses or studies. The traditional gulf between operations personnel and onshore staff was very wide. I heard the comment from one of the shift foremen that "the quickest way to not get something done is to ask engineering about it." I was beginning to understand.

In the process of this verification, I came upon the platform control room power supply, instrumentation, and communications cables. These cables came out of the control room and quarters wall next to the high pressure gas reinjection unit. The cables were exposed. The platform operating personnel said that the facility engineers had been studying how to protect these cable runs for more than a year. They needed to be protected, but they still had to be maintained, and occasionally replaced. The measures that had been proposed by the facilities engineers would not facilitate maintenance. Thus, there had been a 'stand-off' between engineering and operations. They hoped that a practical solution would soon be developed and implemented. Again, there was no recognition of the exposure of the control room power supply and instrumentation cables in the Safety Case analyses.

There was no fire and blast protection wall between the gas reinjection unit and the quarters and control room. Given a major explosion in the high pressure gas reinjection unit, the control room cables could be severed and the quarters and control room could be severely damaged. I was told by the OIM that the Safety Case analyses indicated that the risks associated with an explosion in the gas reinjection unit were ALARP and that a fire and blast protection wall was not required. In this case, results from the Safety Case study were used to justify not doing anything to protect the quarters and control room. Looking at the thin wall that separated the control room and quarters from the gas reinjection unit, I wondered.

helped the author begin to understand and learn about HOF, their potential impacts on complex technological systems, and how engineers might best begin to improve HOF in these systems. In particular, the author would like to thank Professor Ed Wenk (Emeritus University of Washington) and Professor Karlene Roberts (Haas School of Business, University of California at Berkeley) for their help and guidance.

This paper has been funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, under grant number NA89AA-D-SG138, project number R/0E-28 through the California Sea Grant College, and in part by the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U. S. Government is authorized to reproduce and distribute for governmental purposes.

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TABLE 1 - LP/HC ACCIDENT CAUSES		
20 %	**80%**	**Involves**
2		platform structure
	3	platform equipment & facilities
2		environmental hazards
	3	human & organization factors
2		design / construction sources
	3	operation / maint. sources
2		storms, collisions
	3	blowouts, fires, explosions
2		contributed & compounded by individuals
	3	contributed & compounded by organizations

TABLE 2 - ENGINEERING ASSESSMENTS	
what is	**is seen to be**
complex	simple
dynamic	static
uncontrollable	controllable
illogical	logical
emergent & organic	mechanical
dependent	independent
uncorrelated	correlated
uncertain	certain
expected	observed
unknowable	knowable
governed by actions of people & organizations	governed by laws of physics & mechanics

TABLE 3 JUDGMENT BIASES	
Type	**Influence**
Hindsight	Over estimation of the predictability of past events
Rational	Logical construction of events that can not be accurately characterized
Control	Over estimation of personal and corporate control over outcomes
Wishful thinking	Likelihood of desired outcomes judged to be inappropriately high
Small samples	Overestimation of the degree to which small samples represent a population
Knowledge	View that what needs to be known is known even though it is not adequately understood
Correlation	Belief that unrelated variables are correlated
Perception	Expectations distort observations of variables and outcomes
Recall	Likelihood of easily recalled experiences are distorted
Belief	Failure to revise forecasts and beliefs based on new information

Discussion of Key Points in Lecture 3
Assessment of Offshore Platforms To Evaluate Human and Organizational Factors

Quantitative & Qualitative Risk Analyses: The Safety of Offshore Platforms

1. In the previous session, we outlined three methods to 'analyze' the reliability characteristics of offshore platforms: quantitative, qualitative, and mixed qualitative - quantitative.

   Qualitative methods use linguistic variables to describe the quality attributes of systems. These methods include HazOp (Hazard Operability) and FMEA (Failure Modes and Effects Analyses). These methods rely on the experience and insights of the assessors to identify potential critical flaws in offshore platforms. These methods can be used as a starting point to evaluate complex systems. If an adequate job can be done with these methods, then they can become the sole means of proactively evaluating the reliability characteristics of offshore platforms

   Quantitative methods use numerical analytical models. These methods include Fault Tree and Event Tree methods, Probabilistic Risk Analyses (PRA) and Quantitative Risk Analyses (QRA). These methods are generally very intricate and time consuming. These methods require a high degree of technical proficiency. However, it is important to recognize that because of the general lack of definitive 'objective' data on which to base quantitative methods and the general unpredictability of human activities that are of critical importance to the reliability of offshore platforms, quantitative methods have some very important limitations. As or qualitative methods, the results from the methods rely heavily on the experience and technical expertise of the assessors that perform the analyses. Quantitative methods are generally used to perform detailed analyses of systems whose reliability can not be assured otherwise.

   Mixed qualitative and quantitative methods represent an attempt to synthesize and integrate the best aspects of qualitative and quantitative methods. The analytical structure of quantitative PRA and QRA are abandoned in favor much less structured and detailed evaluations. The qualitative evaluation processes of HazOps and FMEA are retrained and the linguistic variables and descriptors translated to quantitative terms. Sometimes, weightings are introduced in an attempt to allow the assessors to express differences in the importance of some elements to the reliability of a system. The FLAIM (Fire and Life Assessment Indexing Method) was developed using this approach.

2. During this session we defined a number of short comings in all of these methods. These short comings essentially focus in the lack of knowledge of the 'mechanics' that control the future actions of people. Without such knowledge, the system is not 'predictable.' We can only evaluate how the people might perform and how the system might behave given this performance. All forms of Human Reliability Analysis (HRA) suffer from this shortcoming.

3. Added to this shortcoming are a number of important 'biases' that generally pervade engineering analyses of reliability. These biases include those due to hindsight, rationality, controllability, simplicity, correlations, belief, wishful thinking, and knowledge. Engineers have a powerful ability to build models. Engineers have an equally powerful weakness in believing the results from these models represent reality. This is particularly true in the instance where the primary aspects that control the quality of the system are human. Engineers tend to ignore or neglect the roles of humans in otherwise 'well controlled' and 'well behaved' systems.

4. These comments are not meant to take away anything from engineering analyses of the reliability of offshore platforms. Rather, to encourage perspective and caution in use of these methods and in belief in their results. All of these methods should be used appropriately.

5. What does all of this mean to those that have responsibilities for the reliability of offshore platforms? It means

Lecture 4
Strategies to Improve the Safety of Offshore Platforms

MANAGING RAPIDLY DEVELOPING CRISES: REAL-TIME PREVENTION OF MARINE SYSTEM ACCIDENTS[4]

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ABSTRACT

This paper summarizes results from a study exploring how various communities of organizations manage rapidly developing crises and turn such crises into successes that are often referred to as 'near-misses.' The communities included in this research include commercial and military aviation, nuclear power, emergency medical services, fire fighting, law enforcement, oil refining, commercial shipping, and offshore oil and gas drilling and production. Here, we address strategies that can be used to better anticipate and manage rapidly developing crises that can develop into low probability-high consequence accidents involving marine systems such as ships and offshore platforms. We focus on crisis intervention: learning how to more frequently turn potentially catastrophic sequences of events into near-misses.

INTRODUCTION

During the past three years, the Berkeley *Marine Technology and Management Group* human and organizational error research has addressed strategies to better anticipate and manage rapidly developing crises that can result in low probability - high consequence accidents. Development of safety in marine systems has traditionally used two fundamental approaches: proactive and reactive (Rasmussen, 1996). The proactive approach is analytical, depends on the predictability of the system, and is focused on infrequent accidents. A major difficulty with most proactive approaches (e.g. probabilistic risk analyses) is that they can not adequately characterize and analyze complex future human and organizational interactions with systems. How can one develop an analytical model of what one can not characterize and predict? The reactive approach is fundamentally empirical, based on experience, focused on fixing the last accident, and primarily addresses frequently occurring accidents. Much of the field of worker and system safety has been built on the reactive approach.

We propose that there is a third approach to achieving safety in marine systems. This is real-time management as the accident unfolds. This is management based on OODA (Observe, Orient, Decide, and Act) 'loops' (recursive trials), migrating decision making, divide and conquer deployment, and requisite variety in problem identification and solving. We specifically focus on crisis intervention and learning how to more frequently march backward from the precipice of crisis to 'near misses.'

Experience with complex technological systems indicates that behind each major accident is something of the order of 10 to 100 near-misses, and perhaps 100 to 1000 hazardous acts or events (Groeneweg, 1994; Wagganer, Groeneweg, 1988). It is obvious that people frequently interact with systems to produce safe operations. We want to increase the proportion of successful interventions, particularly as potentially high hazard or consequence events unfold.

The vast majority of high consequence - low probability accidents involving marine systems such as ships, fixed platforms, mobile offshore drilling units, and pipelines, are caused by human and organizational factors. The fundamental problem in most cases is not hardware but 'peopleware.' That most of these accidents could have been prevented even though they involve operator actions that contain fundamentally unpredictable combinations of events, is unsettling. Many of these accidents consist of rapidly unfolding sequences of events in which the pace of operations is dramatically increased and the normal organization structure rendered ineffective.

Many marine accidents are fundamentally the result of human operators 'pushing the envelope,' and thereby breaching the safety defenses of an otherwise safe system (Bea, 1995; Bea, Roberts, 1995; Moore, Bea, 1995). Today, frequently these breaches develop under pressure to 'out-

[4] Proceedings of the 16th International Conference on Offshore Mechanics and Arctic Engineering, Yokahama, Japan

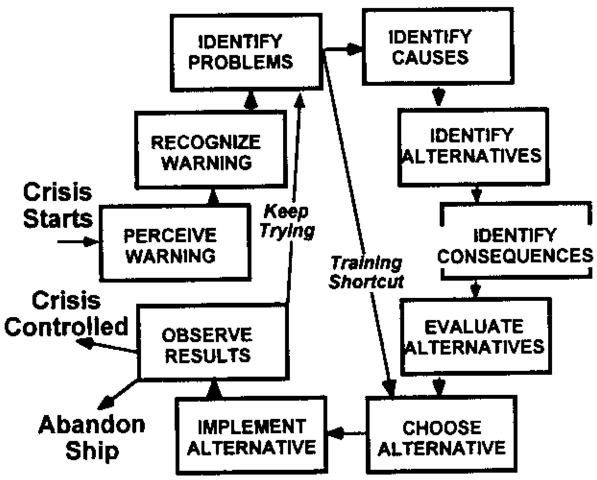

Fig. 2 - Management of crisis

Note the potential effect of training in Fig. 5 (other 'short-cuts' are possible but not shown). Training can help eliminate much of the cognitive processing required to determine what should be done (Hale, 1983). This allows effective alternatives to be rapidly defined and implemented.

Also, note the importance of observations. Observations provide clues to determine if implementation is producing the desired results. If it is not, the processes of identification and evaluation need to be repeated to help arrest the crisis. If clues indicate the crisis is being arrested, the process must be continued until the emergency is over. The process should not be stopped until adequate safety has been achieved.

CRISIS RECOGNITION

Perhaps no stage in a crisis is as important as the first stage: recognition or perception. Because the crisis is just unfolding, if the situation can be quickly and correctly recognized, there will be more opportunity and time to bring it under control.

Humans seem to have a fundamental difficulty accepting the potential danger of a situation under development. In a study of crew and passenger reactions to accidents onboard passenger vessels or ferries (Harbst, Madsen, 1995), it was found that 60% of the people (passengers, crew) ignored or mis-judged the hazards, 30% investigated, and 10% accepted that hazards existed and initiated action. Once the hazard was recognized, something of the order of 10% to 25% panicked or went into shock (crisis paralysis), 50% to 75% behaved in confused helpless ways, and 10% to 30% made realistic evaluations and started positive corrective actions. These researchers observed that "people who have generally accepted the risks associated with an activity are not usually motivated to study or practice safety procedures or recognize early warning signs of a developing crisis." They have become 'risk habituated.'

Three classes of cognitive factors seem to govern how and how well people perceive a crisis (Cook, Woods, 1994):

1) knowledge - background that can be accessed when solving problems,
2) attention dynamics - control and management of mental workload, maintenance of situation awareness, and avoidance of fixations,
3) strategy development - successful trade-off between conflicting goals, dealing with uncertainty and ambiguity, avoidance of organizational double binds, and development of good priorities and decisions.

Developing and maintaining an awareness of potentially hazardous situations involves a constant process of detecting anomalies; things that are not right or don't fit. This requires constant shifting of attention, a very limited resource, to modify a picture (mental model) of a system as a whole. Building and maintaining the picture of the system requires cognitive effort, which when it breaks down is called 'loosing the bubble' (Roberts, 1994). It is here that team work can provide additional information, attention capacity, and requisite variety (Weick, 1995a) in insights and potential solutions and enable the team to recognize the early warning signs of the developing crisis and quickly implement effective control strategies.

HOW CRISES ARE USUALLY STUDIED AND HOW THEY SHOULD BE STUDIED

There are two common ways to develop safety practices in the marine industry. One is to develop statistical predictive models based on past incident data. The data come from accident data bases or from case studies. Our research includes study of a wide variety of accident databases on marine systems (Wagenaar, Groeneweg, 1987; Moore, Bea, 1993). We have not identified one database which adequately addresses initiating, contributing, and propagating factors, has incorporated an adequate HOE taxonomy, has addressed the identified five elements, or has utilized sufficiently well trained accident investigators over a sufficient period of time.

The implication is that existing accident databases cannot be relied upon to provide objective and definitive information on HOE in marine systems. Much database development has its roots in the nuclear power and chemical processing industries and in the military (organizations which are developing a healthy skepticism about the quality of such data). Our research indicates a prevalent tendency to over use or over believe quantitative or 'hard' approaches (e.g. probabilistic risk analyses based on event trees, fault trees, and influence diagrams). The qualitative or 'soft' approaches frequently lack rigor and consistency.

The other approach is to use experienced based empirical methods that utilize information from past accidents to help remedy causes of infrequently occurring accidents. A large body of experience is the basis for identifying and implementing effective safety measures. Many work safety practices were derived from such methods.

Information from infrequently occurring accidents can provide insights to identify progressive changes to remedy accident causes. Regulations and safety measures put in place following major accidents are symptomatic of this approach. Both of these retroactive strategies represent a fall back position based on the near impossibility of studying accidents in the making 'real time'.

sense of events after they happen. It enacts sensible environments and is driven by plausibility rather than accuracy. People extract cues from their environments from which they draw sense and they try to produce the environments they're in. It is social and ongoing suggesting that the individual never really makes sense of things alone.

These seven characteristics of sensemaking have some implications for people who must perceive changes in risk in their organizations. One implication is that people need to talk constantly with one another to see what they say. They need to create a climate in which differences in perceptions are accepted and the acknowledged work is to develop as rich a picture of the organization as possible, that includes all of its interacting participants. Organizational members need to clearly understand that each of them brings a different set of identities to the task. They need to be alerted to the fact that their prescriptions of future events are based on sensemaking of the past. Writ large, this acknowledges what militaries have long known, in practicing for the next war they fight the last war. They should also be aware of the fact that they draw limited cues from their environments and that environments may not be as sensible as they enact them to be, but that trying to draw some order from chaos may have positive implications in terms of directing otherwise turbulent activity. It may be artificial to parse activities as initiating, contributing and propagating factors but this parsing provides a framework on which to develop a control plan. The social and ongoing nature of sensemaking draw our attention to the fact that an individual in isolation is almost never the total sensing unit. About as close as one comes to that is in sensemaking in isolation with only thoughts about other people's reactions, inputs, etc.

ENTER THE ORGANIZATION

Wiley (1988) discusses three levels of sensemaking above the 'individual' level. In ascending order they are intersubjective, the generic subjective, and the extrasubjective (Weick, 1995, p.70)." Intersubjective meaning occurs when a person's thoughts, feelings, and intentions are merged into conversation in which the individual is transformed from I to we. People are joined or merged. Organizations are included at the next level, the level of social structure. "Social structure implies a generic self, an interchangeable part - as filler of roles and follower of rules-but not concrete, individualized selves (Weick, 1995, p.71)." Sensemaking through generic subjectivity is the main work of the organization. In stable times generic subjectivity takes many forms, including scripts or SOP's (Standard Operating Practices). When something happens to disrupt stability, such as the introduction of a new technology, the current form of generic subjectivity no longer works. Inter-subjectivity is the focus of sensemaking because new views of what's going on emerge and have to be synthesized.

Weick argues that organizing is the umbrella over the movement from intersubjective to generically subjective. Organizing is a mixture of intersubjective understandings and understanding that can be picked up, expanded, enlarged, perpetuated, etc., by people who did not participate in the original intersubjective construction. Organizations are adaptive social forms. As intersubjective forms they create, preserve, and implement innovations that arise from contact. Generic subjectivity focuses and controls the energies of that intimacy. That control drives out innovation and one needs to worry about keeping a balance between the two. Intersubjective processes detect through monitoring, cues about potential destabilizers. Intersubjective and generic subjective processes develop control plans or actions and steps for implementing those plans and actions. Together these processes can extend the time of increased performance in high stress situations.

If organizations are understood to be nets of collective action undertaken to shape the world, with interlocking routines and habituated actions that allow for substitutability, we might look at crisis prevention in a different light than we do now. First, we would almost never look to the human operator as the single source of failure. Returning to Rasmussen's six stages of crisis decision making, our monitoring and detection systems would focus on the content of intersubjective interactions. We would begin to build taxonomies of content interaction that do and do not result in safe performance. Our interpretations of the current state of things would focus on the innovative intersubjective interaction and the generic subjectivity controls. We would look for accord as well as tensions between the two. Our control plan might be formulated with many more possibilities than we usually see, because we would reward the flowering of a thousand visions knowing that generic subjectivity is the mechanism for enhancing as well as pruning those visions. Feedback would be obtained in a different way relying as it would on assessment of its ability to mirror the collective action.

Wiley's (1988) final level of analysis, culture is extra-subjective. A generic self that occupies roles is now replaced by 'pure meanings' (Popper, 1972) without a knowing subject. This is a level of symbolic reality such as we might associate with capitalism or mathematics, each viewed as a subjectless batch of culture (Weick, 1995, p.72)." Again, returning to Rasmussen, his stage of crisis decision making we failed to address previously is determining the implications of the current state of affairs. To do this, decision makers in the organization need to look well beyond the organization's skin to identify those institutional aspects of society that both infiltrate the implications and may be impacted by those implications. Some possibilities are the values a society places on the loss of life and property, and the values it places on selection and education that in the current crisis or pre-crisis state is needed by the organization.

Our research clearly shows that the culture of an organization has important influences on its ability of to operate safely. Others have found the same thing (Pidgeon, O'Leary, 1994; Zohar, 1980; Turner, 1978; 1990; Weick, 1995a; Wenk, 1988). The culture of an organization is not a simple thing to define, characterize, or measure. It is rooted in the organization's history and the society in which it exists. Culture has many potential layers and facets. Organization cultures are extremely resistant to change. Many researchers would contend that organization cultures are impossible to change rapidly.

this strategy, members of the team were assigned management of different aspects of the evolving crisis (Fig. 3).

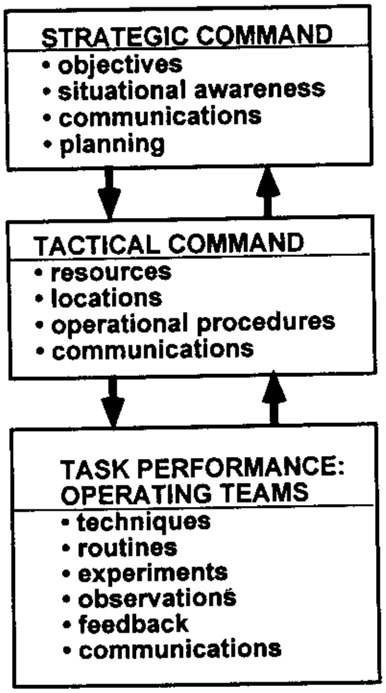

Fig. 3 - Divide and conquer crisis management team organization

The teams organized into three components: 1) strategic command, 2) tactical command, and 3) task performance. The strategic command acted as a mega-brain central point for information, verifications, planning, and situation awareness. The incident commander maintained the bubble , accessed the necessary requisite variety to understand the overall problem and identify the alternatives available to solve the problem/s.

Tactical command determined resources, their locations, operational procedures, and served as a central communications link. Strategic command determined what should be done, and tactical command determined how it should be done (procedures), who should do it (personnel), and what would be required (hardware, system support). Most importantly, tactical command acted as a central communications link between the strategic command and the task performance team/s.

Task performance was relegated to the operating teams that provided techniques, routines, observations, feedback, and 'experiments' with alternative measures to help arrest development of the crisis. The operating teams had to possess highly developed operating skills, had to utilize rule-based behavior and adopt this behavior to the unique circumstances of the crisis (improvisation), and had to have basic knowledge of the system that was managed.

The degree of success of crisis management team depends on an accurate assessment of the nature of the problem/s at hand. This 'sensemaking' is obtained through pattern recognition, a basic mechanism in learning. Pattern recognition relies on past experience in which the new problem may look something like a problem previously encountered. This permits the team to recognize applicable solutions or adaptations much earlier in the crisis. This is the reason that training and experience are so important. Experienced people bring pattern recognition skills with them. This enables them to identify the crucial pieces of information from the mass of information that floods in during a crisis and the crucial pieces that may be missing. Inexperienced personnel can only process protocols and execute available skill based behaviors.

A team-related crisis management technique used successfully by the airline industry is Crew Resource Management or (CRM) (Helmrich, 1994, 1995; United Air Lines, 1996a; 1996; Boeing, 1996). This technique has been successfully applied on the flight deck and on the tarmac (ground teams), and successfully extended to hospital operating rooms (Helmrich, 1994).

Helmrich identifies the following factors that influence how teams perform in crisis situations: individual aptitudes, personality and motivation, physical and emotional states, composition of the team, organizational climate and norms, time pressures, and the environmental conditions. The critical performance factors in CRM include information, inquiry (assertion, advocacy), management (briefings), technical procedures, communications, workload distribution (avoidance of distractions), decision processes, situation awareness, and resolution of conflicts.

United Airlines' C/L/R (Command / Leadership / Resource) management program (Hutchings, 1996) addresses command authority, crew climate, crew member training and development, communications, problem definition, decision making, inquiry, advocacy, conflict resolution, critique (feed-back), workload management, situation awareness, and use of resources (United Airlines Inc., 1996a, 1996b).

Management of the crisis action plan starts with the premise: keep the plane flying (maintain the vital functions). It is followed with displaying options and essential objectives, anticipation and taking the initiative; tracking down gaps, mistakes, and weak points in the plan; recognizing, resolving, and managing contradictions, and keeping the airplane flying (Hutchings, 1996).

Training in simulators in which the crew behavior is video taped has proven to provide valuable feedback on how crisis situations are managed (the camera doesn't blink). A formal training program to impart knowledge, skills, and observable behaviors has been documented and carried out, and the process institutionalized through flight operations policies. United Airlines contends this program has proven itself to be extremely valuable and it is now being used for ground crew operations (Boeing, 1996).

Given this background, it is no wonder that there have been and will continue to be problems in crisis management operations involving 'contract crews.' Often, although not always, these crews do not possess the requisite variety and knowledge of the system or training to deal with it. Experience with the system, requisite skills and knowledge are frequently lacking. In addition, at the interfaces between the parent operating organization and the contract crew/s, communications breakdowns and inefficiencies can and

CONCLUSIONS

From our research we have learned the pervasive importance of the organizational influences on safety and reliability. Some industries, such as the marine industries, fail to realize this because they often subjugate the goals of safety and reliability to the goals of production and profitability. This is a problem, because there must be profitability to have the necessary resources to achieve safety and reliability. Perhaps, with present high costs of lack of safety and reliability, these two goals are not in conflict. Safety and reliability can help lead to production and profitability. One must adopt a long term view to achieve the goals of safety and reliability, and one must wait on production and profitability to follow. However, often we are tempted for today, not tomorrow.

The second important thing we learned, is the importance of selecting, training, and organizing the 'right stuff' for the 'right job.' This is much more than job design. It is selecting those able to perform the daily tasks of the job within the daily organization required to perform that job. Yet, these people must be able to re-organize and re-deploy themselves and their resources as the pace of the job changes from daily to unusual (it's improv time!). Given most systems, they must be team players. This is no place for 'super stars' or 'aces.' The demands for highly developed cognitive talents and skills is great for successful crisis management teams. In its elegant simplicity, Crew Resource Management has much to offer in helping identify, train, and maintain the right stuff. If properly selected, trained and motivated, even 'pick-up ball teams' can be successful crisis management teams. If not, expect disaster.

The physical systems must provide adequate support and security for crisis management teams to accomplish their tasks. They must provide adequate warning of approaching danger and important data that do not overload cognitive resources. The systems must provide protection, and if finally necessary, a good chance of escape. Most important, these systems must be tolerant of human errors through the incorporation of adequate measures of robustness and stability.

Our research has not identified how to preserve readiness for crisis management for the crisis that may never happen (low probability, high consequence events). The results of training degrade rapidly when the results are not used. Apathy can develop relatively quickly in the normal pace of daily activities, particularly when these activities are successful (crisis and incident free). Vigilance is replaced by complacency. Identifying mechanisms to help preserve the right degree of crisis management readiness is an area for future research.

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Discussion of Key Points in Lecture 4
Strategies to Improve the Safety of Offshore Platforms

Managing Rapidly Developing Crises: Real-Time Prevention of Marine System Accidents

1. Why are we concerned with management of crises? Because management of crises is one of the daily skills that people acquire to keep systems working and safe. As was developed earlier, two general approaches to safety and reliability management have been recognized: 1) proactive (analyze and ameliorate), and 2) reactive (experience based understanding and ameliorate). Our work indicates that there is a third approach that needs to be recognized and we have chosen to identify this approach: management of rapidly developing crises.

2. This work indicates that there are two important lines of development of improved crisis management: a) improved people support, and b) improved system support.

3. Improved people support approaches the problem through improvements in how we select, train, and organize operating teams (design, construction, operations, maintenance). One of the very difficult elements of this approach is maintenance of crisis 'readiness' when the majority of the time is non-crisis oriented. Being prepared and maintaining awareness in the face of everyday life is not one of mankind's strong points. Boredom, fatigue, and apathy lead to carelessness and these in turn lead to poor crisis management.

4. Perhaps one of the more important elements of people support regards organizations for crisis management. The key crisis management organization concepts of 'migrating decision making' and 'requisite variety' are not the traditional bill of fare of the offshore industry. The organization tends to be very hierarchical and bureaucratic. And, there is nothing wrong with this for the low pace of daily operations. But, when the tempo increases, there needs to be a different operating organization and management needs to understand this and allow the organization to shift to a decentralized authority in which high expertise drives the decision making processes. Different people have different talents for different things. The crisis management organization needs to be one that will allow these talents to be recognized and mobilized in the heat of battle.

   Requisite variety is a similar challenge. There needs to be a variety in the crisis management team that matches the variety of the potential problems that are being faced. This requires a diversity of skills and backgrounds in the operating teams and a recognition of the need to shift the composition of the crisis management team depending on the nature of the potential problems.

   At this point, engineers are probably asking 'where is the beef?' Engineers are probably saying to themselves, this is a bunch of psychological mumbo jumbo. And, it has little or nothing do with us. This is true only if engineers make it true. People are a critically important part of crisis management, and someone needs to be concerned with them and their roles in maintaining the safety of offshore platforms. The alternative is to surrender the responsibility to others. But, then who else should have the primary responsibility for integrating the roles of people and systems?

5. System support for crisis management is where engineers generally start to get interested. System support addresses provision of protection, support, and information for people to manage crises. Protection can include blast and fire walls, evacuation and escape equipment, and a robust structure and hardware system that can tolerate damage and yet remain workable. Communications systems and instrumentation systems are a vital part of crisis system support. Communications that work and do not escalate the problems, and instrumentation that is simple, understandable, and reliable are key elements of system support. Effective early warning systems are particularly important to allow truly hazardous evolving situations to be recognized as early as reasonable. Note that the word 'possible' was not used. If the sensitivity settings of the early warning systems are set too low, then there can be too large a number of 'false alarms.' Determining the settings and configurations of early warning systems to provide as much time as possible to bring the situation under control yet avoid the 'cry

Summary and Closure

1. The primary challenge in learning how to further improve the reliability and quality of offshore platforms is to learn how to improve the reliability and quality of the people that design, construct, operate, and maintain these systems. We understand that people can not always be safe, durable, serviceable, or compatible. We understand that people can not be absolutely reliable. Perfection in people is not possible.

2. What we want to find out how to do is to reduce the chances of people malfunctions and to reduce the chances that the systems that they operate will become less reliable. Engineers bear a primary responsibility in helping accomplish these two reductions. But, first they must recognize this responsibility and then acquire the knowledge and skills that are necessary to improve the reliability and quality of human - hardware - structure systems.

3. There are a variety of ways to accomplish these two reductions. Eliminating people is not the answer. Neither is blaming, punishing, ignoring, exiling, or telling these people to only operate 'by the book.' Other ways not to accomplish the two reductions are substituting hardware, investigating, sending to seminars to 'fix' their problems, hiring an expert to fix 'them' or 'it,' performing an analysis, or attempting to legislate reliability. Providing positive incentives, recognizing the true importance of, giving knowledge and skills, and providing sufficient resources can lead to major improvements in reliability. Other ways to improve reliability are to provide robust (damage and defect tolerant) systems, and people friendly systems that are not based on what people can do, but on what people will do. One of the most important measures to help assure adequate and acceptable reliability in offshore platforms is to develop and maintain High Reliability Organizations.

4. People that design, construct, operate, and maintain offshore platforms can be viewed as continuously migrating in a 'reliability space.' This is the admirable human quality of adaptability. The boundaries of this space are provided by economic / financial, psychological, social, and physical 'limits.' Tightening the economic boundary causes people to adapt and to migrate toward the other boundaries. The objective is to make the space as large as possible, to provide early warnings that people are approaching the limits, and to make the boundaries as stabilizing as possible. The objective is to provide incentives that will encourage people to be aware and alert to crossing the limits, to behave reliably, and to develop systems that will have the highest possible life-cycle quality. I saw a bumper sticker in Houston recently that said "if you are not standing close to the edge, you are taking up too much room." We need to overcome this culture of pushing the envelope and create the culture of operating reliably.

5. There are a variety of ways to go about evaluating or assessing systems to determine and how, where, and when to improve their reliability characteristics. These methods have been developed during the last 50 years, chiefly by the military and the chemical process industry. These methods have found applications and development in the nuclear and fossil power industry, commercial aviation, and a wide variety of manufacturing industries. The methods are qualitative, quantitative, and mixed qualitative - quantitative. The author terms the latter method a Safety Indexing Method. All of these methods have their powers and their weaknesses. All of these methods are potentially complementary in 'sieving' a system to define what needs to be done to improve its reliability. The coarsest mesh in the sieve is that of the qualitative methods like HazOps and FMEA. The next finer mesh sieve is that of the Safety Indexing methods like FLAIM and the International Safety Rating System. The finest mesh sieve is the PRA and QRA.

6. It is important to recognize that all of these methods are 'stretched' when it comes time to evaluate the human and organizational aspects of offshore platform systems. All of the methods have very rudimentary capabilities to capture the important aspects of human operators and organizations as they influence reliability of offshore platforms. The single most important element of any of these methods are the people that guide and perform the analyses and evaluations. It is their experience and insight that is crucial to the end results.

APPENDIX C: Organization and Operating Team Factors

(Supplemental Information for Section 4)

1.0 INTRODUCTION

The focus of this paper is to identify Human and Organization Factors. The criteria for selecting a set of Human factors and Organization factors are that they are related to Human and Organizations, and specifically to High Reliability Humans and Organizations. Since these factors will be used in a newly created process, the list is subject to modification.

The first step in evaluating Human and Organization Factors (HOF) is identifying them. The following sources were examined to determine a set of these factors:

1. Regulations
2. Textbooks
3. Assessment methods
4. Research.

Lists of elements from each of these sources are included later in this document.

Using the above criteria, the following list of Human Factors and Organization Factors was created.

2.0 HUMAN AND ORGANIZATIONAL FACTORS

This section presents the factors and definitions for Human Factors and Organizational Factors.

2.1 Human Factors

The following table lists the Human factors (also called Operating Team factors):

Communications	The ability of the person to clearly and accurately transmit and receive information.
Selection and Training	The selection process by which the personality and individual characteristics are taken into account. The training of those individuals.
Education	The ability of the person to learn and understand information. The ability to counter ignorance.
Limitations and Impairment	Limitations and impairments due to a person's physical and emotional make-up.
Organizational (Planning & Preparation, Changes)	The ability of the individual to plan, prepare, organize, and adjust to changes.
Training	The quantity and quality of training which the person receives.
Experience (Mistakes, Slips, Violations)	The amount of experience a worker has to avoid mistakes, slips, and violations.

2.2 Organizational Factors

The following table lists the organizational factors:

Process Auditing	The action of monitoring processes and when necessary, taking actions to correct deviations which lie outside of the established norms.
Culture	The cognitive framework consisting of attitudes, values, behavioral norms, and expectations shared by organization members. In High Reliability Organizations, this includes a high state of quality and an appropriate reward system. **Mission/Vision:** The "Big Picture" goal of the organization is accepted and wholeheartedly believed by all personnel.
Appropriate Risk Perception	The organization's acknowledgment that risks are both known and unknown.
Emergency Preparedness	The organization's plans to minimize risks, and their severity by preparing mitigation plans. This includes drills and emergency plan exercises.
Command and Control Functions	The organization's structure for making decisions. This includes migrating decision making, redundancy, rules, seeing the "big picture", requisite variety, and alert systems.
Training	The organization places emphasis on training which is indicated by the amount of money and time invested. Also, the operator feels training is relevant.
Communications	The ability of the organization to clearly and accurately transmit and receive information within the organization.
Resources	The ability of personnel on the front-line to receive resources quickly and in adequate supply.
Equipment and System Maintenance	The organization places significant emphasis on the procurement, installation, construction, and maintenance of equipment and systems. Quality equipment is installed and properly maintained. "Gerry rigging" is not allowed, and repair parts are quickly delivered.
Procedures	This topic covers the paperwork required by regulatory agencies and the organization's internal audits. Procedures are in place for safe work practices and regulation compliance. Procedures are involved in the documentation of work completed, certification of personnel, and the reporting of accidents

3.0 SOURCES OF THESE FACTORS

The sources for these factors are: regulations, textbooks, assessment methods, and research.

3.1 Regulations

The following regulations and guidelines were examined for human and organizational related factors. The topics in each are listed.

- API (American Petroleum Institute) RP (Recommended Practice) 75: Recommended Practices for Development of a Safety and Environmental Management Program (SEMP) for Outer Continental Shelf (OCS) Operations and Facilities
- International Maritime Organization (IMO): International Safety Management (ISM) Code
- Health and Safety Executive (HSE): Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) (PFEER) Regulations 1995
- International Organisation for Standardization (ISO): Petroleum and natural gas industries - Health, Safety and Environmental Management Systems (HSEMS) ISO/CD 14 690

Minerals Management Service

The Minerals Management Service (MMS), an agency within the US Department of the Interior, is the regulatory agency which oversees the offshore oil industry. The MMS monitors the amount and type of hydrocarbons being produced by platforms and then assesses royalties. The MMS conducts regular safety and environmental protection inspections of all offshore platforms. Regulations are solicited from the American Petroleum Institute (API), the industry standard within the United States.

American Petroleum Institute

The American Petroleum Institute (API) is the oil industry's standard bearer. Its recommendations usually become the regulations enforced by the MMS. In 1993 API published their *Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities (RP75).* The stated purpose and objective is "to assist in developing a management program designed to promote safety and environmental protection during the performance of oil and gas and sulphur operations on the Outer Continental Shelf (OCS). The recommended practice addresses the identification and management of safety and environmental hazards in design, construction, startup, operation, inspection, and maintenance, of new, existing, or modified drilling and production facilities. The objective of this recommended practice is to form the basis for a Safety and Environmental Management Program (SEMP)."

The following is a table which summarizes the API RP75 and SEMP chapters:

Safety & Environmental Information	Process, mechanical, and facilities design information and the availability of this information. Includes: documentation, availability, databases.
Hazards Analysis	To identify, evaluate, and where unacceptable, reduce the likelihood and/or minimize the consequences of uncontrolled releases and other safety or environmental incidents. Includes: Hazard Analysis RP14J, risk perception, risk mitigation, lives onboard, materials, multiple operations, environmental, written reports, and communications.
Management of Change	Establishing procedures to identify and control hazards associated with change and maintain the accuracy of safety information. Two areas of change are the facilities and the personnel. Includes: permit-to-work procedures, risk perception.
Operating Procedures	Written facility operating procedures designed to enhance efficient, safe, and environmentally sound operations. Includes: procedures, chain of command, monitoring and control, risk perception and procedures, review of procedure changes.
Safe Work Practices	Establish and implement safe work practices. Includes: risk mitigation, permit-to-work, simultaneous operations, hazard situations and communications.
Training	Establish and implement training programs so that all personnel are trained to work safely and are aware of environmental considerations offshore. Includes: initial training, periodic training, certification and contractor training.
Assurance of Quality and Mechanical Integrity of Critical Equipment	Procedures are in place and implemented so that critical equipment on any facility meet service, manufacturers, and industry standards. Includes: critical equipment quality, procurement, fabrication, installation, maintenance, testing and inspection.
Pre-Startup Review	The commissioning process includes a pre-startup safety and environmental review for new and modified facilities. Includes: commissioning process, risk perception, quality and data accuracy.
Emergency Response and Control	Emergency response and control plans are in place and ready for immediate implementation. Includes: risk perception, plans and procedures, emergency action plan, control center for monitoring and control, training and drills.
Investigation of Incidents	Establish procedures for investigating incidents with serious safety or environmental consequences. Includes: investigations, lessons learned (training), review, management, action, and communications.
Audit of Safety and Environmental Management Program Elements	Includes ten elements of the management program and are periodically self audited. Includes: audit program, review, periodic inspections, feedback to management.

Health and Safety Executive

The Health and Safety Executive (HSE) in June 1995 set forth their regulation called *Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) (PFEER) Regulations 1995.* The basic objective of PFEER is that "The duty holder shall take appropriate measures with a view to (a) protecting persons on the installation from fire and explosion; and (b) securing effective emergency response."

The following is a table listing the twelve chapters within the regulations and a short summary of each:

Assessment	To repeat as often as may be appropriate an assessment of the installation.
Preparation for emergencies	Establish appropriate organisation and arrangements in anticipation of an emergency.
Emergency response plan	Prepare and revise as appropriate an emergency response plan.
Prevention of fire and explosion	Take appropriate measures to prevent fires and explosions.
Detection of incidents	Take appropriate measures to detect fire and other events, detect and record accumulations of flammable or toxic gases, and identify leakage of flammable liquids.
Communication	Make appropriate arrangements for warnings of an emergency, communications, and capable of remaining effective in an emergency.
Control of emergencies	Take appropriate measures to limit the extent of an emergency and to ensure the remote operation of plant.
Mitigation of fire and explosion	Take appropriate measures to protect persons during an emergency from fire and explosion.
Muster areas etc.	Make appropriate provision for safe muster areas, egress, and evacuation.
Arrangements for evacuation	Ensure, so far as is reasonably practicable, the safe evacuation of all persons to a place of safety.
Means of escape	Provide, so far as is reasonably practicable, the safe escape of all persons in case arrangements for evacuation fail.
Arrangements for recovery and rescue	Arrangements are made for recovery of persons and taking them to a place of safety.

International Maritime Organization (IMO)

The International Maritime Organization (IMO) is an agency of the United Nations. IMO regulates the standards of international shipping, which includes ships transporting crude oil. The IMO in 1993 put forth the International Safety Management (ISM) Code. The objective of the code is "to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular, to the marine environment, and to property." The following table lists the chapter titles and provides a short summary of each chapter:

Safety and Environmental Protection Policy	Requires the company to establish a policy to be implemented and maintained at all levels of the company. Included in this area is Planning and Culture.
Company Responsibility and Authority	Delineates the responsibility and accountability of the company and individuals in the company. Included in this section are the factors of culture and appropriate risk perception.
Designated Persons	Requires a person or persons have direct access to the highest level of management to liaison on behalf of those onboard ships. Included in this section would be culture and communications.
Master's Responsibility and Authority	Defined role is documented, master is qualified, knows SMS, and is supported by the management. Included in this section would be the factors of culture, command and control, resources, and rules and procedures.
Resources and Personnel	Requires personnel to be properly qualified and understand all aspects of the policy. Included in this section are training, process auditing, culture, and communications.
Development of Plans for Shipboard Operations	Directs the company to "establish procedures for the preparation of plans and instructions for key shipboard operations concerning the safety of the ship and the prevention of pollution". Included in this section are procedures, quality, culture and training.
Emergency Preparedness	Risks are properly perceived and Emergency response plans are created, drills and exercise of these plans are conducted. Included in this section are appropriate risk perception, command and control, training, and planning and procedures.
Reports and Analysis of Non-Conformities, Accidents and Hazardous Occurrences	Includes "procedures ensuring that non-conformities, accidents and hazardous situations are reported to the Company, investigated and analyzed with the object of improving safety and pollution prevention." Included in this section are process auditing, communications, and culture.

International Maritime Organization (IMO) *(continued)*

Maintenance of the Ship and Equipment	This section "establishes procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Company." Included in this section are the organizational factors of command and control, process auditing, culture, and training. This falls under the equipment factor.
Documentation	Responsibility, Authority, and Interrelations are documented. The control and validation documents are available on board, changes reviewed and approved, obsolete documents removed. Included in this section is process auditing, culture and communications.
Company Verification, Review, and Evaluation	Internal safety audits, efficiency evaluations, audits and corrective actions are carried out. Independent auditors produced results are made known to all and actions are taken to correct any deficiencies. Included in this are process auditing, culture, command and control, and appropriate risk perception.
Certification, Verification, and Control	Compliance document issued and onboard the system. A safety management certificate onboard to verify proper function of the ship. The factors within this section are process auditing, training, and communications.

International Organisation for Standardization (ISO/CD 14 690) Petroleum and natural gas industries - Health, Safety and Environmental Management Systems (HSEMS)

ISO is a worldwide federation of national standards bodies. The purpose of "this International Standard is to assist in the development of safety, health and environmental management systems (HSEMS) for oil and gas production operations and facilities." The following is a summary of the seven key elements:

Leadership and commitment	Top-down commitment and company culture essential to the success of the system.
Policy and strategic objective	Corporate intentions, principles of action, and aspirations with respect to health, safety and the environment.
Organisation, resources and documentation	Organisation of people, resources, and documentation of sound HSE performance.
Evaluation and risk management	Identification and evaluation of HSE risks, for activities, products and services, and development of risk reduction measures.
Planning	Planning the conduct of work activities, including planning for change and emergency response.
Implementation and monitoring	Performance and monitoring of activities, and how corrective action is to be taken when necessary.
Auditing and reviewing	Periodic assessments of systems performance, effectiveness, and fundamental suitability.

Oil Company "X"

Oil companies have also set up their own safety and environmental management programs. The following table is a summary from one company:

Management Leadership, Commitment and Accountability	Management provides the perspective, establishes a system, sets the expectations, and provides the resources for successful operations. Assurance of operations integrity requires management leadership and commitment to be visible to the organization, and accountability at all levels.
Risk Assessment and Management	Comprehensive risk assessments reduce risk and mitigate the consequences of operational, health, safety and environmental incidents by providing essential information for making decisions.
Facilities Design and Construction	Inherent safety is enhanced and environmental and health risks minimized by using sound standards, procedures and management systems for facility design, construction, and start-up activities.
Operations and Maintenance	Operation of wells and facilities within established parameters is essential to control risk. This requires procedures, structured inspection and maintenance systems, reliable safety systems and control devices, clean and tidy facilities, and qualified personnel who execute the procedures and practices consistently.
Management of Change	Changes in operations, process fluids, chemicals, procedures, site standards, facilities or personnel are evaluated and managed to ensure that operations, safety, health and environmental risks arising from these changes remain at an acceptable level. Changes in laws and regulations are reflected in facilities and operating practices to ensure ongoing compliance.
Information / Documentation	Current information on the configuration and capabilities of processes and facilities, properties of materials handled, potential health, safety and environmental hazards and regulatory requirements is essential to assess and manage risk.
Personnel and Training	Control of operations depends on people. Maintaining operations that are healthy, safe, environmentally-sound, conform to laws and regulations require the careful selection, placement, ongoing assessment, and proper training of personnel.
Third Party Services	Third parties working on Company X's behalf have an impact on its operations and reputation. It is essential that the third party perform in a manner that is consistent and compatible with Company X policies and business objectives.

Oil Company "X" (*continued*)

Incident Investigation and Analysis	Effective incident investigation, reporting, and follow-up are necessary to achieve improvement in health, safety and environmental performance. This provides the opportunity to learn from reported incidents and use the information to take corrective action and prevent recurrence.
Community Awareness and Emergency Preparedness	Community awareness is essential to maintaining public confidence in the integrity of operations. Emergency planning and preparedness are essential to ensure that, in the event of an accident, all necessary actions are taken for the protection of the public, environment, and company personnel and assets.
Operations Integrity Assessment and Improvement	A process that measures performance relative to expectations is essential to improve operations integrity and maintain accountability.

Other Safety Related Guidelines:

The following are lists of factors from various other safety related guidelines. The guideline references are provided.

Center for Chemical Process Safety "Guidelines for Technical Management of Chemical Process Safety" (1989).

- Accountability - objectives and goals
- Process knowledge & documentation
- Process safety review procedures for capital projects
- Process risk management
- Management of change
- Process and equipment integrity
- Human Factors
- Training and performance
- Incident investigation
- Company standards, codes and regulations
- Audits and corrective action
- Enhancement of Process Safety knowledge

OSHA "Process Safety Management of Highly Hazardous Chemicals" (1990)

- Process safety information
- Process Hazard Analysis
- Operating procedures
- Training
- Contractors
- Pre-start up safety review
- Mechanical Integrity
- Hot work permits
- Management of Change
- Incident investigation
- Emergency planning
- Compliance safety audit

Boyen, Brandes, Burk and Burns "Process Hazards Management - Key Elements", (1987).

- Process Safety Information Technology
- Process Hazards Analysis
- Management of change
- Rules and procedures
- Personnel training and performance
- Unusual incident Investigation/reporting/communication
- Auditing
- Equipment tests and inspections
- Pre-startup safety inspections
- Management of change facilities
- Quality assurance
- Emergency control

Lees, F., (1978), "Loss Prevention in the Process Industries".

- Management attitude
- Management organization
- Competent People
- Systems and procedures
- Standards and codes of practice
- Pressure systems
- Documentation
- System audits
- Independent checks
- Feedback
- Training

3.2 Textbooks

Textbooks also provide valuable information concerning human and organizational factors. The following sections provide lists of factors from human factor textbooks and organization behavior textbooks.

3.2.1 Human Factors

Two textbooks on Human Factors is Beaty's (1969), "The Human Factor in Aircraft Accidents", and Green, et al., (1991), "Human Factors for Pilots". The following are lists of factors from each textbook.

<u>Factors from Beaty</u>

Environment
- Home situation (social)
- Flight Deck (ergonomics)
- Selection and Training

Half-hidden factors
- On Seeing (visual)
- On Being Deceived (perception)
- On Expecting (expectations)
- On Saving Time (external pressures)
- On Deciding (decision making)

Hidden factors
- The Desire to Please (external pressures)
- Left Hand, Right Hand (personal trait)
- On Being Tired (rest time)

<u>Factors from Green et al.</u>

Basic Physiology and the Effects of Flight
Flying and Health
Human Information Processing
Cognition in Aviation
Stress and Stress Management
Sleep and Fatigue
Individual Differences, Social Psychology, and Flight Deck Management
Design of Flight Decks, Documentation, and Procedures

3.2.2 Organizational Behavior

Two textbooks on Organizational Behavior were also examined. List of factors from Northcraft and Neal (1994), "Organizational Behavior - A Management Challenge" and Greenberg and Baron's (1995)"Behavior in Organizations" follows.

<u>Factors from Northcraft and Neale</u>

Individual Behavior
- Perception, Attitudes, and Personality
- Learning and Motivation
- Individual Decision Making
- Conflict and Stress in Organizations

Behavior in Groups
- Groups and Communication
- Power, Politics, and Influence
- Group Decision Making
- Leadership

Managing for Performance
- Organizational Entry and Socialization
- Job Design
- Maintaining Performance

The Larger Context of Organizational Behavior
- The Environment
- Technology
- Organizational Structure and Design
- Managing Change
- Diversity in the Workplace: Managing in the Twenty-First Century

Factors by Greenberg and Baron

The Nature and Study of Organizations
Perception and Learning: Understanding and Adapting to the Work Environment
Personality: Individual Differences in Organizational Behavior
Motivation in Organization
Work-Related Attitudes: Their Nature and Impact
Becoming and Organizational Member: Socialization and Careers
Stress: Its Nature, Impact, and Management
Group Dynamics and Teamwork in Organizations
Interpersonal Communication in Organizations
Decision Making in Organizations
Helping, Cooperation, and Conflict in Organizations
Influence, Power, and Politics in Organizations
Leadership: Its nature and impact in organizations
The Work Environment: Culture and Technology
Organizational Structure and Design
Organizational Change and Development

3.2.3 Management

The following are two of many books on management. These two books put forth some factors for organizations.

Drucker, P., (1974), "Management -- Tasks, Responsibilities, Practices"

- Set objectives
- Organize
- Motivate and communicate
- Establish yardsticks
- Develop people (including yourself)

Eilon, S., (1979), "Management Control"

- Determining the goals
- Determining the structure
- Planning the acquisition of resources
- Planning the utilization of resources
- Instituting measurement, recording and communication systems
- Determining control procedures
- Evaluating the performance of the enterprise
- Evaluating the control procedures

3.3 Factors in Assessment Methods

Examination of some other assessment methods reveals human and organization factors. These assessment methods include MANAGER, and the International Safety Rating System (ISRS). The following are lists of factors for each.

<u>MANAGER</u>

- Written procedures
- Incident and accident reporting
- Formal safety studies
- Organizational factors
  - Management structure
  - Job descriptions
  - Independence of safety and inspection functions
- Maintenance
- Emergency resources and procedures
- Training
- Management of Change
- Control room instrumentation and alarms
- Other Human Factor influences
  - Site housekeeping
  - Shift system and manning levels
  - Communications channels
  - Log keeping
  - Stress
- Fire protection systems

<u>ISRS</u>

- Leadership and administration
- Management and Training
- Planned inspections
- Task analysis and procedures
- Accident/incident investigation
- Task observation
- Emergency preparedness
- Organizational rules
- Accident/incident analysis
- Employee training
- Personal protective equipment
- Health control

ISRS *(continued)*

- The program-evaluation system
- Engineering controls
- Personal communications
- Group meetings
- General promotion
- Hiring and placement
- Purchasing controls
- Off-the-job safety

3.4 Research - HRO Factors

Research also provides factors related to High Reliability Organizations and Human Error. Factors from research by Libuser and Roberts, Moore and Bea, Gale et. al., The National Research Council, Boniface, and Tripod Delta, are listed below.

Libuser and Roberts

During the past ten years Roberts has done research on High Reliability Organizations (HRO). She examined such organizations as flight deck operations on US Navy nuclear powered aircraft carriers, the Federal Aviation Administration's air traffic controllers, and Pacific Gas and Electric's Commercial Nuclear power generation plants. Each of these organizations requires high reliability in daily operations to avoid catastrophic consequences. Roberts and Libuser determined the following factors to be common to each of these organizations.

High Reliability Organization (HROs) Factors (Libuser and Roberts)

Process Auditing	A system of ongoing checks to spot expected as well as unexpected safety problems.
Appropriate Reward Systems	Organizational and inter-organization rewards for desired behaviors.
High Standards of Quality	Quality standards that meet or exceed quality in referent system.
Appropriate Risk Perception	Is Risk perceived? Are appropriate strategies in place to mitigate risk?
Command and Control Functions	Migrating decision making Redundancy Formal rules and procedures Training Senior managers who can see the "big picture"

Moore and Bea

Moore and Bea (1993, 1993a, 1993b) conducted research on factors which cause accidents on marine systems. Their research determined that over 80 percent of all marine system accidents were due to Human and Organizational factors. They produced a taxonomy of factors which cause organizational errors. These factors are listed in the table below.

Organization Error Factors (Moore and Bea)

Communications	Ineffective transmission of information
Culture	Inappropriate goals, incentives, values, and trust
Violations	Intentional infringements or transgressions
Ignorance	Unaware, unlearned
Planning & Preparation	Lack of sufficient program, procedures, readiness
Structure & Organization	Ineffective connectedness, interdependence, lateral and vertical integration
Monitoring & Controlling	Inappropriate awareness of critical developments and utilization of ineffective corrective measures
Mistakes	Cognitive errors of perception, interpretation, decision, discrimination, diagnosis, and action

The following is a conversion of these factors into positive elements to better match them with the guidelines of SEMP, PFEER, and ISM and to also match with other factors.

Communications	The ability to clearly and accurately transmit information.
Culture	The goals, incentives, values, and trust within a company.
Planning and Preparation	The programs, rules and procedures, and readiness which the company has invested time and money to examine the long term goals of the company.
Structure and Organization	The connectedness and interdependence of all parts of the company.
Monitoring and Controlling	Being aware of the processes within a company and the ability to make corrections to the processes.
Training	**a. Knowledge (ignorance):** Knowing what to be aware of and learning how to react to circumstances. **b. Compliance (violations):** Knowing the regulations and the reasoning behind the regulations, and complying with the spirit of the regulations (if not the letter). **c.** Minimize **Mistakes (mistakes):** Training people to make fewer cognitive errors.

Gale et. al.

In their research on Fire and Life Safety Assessment and Indexing Methodology, Gale et. al.(1994) integrated organization factors as part of the assessment process. The assessment modules which directly reflect human and organization factors are the Operational/Human Factors Assessment (OHFA) module and the Safety Management System Assessment (SAMSA) module. The following are tables with each of the submodules.

Operational/Human Factors Assessment

MARW	Maintenance and Repair Work
MULOPS	Multiple Operations Assessment
OPSMOC	Operational Management of Change
OPSDAR	Assessment of Operator Dependence and Response
OPHIST	Operational History

SCULA		Management Systems Safety Culture Assessment
		Organizational Responsibility & Resources
	POLPRO	Company Policies and Procedures
	ACAU	Accountability & Auditing
FIPA		Fire Preparedness Assessment
SATA		Safety Training Assessment
MOCMAP		Management of Change Management Program

National Research Council - "Workload Transitions"

The National Research Council studied the implications of workload for individual and team performance, specifically directed at US Army tank crews. Their findings have direct bearing on the operation of marine systems during normal and crisis situations. The following is a summary of their findings:

Team Transition Process Factors

Time	The abruptness with which a crisis transition unfolds, the expectancy or perceived probability that a transition will occur, and the length of time that a crew must remain on watch before an event may occur.
Structure of the event	The extent to which its nature is predictable and whether the desired response can be effectively preprogrammed.
Environment	Physical conditions
Personal risk	The extent to which the team is exposed to risk of personal injury or death, both to themselves and to others.
Organization structure	1. Team structure or command authority 2. Team integrity or continuity of team membership over time 3. Autonomy or extent to which the team functions alone rather than in close coordination with a higher organizational structure.

The following are the factors which are important to team performance:

a. Workload factors
b. Stress
c. Sleep disruption and fatigue
d. Vigilance and target detection
e. Geographic orientation
f. Decision making
g. Strategic task management
h. Team leadership and crew coordination
i. Training for emergency responses

Boniface HOF

The following is a table of factors which Boniface (1995) created based on a review of data bases from the National Transportation Safety Board, the U.S. Coast Guard, and others.

Boniface Factors

Changes	Life, Work, Environment
Impairment	Fatigue, Well Being, Medical, Drugs
Training	Routine Tasks, Unfamiliar Events, Emergency Response
Education	Background principles, Analytical knowledge
Experience	In industry, at job/position, in task, in environment, with equipment, with team members
External Environment	Motions, Lighting, Ventilation, Noise, Vibration
Workload	Occupational Regulatory, Societal, Personal
Communication	Oral, NonVerbal, Written
Organizational	Adaptability, Maturity, Hazard Awareness, Attention to Detail, Role Clarity, Risk acceptance, Openness/Cooperation, Goal Incompatibility, Rewards, Feedback, Supervision
Personality	Hardiness, Self-Monitoring, Self-Esteem, Locus of Control, Need to Achieve, Individual vs. Team

Tripod Delta Factors

General Failure Types

Hardware
Design
Maintenance
Procedures
Error Enforcing Conditions
Housekeeping
Incompatible Goals
Organisation
Communication
Training
Defenses

4.0 CONCLUSION

In conclusion, a review of the above sources of factors has resulted in two lists of factors. These factors are for the Human/Operating Team and Organization.

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APPENDIX D1: STEPS TAKEN IN THIS TABLE-TOP EXERCISE

The following is a summary of the steps taken for the table-top exercise of a marine terminal in Northern California.

An assessor team was assembled consisting of two marine inspectors and a graduate student. One marine inspector had worked on the marine terminal for seven years and left as an operator.

Phase 1:

Reviewed the following documents:

1. Spill Preparedness and Emergency Response Plan
2. Operations Manual
3. CSLC training audit
4. Annual Inspection results

Answered Minimal Basic Questions for the marine terminal

Assigned initial evaluations to the questions

Asked a lot of questions of the experienced marine inspector

Determined five Areas of Concern (AOC):

1. Connections - scenario - a connection breaks during the steady flow state
2. Vessel Overflow openings - scenario - topping off a vessel
3. Sample system - scenario - the sampling system was not properly closed
4. Vapor recovery system - scenario - a pin-hole leak develops releasing natural gas
5. Sumps - scenario - a rainy night and the sump pump fails

Phase 2:

Visited the marine terminal

1. Walked down the terminal
2. Asked questions about the terminal

Confirmed or adjusted evaluation of Minimal Basic Questions

Phase 3:

Assimilated information

Finalized likelihood and consequence for AOC

Calculated relative risk

Plotted graphs

Created various reports

APPENDIX D2: ANSWER SHEET TO BASIC MINIMAL QUESTIONS FOR TABLE-TOP EXERCISE

(2) Hazards Analysis

(Evaluation) Reviewed Contingency Plan and Operations Manual

(2) 1. Hazards Analysis/HAZOP

BASIS:

1. HAZOP is located in the contingency plan, section 300 Hazard Evaluation. Appears to be comprehensive
2. Safety Analysis Function Evaluation (SAFE) API RP 14C in Ops Manual
3. Safety Analysis Table (SAT) in Ops Manual
4. Focused on equipment, structures and procedures
5. No items concerning organization and operating teams

PHASE 2:

Ask if workers had input into the HAZOP and did the people who conducted the HAZOP visit the wharf.

(4) 2. Hazards and Risk Reduction

BASIS:

1. Interview with inspectors reveals that items identified in HAZOP are not always mitigated in a timely fashion, in one case led to a small oil spill.

PHASE 2:

Ask workers if their suggestions for safety are acted upon in a timely manner.

(2) 3. Process Design Information Diagram

BASIS:

1. Former employee (now inspector) was able to draw out a diagram.
2. Not all information was on the diagram.
3. Composition was usually on the diagram (black oil, etc.)

PHASE 2:

Ask workers to draw up a diagram with information on it.

(2) 4. Mechanical and Facilities Design Information

BASIS:

1. Vapor Recovery System is extensively documented in the operations manual with its certificate in the Ops. Manual.
2. Ops Manual has three types of inspections, structural, pipeline, and annual component inspection.
3. Ops manual certified by USCG and CSLC to comply with state and federal regulations.

PHASE 2:

Check with design department of company to see if meeting applicable standards. From Annual Inspection, it appears that they are meeting standards.

(2-3) 5. Hazard monitoring

BASIS:

1. Ops manual lays out the organizational structure in words (a diagram would help clarify the organizational structure), and each berth has at least two people on the wharf side, a wharf operator and a berth operator.
2. Interview with inspectors reveals that wharf master spot-checks evaluations.

3. DOI is signed during a pre-transfer conference between the TPIC and VPIC to plan out any transfer evolution.

PHASE 2:

Ask workers if management is aware of the hazards at the wharf, and is management responsive once hazards are reported. Ask when was the last time management came to the wharf.

(1-2) 6. Risk acknowledgment

BASIS:

1. Review of Contingency plan and SLC-MFID training checklist shows that the company acknowledges risk and trains management, operators, and maintenance personnel on "problem assessment," "local environmental sensitivity," and "decision making for abnormal operating events and emergencies."

PHASE 2:

Ask a worker about these three areas of training.

<u>(3) Management of Change</u>

*Need to review their MOC program as outlined in Refinery Instruction RI 360

Also, review Safety Action Committee

(3-4) 1. Change in Facilities

BASIS:

1. For the Vapor Recovery System, the company did a management of change program.

(2-3) 2. Change in People

BASIS:

1. Before any operator is qualified, he experiences extensive training. This is a three-year program that involves classroom work as well as "piggy backing" of trainees. The Wharfmasters usually come from other parts of the refinery and stay only three to five years. However, they are more of an administrative supervisory position. The Wharfmasters are qualified in the Incident Command System.

(2-3) 3. Managing the Changes

BASIS:

1. One example is the Vapor Recovery System, in which changes were managed. The other change was the installation of the computer system into the wharf control room. Preparation and training for it was quite extensive.

(2-3) 4. Pre-Start Up Review

BASIS:

1. Review of Ops manual, DOI and pre-transfer conference are conducted between TPIC and VPIC before any transfer. Checklist is quite extensive.

(2) Mechanical Integrity

*Review latest plans, designs, MOC, safety for pipeline going in. Talk to engineers.

(2-3) 1. Quality Assurance Strategy

BASIS:

1. Vapor Recovery System was extensively documented. The maintenance system has increased in efficiency as the life time of various parts becomes known.

PHASE 2:

Review maintenance records and the qualification of maintenance personnel.

(3) 2. Mechanical Reliability

BASIS:

1. Review of Ops manual shows that equipment is regularly assessed and inspected (VPS, pipelines, compressors, and pumps).

PHASE 2:

Review maintenance records of critical pieces of equipment (Vapor Recovery System). Check for overall state of repair of pipes and equipment.

(1-2) 3. Repair parts availability

BASIS:

1. Repair parts are readily available on wharf. Parts can also be obtained on the refinery.

(2-3) 4. Layout and Configuration

BASIS:

1. Review of the wharf layout; berth transfer stations are as far apart as possible.
2. Piping from berths go under pier to the land side of wharf, where they connect and travel back to shore.
3. Appears to be the safest layout for separation.

PHASE 2:

Walk down wharf to look at actual pipe and equipment layouts. Need to review layout of the wharf, looking at how loss of containment can cause fires and explosions.

(2) Operating Procedures

Reviewed Ops Manual

*Need to review Standing Orders

(2) 1. Content of Operating Procedures

BASIS:

1. Very detailed procedures to start-up and shutdown of vapor recovery system.
2. Very detailed procedures for loading arms.

PHASE 2:

Observe an operation

(2-3) 2. Ability to minimize risks

BASIS:

1. Procedures are understandable. SAFE and SAT conducted for Vapor Recovery System.

PHASE 2:

Ask workers if procedures work. Review the berth's copy of manual

(4) 3. Periodic Review

BASIS:

1. USCG and CSLC review operating manuals.
2. One worker never remembers being asked about input into operations manual.

PHASE 2:

Need to check how often the wharf reviews the Ops manual.

(2) 4. Plan preparation

BASIS:

1. Op. manual last submitted for review was 1994. Two updates in 1996.

PHASE 2:

Ask workers if they had any input into the manual.

(2) 5. Operations and Maintenance

BASIS:

1. Ops. Manual seems quite extensive.
2. Contractors' role in maintenance is decreasing.

PHASE 2:

Walk down the facility. Ask workers about the operations and maintenance parameters they work within. Observe a maintenance procedure.

(2) Training

(Based on a review of the SLC-MFID checklist for training and certification program approval)

(2-4) 1. Resources

BASIS:

1. Training budget goal is 15% of operations budget, but that has been short this past year, presumably because profits are down.

PHASE 2:

Ask operators of their view of training (is it meaningful?)

(2) 2. Personnel Selection and Training

BASIS:

1. Based on interview with former employee, highly selective and training is intensive.
2. The wharf coordinator is the busiest person and needs to keep the big picture with the ship, wharf, and refinery. This job is very detail-oriented and fast-paced.

(2) 3. Initial Training

BASIS:

1. Based on interview, first six months of training followed by on-the-job training. Three-year training program.
2. Operations manual covers initial training.

PHASE 2:

Need to review training records for specific items trained for.

(2) 4. Safework Qualification

BASIS:

1. People are trained and certified, and then get hands on-the-job training before taking on a position.
2. Based on training review, has all safework qualifications in place.

PHASE 2:

Need to review training records.

(2) 5. Hazards Communication Training

BASIS:

1. Review of training and certification checklist shows that hazards communication is conducted during training.

(2) 6. Operations Training

BASIS:

1. Review of training and certification checklist; operations training is conducted to detect hazards and combat fire and explosions.

(2-3) 7. Competent Examiners

BASIS:

1. Based on training and certification checklist review, competent examiners were used.

(2-3) 8. Management Training

BASIS:

1. Based on training and certification checklist review, management is being formally trained on hazard prevention and response.

(2) 9. Periodic Training

BASIS:

1. Based on training and certification review, periodic training is being conducted on hazard prevention and personal protective devices.
2. Refresher training is conducted.

PHASE 2:

Ask workers about their training.

(2-3) 10. Communication Training

BASIS:

1. Based on training and certification checklist review, both routine and emergency communication training is conducted.

PHASE 2:

Need to ask workers.

(3) 11. Contractor Training

BASIS:

1. Based on training and certification review, contractors are adequately trained.
2. The number of contractors is decreasing.

(2) Safe Work Practices

(2-3) 1. Leadership

BASIS:

1. Based on ops. manual and contingency plan, senior management seems to emphasize prevention of hazards and reduction of unacceptable risks.

PHASE 2:

Ask worker's impression of senior management. Review company mission statement.

(2-3) 2. Policy

BASIS:

1. Policy in operations manual is clear.
2. Page 300-3 in contingency plan. Last three spills and their correction.

(2-3) 3. Safe Conduct of Work Activities

BASIS:

1. Extensive training and also supervision.

PHASE 2:

Review maintenance manual. Observe a maintenance procedure.

(2) 4. Prevention

BASIS:

1. Lots of supervision, HAZOP and corrections. Testing of relief valves on a regular basis.

PHASE 2:

Ask operators about prevention measures.

(2) 5. Control of Materials

BASIS:

1. Extensive Safety Analysis Tables (SAT) and MSDS in ops. manual.

PHASE 2:

Observe during phase 2.

(3) 6. Contractor Selection

BASIS:

1. Use of contractors is decreasing.

PHASE 2:

Need to review contractor selection procedures.

(2) Emergency Response

(Based on a review of the contingency plan and response plan)

(1-2) 1. Emergency Response Preparation

BASIS:

1. Plan seems quite extensive, but also looks like a template for other refineries.

PHASE 2:

Review preparation policy

(2) 2. Hazards Review

BASIS:

1. HAZOP conducted and in the Contingency plan.
2. Actions to take are outlined.
3. Also has information in the ops. manual.

(2) 3. Emergency Action Plans (EAP)

BASIS:

1. Response plan reviewed. Quite extensive.

PHASE 2:

Observe a drill

(2-4) 4. Command and Control Functions

BASIS:

1. Command Center on the Wharf, or in the Training Building if required.
2. Functions are clearly identified for all supervisory people and their roles.
3. Left out is how the person on scene is trained to make decision on their own if required (unique and unusual situations).

PHASE 2:

Ask about front line worker decision making

(2) 5. Training and Drills

BASIS:

1. Section 500 in emergency response plan

PHASE 2:

Need to review any lessons learned. Observe a drill.

(2-4) 6. Detection of Incidents

BASIS:

1. Training seems to be adequate for detection of incidents.
2. Much reliance on human observation for detection.

PHASE 2:

Ask workers about how incidents are actually detected.

(2-4) 7. Communications

BASIS:

1. Two-way hand-held radios, however only one channel.
2. Emergency horn blowing signal system

PHASE 2:

Watch an emergency drill for communications and warnings.

(2) 8. Personnel

BASIS:

1. Evacuation plan and location of personnel shelter on diagram.
2. Primary and secondary routes.
3. Training on Personal Protective Devices (PPD) seems to be adequate.

PHASE 2:

Observe a drill. Ask worker to put on PPD, also if they know the evacuation routes.

(2-3) 9. Emergency Equipment and Systems

BASIS:

1. Fire water lines.
2. Emergency shutdown and spill containment checked during annual inspection.

PHASE 2:

Review maintenance records and make observations.

<u>(2) Investigation and Audit</u>

*Need to review investigation and auditing policy

(1-2) 1. Investigations Policy

BASIS:

1. Need to review investigation procedures, review results of latest investigations and action. During phase 2, confirm actions are taken.

(2) 2. Investigation

BASIS:

1. Deadlines for investigations were not available for review. Investigators get statements from all parties, which is not meant to punish anyone, but to find out what happened. Need to review investigation records.

(2-3) 3. Follow-up

BASIS:

1. Follow-up being done. One example is that of a 30" pipeline that had a leak at a sample area; that area was redesigned and changed. Need to review investigation records and determine if follow-up actions are complete.

(2-3) 4. Auditing System

BASIS:

1. Company audits (vetts) wharves worldwide before letting their ships dock. Need to review auditing procedures, and check for independence

(?) 5. Audit Reporting

BASIS:

1. Need to review audit reports

(3) 6. Documents

BASIS:

1. Document control appears to be in order. Reports do go to headquarters.

(2) 7. Reviewing

BASIS:

1. Headquarters people receive reports and have the number of accidents tallied monthly on a wall chart. Need to review audit reports, check if they are signed by upper management.

(2) 8. Safety Program

BASIS:

1. Safety program appears to be extensive.

PHASE 2:

Ask workers about the safety program.

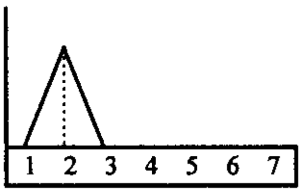
APPENDIX D3: RESULT - TRIANGULAR DISTRIBUTIONS

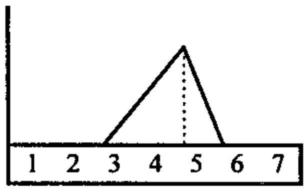
Sampling System - Scenario: The sampling system was not properly closed

Operating Team Factors

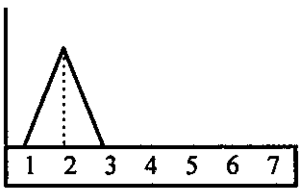
Likelihood / Consequences

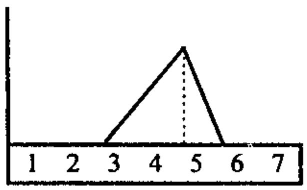
Communications



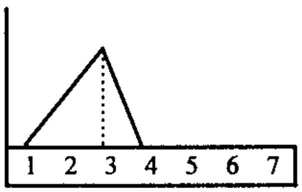


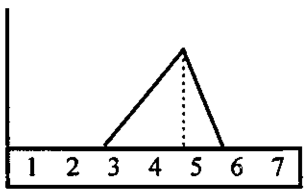
Selection



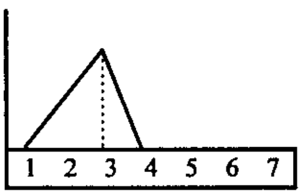


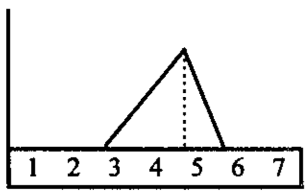
Education



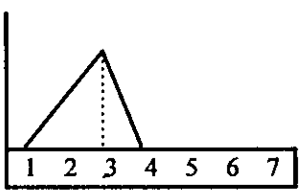


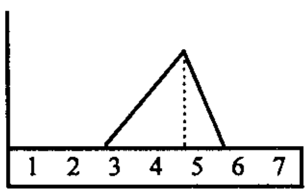
Limits &
Impairment





Organizing
Ability



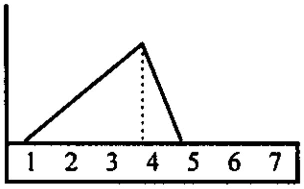


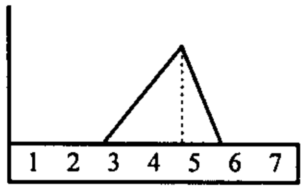
Operating Team Factors (cont.)

Likelihood

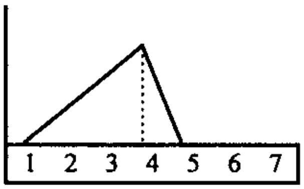
Consequences

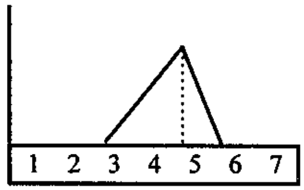
Experience



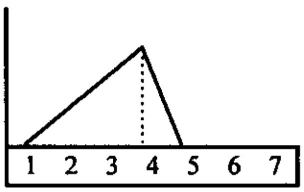


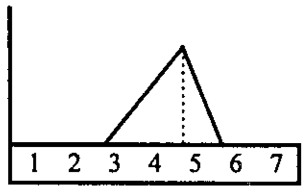
Training





External Environment



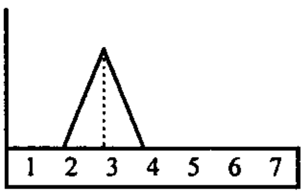


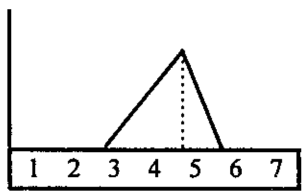
Organization Factors

Likelihood

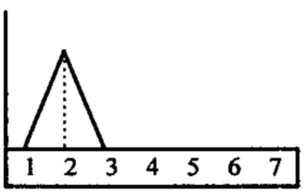
Consequences

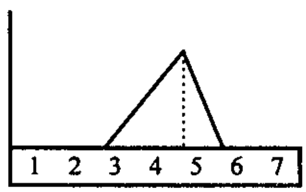
Process Auditing



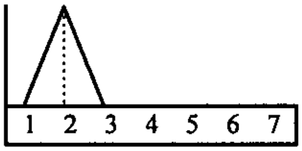
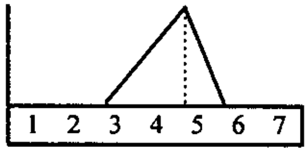
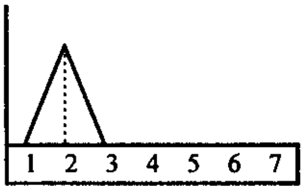
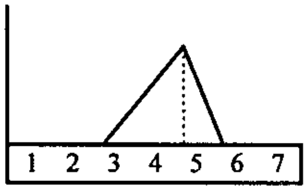
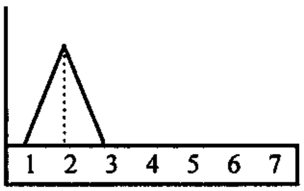
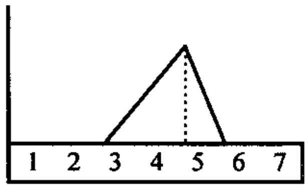
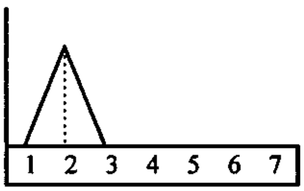
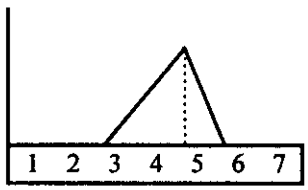
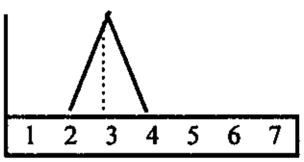
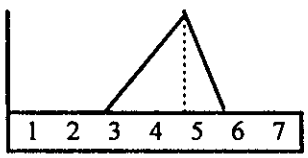
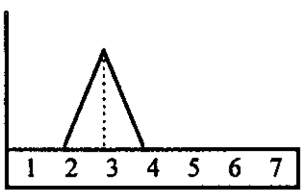
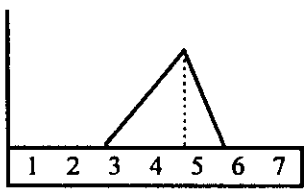


Culture

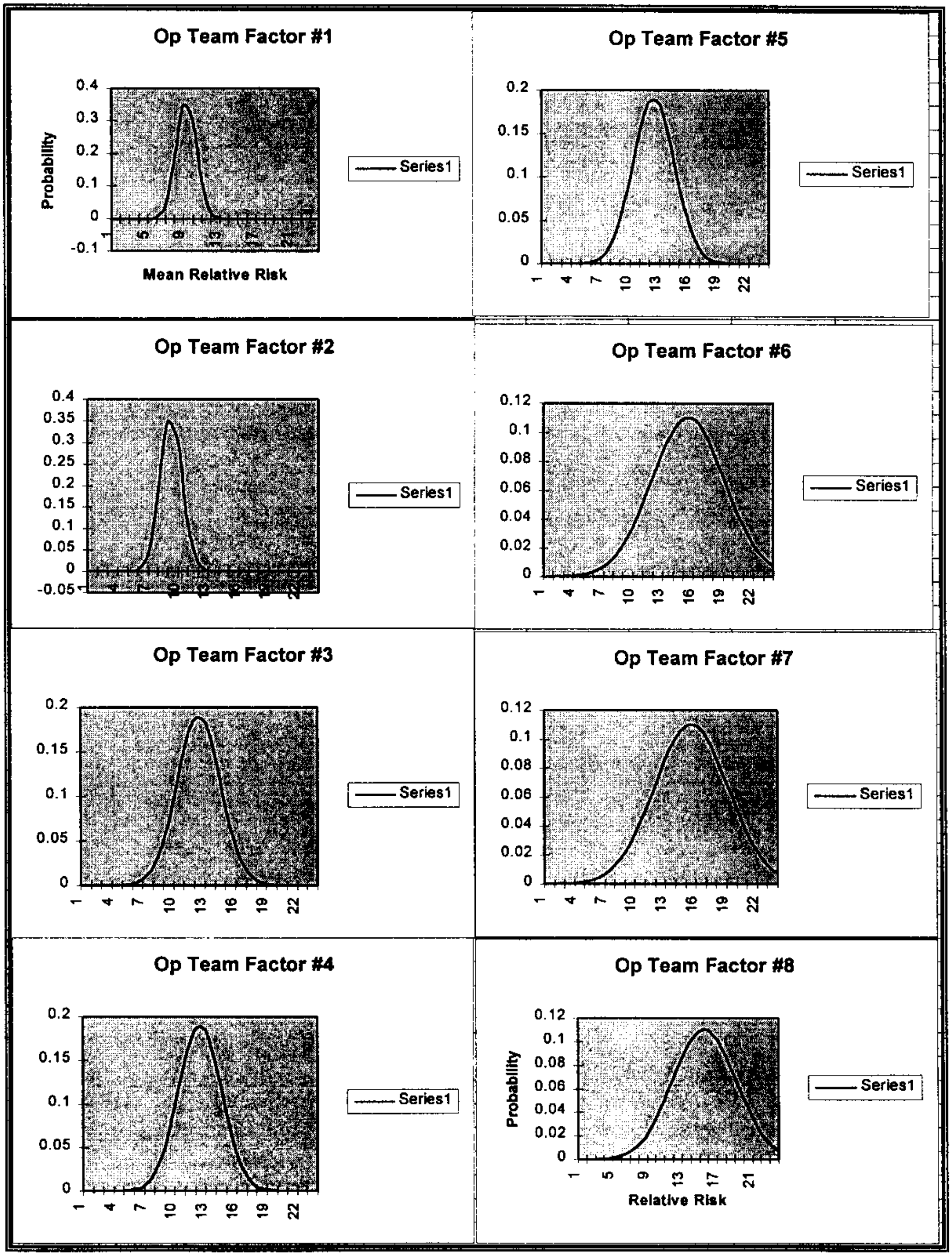


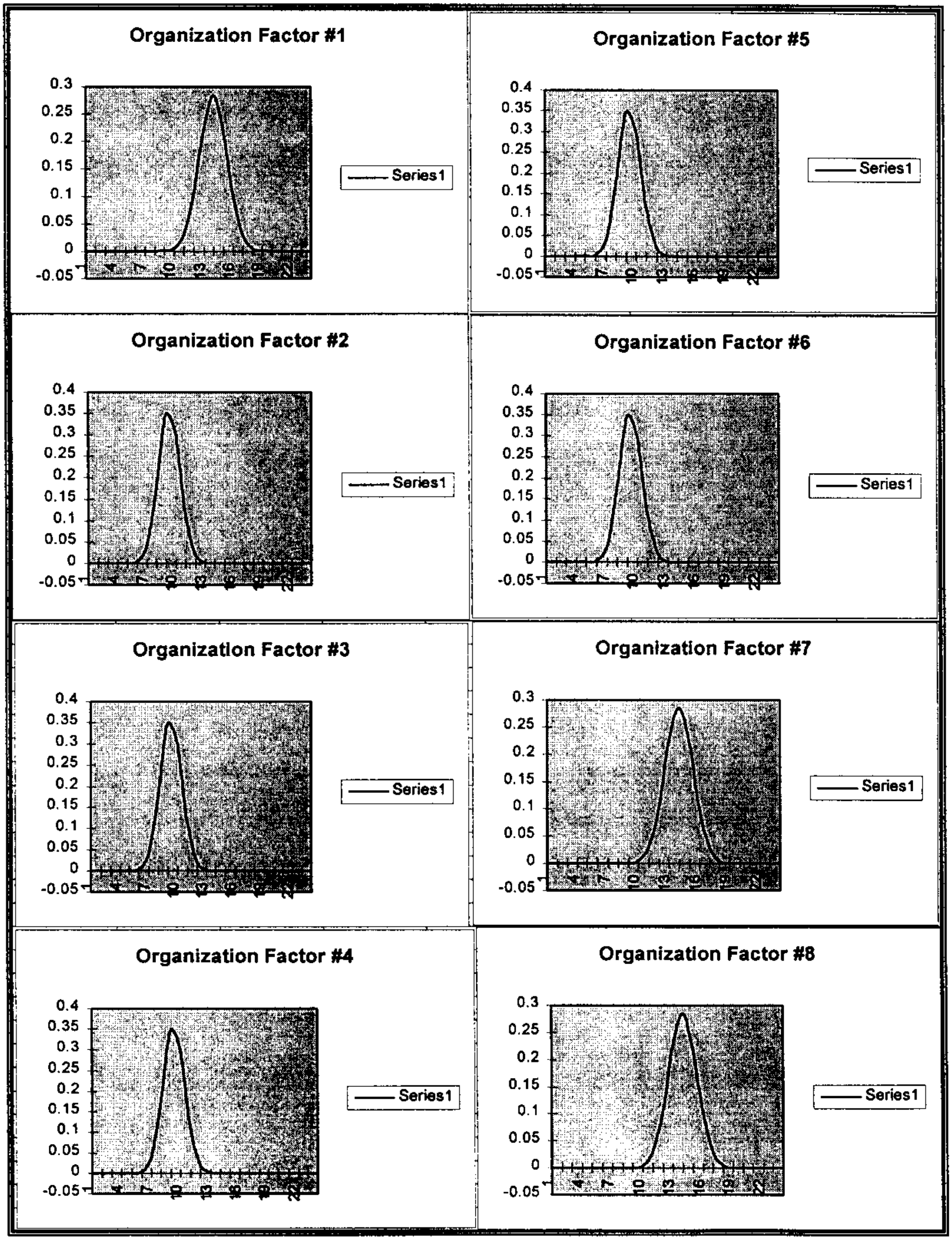


Organization Factors (cont.)

	Likelihood	Consequences
Appropriate Risk Perception		
Emergency Preparedness		
Command & Control		
Training		
Communications		
Resources		

APPENDIX D4: RESULT - RELATIVE RISK DISTRIBUTIONS




Organization Factor #1
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Series1
Organization Factor #5
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Series1
Organization Factor #2
Series1
Organization Factor #6
Series1
Organization Factor #3
Series1
Organization Factor #7
Series1
Organization Factor #4
Series1
Organization Factor #8
Series1

APPENDIX D5: STEP-BY-STEP DESCRIPTION OF REDUCING RISK

1. Identified Relative Risk Factors for Operating Team Factors and Organization Factors

2. Reduce Relative Risk by either reducing Consequences or Likelihood

   Reduce Consequence by reducing hydrocarbons flow through the sampling area.

   or

   Reduce Likelihood

Reduce Likelihood in Operating Team Factors

1. Experience
2. Training
3. External Environment

1. Experience: Complacency could develop for the worker who regularly takes sample. This can be countered with spot checks and allowing workers to teach other samplers.

2. Training: Initial qualifications are good. May need to review refresher training and also allow training others for the task.

3. External Environment: When weather conditions are bad, two people may need to do sampling so that short-cuts and distractions do not occur.

Reduce Likelihood in Organization Factors

1. Process Auditing
2. Communications
3. Resources

1. Process Auditing: Check to see how frequently spot-checking of the sampling procedures is done.

2. Communications: Feedback from the parent organization is required when any changes to procedures are recommended by the workers on the terminal, especially those concerning safety.

3. Resources: Tightening of the refinery budget means there are less funds for training. Workers are feeling that profits are more important than training and their safety.

APPENDIX D6: TRIANGULAR DISTRIBUTION FORMULAS

(Ref: Prof. R. G. Bea class notes)

The triangular distribution has achieved a most prominent position in applied statistics. It is widely used in statistical modeling because only three values of the random variable x are required to uniquely establish the distribution. Use of the triangular distribution implies a great deal of uncertainty concerning the distribution of the random variable.

(a) Frequency Distribution

The probability density function for the triangular distribution illustrated in Figure X is:

$$tr(x; a, b, c) = \frac{2(x-a)}{(c-a)(b-a)} \quad , \quad a < x < b$$

$$= \frac{2}{c-a} \quad , \quad x = b$$

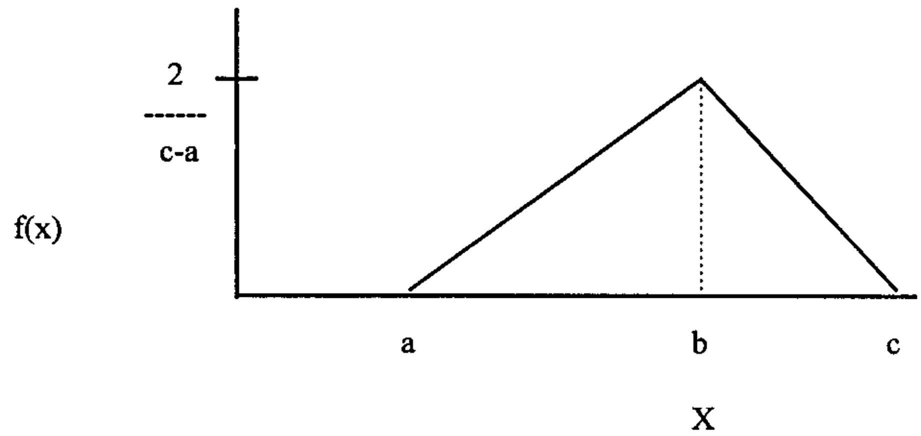
$$= \frac{2(x-c)}{(c-a)(b-c)} \quad , \quad b < x < c$$

The cumulative distribution function is defined as:

$$Tr(x; a, b, c) = \frac{(x-a)^2}{(c-a)(b-a)} \quad , \quad x < b$$

$$= \frac{x^2 - 2cx + b(c-a) + ac}{(c-a)(b-c)} \quad , \quad b < x < c$$

$$= 1 \quad , \quad x > c$$



(b) Distribution Parameters

(1) Mean

$$\mu = \int x f(x)dx = \frac{2}{c-a}\left[\int \frac{x(x-a)}{b-a}dx + \int \frac{x(x-c)}{b-c}dx\right]$$

$$\mu = \frac{1}{3}(a + b + c)$$

(2) Variance

$$\sigma^2 = \int (x-\mu)^2 f(x)dx = \int x^2 f(x)dx - 2\mu \int x f(x)dx + \mu^2 \int f(x)dx$$

$$\sigma^2 = \int x^2 f(x)dx - \mu^2$$

$$\sigma^2 = \frac{2}{c-a}\left[\int \frac{x^2(x-a)}{b-a}dx + \int \frac{x^2(x-c)}{b-c}dx\right] - \frac{(a+b+c)}{3}$$

$$\sigma^2 = (1/18)(a^2 + b^2 + c^2 - ab - ac - bc)$$

APPENDIX D7: ANCHORS FOR SCALES

Description of a company:

	Anchoring point
1	Company practices it 100% of the time
2	
3	
4	Company practices it 50% of the time
5	
6	
7	Company never practices it.

Likelihood:

	Anchoring point
1	Will happen in the next 1,000,000 days (or approx. 100 years or never happen)
2	Will happen in the next 100,000 days (4000 days or approx. 10 years)
3	Will happen in the next 10,000 hours (400 days, or approx. 1 year)
4	Will happen in the next 1000 hours (40 days)
5	Will happen in the next 100 hours (4 days)
6	Will happen in the next 10 hours
7	Will happen any time now

Consequences:

	Anchoring point
1	$1,000
2	$10,000
3	$100,000
4	$1,000,000 ($1 million)
5	$10,000,000 ($10 million)
6	$100,000,000 ($100 million)
7	$1,000,000,000 ($1 billion)

Consequences:

	Anchoring point
1	No Cost
2	Loss of 1 day
3	Loss of 10 days
4	Loss of 100 days (approx. 3 months)
5	Loss of 1,000 days (approx. 30 months or 2.5 years)
6	Loss of 10,000 days (approx. 25 years)
7	Bankruptcy

Consequences - Oil spilled:

	Anchoring point
1	No spill
2	1 cup
3	approx. .6 gallon (10 cups)
4	approx. 6 gallons (100 cups)
5	approx. 60 gallons or 1.4 barrels (1,000 cups)
6	approx. 600 gallons or 14 barrels (10,000 cups)
7	Over 140 barrels

Consequences - Injuries:

	Anchoring point
1	No injury
2	Minor injury, no first aid required
3	Minor injury, first aid required
4	Multiple minor injuries
5	Major injury
6	1 death/ multiple major injuries
7	Multiple deaths