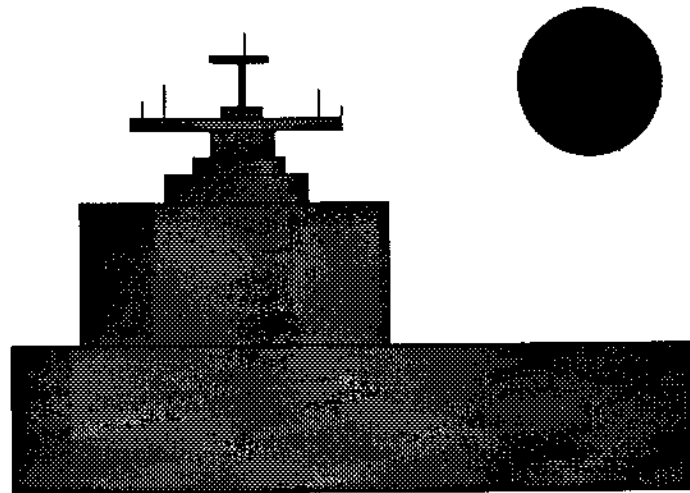


Fire and Life safety Assessment and Indexing Methodology II (FLAIM II)

Development and Test Plan

*Report to Sea Grant College Program
Project R/OE 28*



By

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May 1996

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**FIRE AND LIFE SAFETY ASSESSMENT AND INDEXING METHODOLOGY II
(FLAIM II)**

DEVELOPMENT AND TEST PLAN

by
Derek Hee, Robert Bea, Karlene Roberts, and Robert Williamson

Abstract

FLAIM II fills a unique role in the safety assessment of marine systems. It incorporates three sources of information on Human and Organizational Factors into questions that will be used by trained and experienced assessors to assess offshore platforms and terminals. The methodology is based on assigning scaled values for likelihood and consequence to determine a relative risk value for each category of assessment. The highest relative risk categories are targeted for risk reduction. The assessors also provide valuable information in the form of comments to reduce risk, and their uncertainty in assigned values. The training of the assessors is divided into two parts, the first being informational and the second being "hands-on" use of the instrument. The assessment consists of three phases, a one day initial onshore screen and assessor training, a two day offshore platform assessment, and a one day onshore final evaluation. This three part process tests FLAIM II's utility.

Fire and Life safety Assessment and Indexing Methodology II (FLAIM II)

Development and Test Plan

1.0 Introduction

1.1 Goal and Objectives

The goal of this project is to further develop and test an assessment process (FLAIM) focused on preventing loss of containment which can lead to fires and explosions on offshore platforms and marine terminals. The assessment process includes: a) assessor selection and training, b) an assessment instrument (FLAIM II), and c) an assessment protocol (how to perform assessments).

The FLAIM II project's primary focus is on human and organization factors (HOF) that can influence loss of containment events on offshore platforms and marine terminals. The development of the assessment process incorporates results from such recent associated developments as SEMP (Safety and Environmental Management Programs), PFEER (Prevention of Fire and Explosion and Emergency Response), and ISM (International Safety Management) code.

The primary objective of these office - field studies is to demonstrate the practicality and the workability of the FLAIM process. A secondary objective is to learn as much as possible about the consistency of the FLAIM assessment results, by evaluating its ability to consistently identify high priority elements that deserve remediation and the potential remediation measures.

The assessors are recognized as the most important part of the FLAIM process. Thus, another key objective of this project is to develop an assessor qualification and training protocol, and then to determine the protocol's effectiveness in the office and in the field.

The FLAIM process has been developed so that it can be used effectively and efficiently by those having daily involvement and responsibilities for the safety of offshore

platforms and marine terminals. The FLAIM process is intended to empower those having such responsibilities identify important loss of containment hazards, prioritize those hazards, and then define warranted or needed mitigation measures.

1.2 Background

Many different types of safety assessment methods have been used by the marine industry (Figure 1). The methods range from qualitative (Hazard Operability Studies, Failure Mode and Effects Analyses) to quantitative (Quantified Reliability Analyses, Probabilistic Risk Analyses, Formal Safety Assessments). FLAIM II is intended to fill a gap between the non-quantitative / less detailed methods and the highly quantitative / very detailed methods. FLAIM has been identified as a Safety Indexing Method (SIM) (Bea, 1996). FLAIM II uses anchored rating scales that allow assessors to evaluate likelihoods and consequences of loss of containment events at platform and terminal 'hot spots' (places where loss of containment can lead to significant pollution or fire and explosion events).

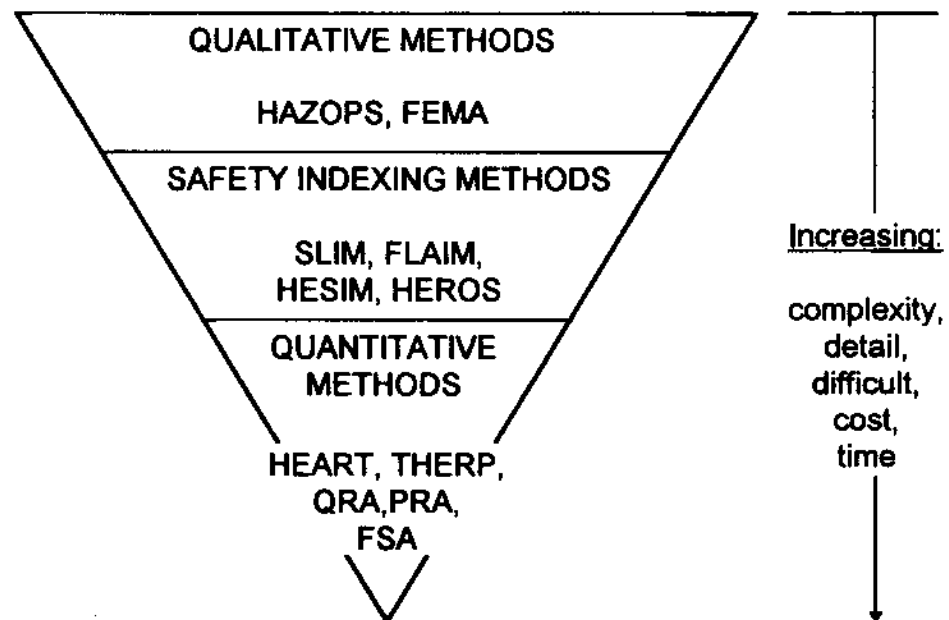


Figure 1. Safety assessment methods

Each of the safety assessment methods outlined in Figure 1 has its own strengths and weaknesses (Bea, 1996; Groeneweg, 1994; Center for Chemical Process Safety, 1994; Safety and Reliability Directorate, 1988). These methods can be viewed as being

progressively more: difficult, time consuming, costly, and complex in identifying how to prevent loss of containment events on offshore platforms and marine terminals. These methods can be viewed in the context of a set of comprehensive safety screening assessment processes that attempt to identify and remedy safety hazards using the simplest methods first, and reserving the more detailed and complex methods for more difficult problems. These methods should be viewed as complimentary frameworks for thought and evaluation in the quest to achieve adequate safety.

1.3 FLAIM

FLAIM is a Fire and Life safety Assessment Indexing Method that was developed at the University of California during the period 1990 through 1994 (Gale, et al., 1994, an article on FLAIM is included as Appendix A). This 'walk-down' assessment instrument addresses critical elements that influence prevention of loss of containment on offshore platforms and marine terminals (Figure 2). These critical elements comprise modules in the FLAIM computer program and includes: platform and terminal structure, equipment / facilities, system safety procedures, operating teams safety, organization safety, safety assessment and improvements, and reporting. The principal emphasis in FLAIM II has been (1) the development of Human and Organization Factors (HOF) elements incorporated into the Operating Teams Safety Module and the Organizations Safety Module, (2) the assessor qualification and training process, and (3) the development of an effective SIM that is incorporated into the Reporting and System Safety Index and Improvement Alternatives Module. As appropriate, components from the original FLAIM will be incorporated into the FLAIM II program to create a comprehensive platform and terminal loss of containment assessment instrument.

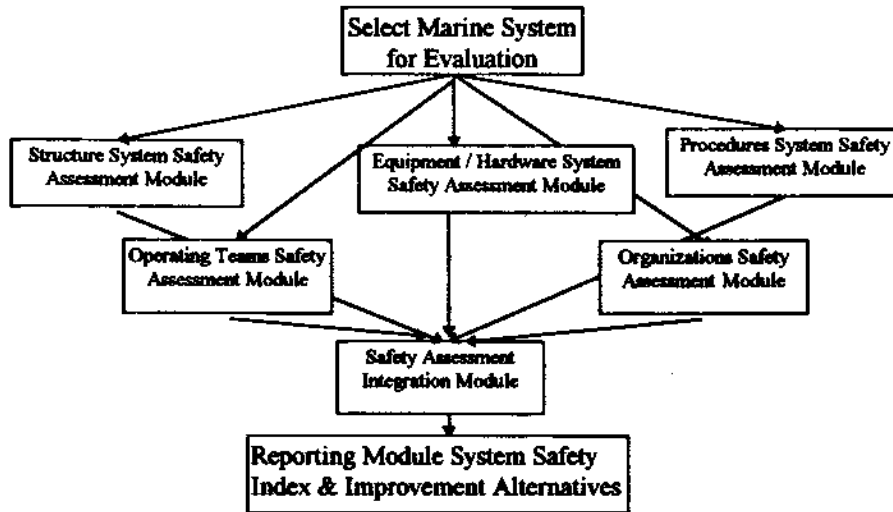


Figure 2. FLAIM II modules

1.4 Development Plan

The basic plan for FLAIM II development and verification is outlined in Table 1. The project is organized into five Stages during the two year project duration. Stage 1 develops the FLAIM II process, Stage 2 implements the Stage 1 developments, Stage 3 revises the FLAIM II process based on the experiences from Stage 2, Stage 4 implements the Stage 3 developments, and Stage 5 wraps up the project.

The remainder of this report summarizes the Stage 1 developments.

Table 1 - FLAIM II development plan

Stage No.	Tasks
1 develop	develop operating teams module develop organizations module develop safety indexing method and scales develop assessor qualification & training protocol develop assessment process identify and select Stage 2 demonstration facilities develop assessor training documentation program FLAIM II
2 implement	conduct assessor training perform field demonstration tests evaluate field demonstration tests
3 revise	revise FLAIM II program revise FLAIM II process revise assessor training program and documentation identify and select Stage 4 demonstration facilities
4 implement	conduct assessor training perform field demonstration tests evaluate field demonstration tests
5 wrap up	summarize project results summarize needed developments document project

2.0 HOF Components of FLAIM II

The four primary components in the FLAIM II process that address HOF are: (1) the questions that comprise the operating teams and organizations modules, (2) the Safety Indexing Method, (3) the assessor qualification and training protocol, and (4) the FLAIM II assessment methodology. The development of these components will now be summarized.

2.1 The Questions

Agencies responsible for the oversight of the oil industry have developed safety and environmental management programs guidelines, with the goal of reducing HOF initiated accidents on marine systems. The following lists three key guidelines along with their agency:

Safety and Environmental Management Program (SEMP) - Minerals Management Service, U.S. Department of the Interior,

Prevention of Fire and Explosion, Emergency Response (PFEER) - U. K. Health and Safety Executive,

International Safety Management (ISM) Code - United Nations International Maritime Organization.

These regulations, along with research done at the University of California at Berkeley focusing on risk reduction and operational reliability, and company responses to regulations provided a set of HOF. These factors are presented with definitions in Appendix B, along with two source matrices. Questions were generated from each category for FLAIM II.

The generation of FLAIM II questions is a four step process (Figure 3). The first step identifies the eight categories. The second step identifies the various sources of information, and decomposes them into component questions. The third step places the component questions into the appropriate categories. The fourth step combines similar questions in each category, the result being a set of questions for each category. This set of questions is summarized in Appendix C as the Basic Minimal Questions. The FLAIM II process allows the assessors to identify other questions and factors that are appropriate for the evaluation of a particular system.

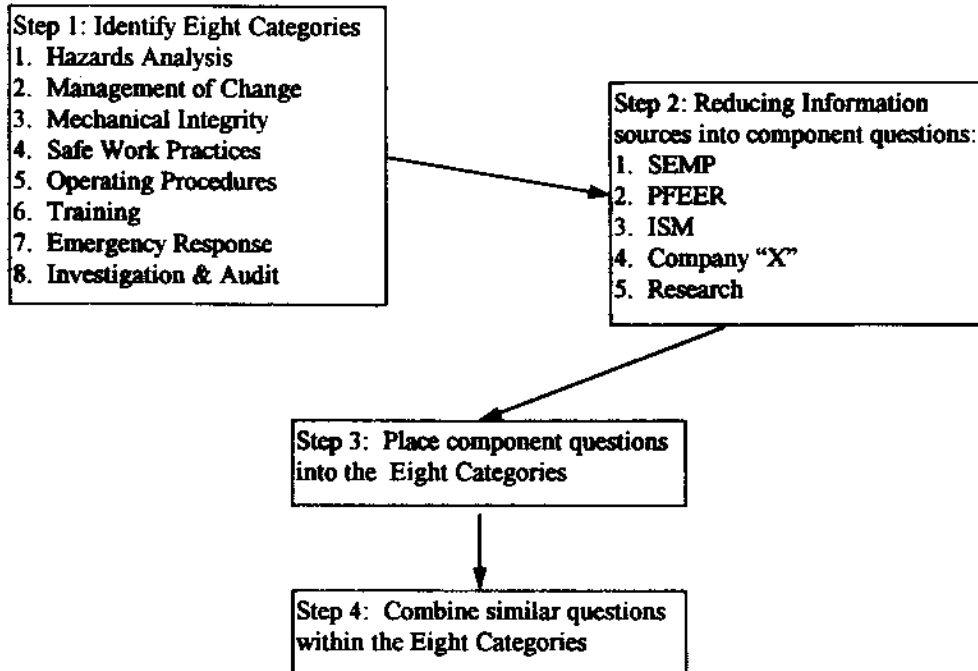


Figure 3. The four steps to combining questions

2.2 The Safety Indexing Method

Once these questions are developed, the next issue is answering them. The method for answering FLAIM II questions relies heavily upon assessors who assign 'most probable' scaled values (likelihood and consequence) to each question (Figure 4). These values are then multiplied to determine the resultant loss of containment risk associated with each question or factor:

$$\text{Risk} = \text{Likelihood} \times \text{Consequence}$$

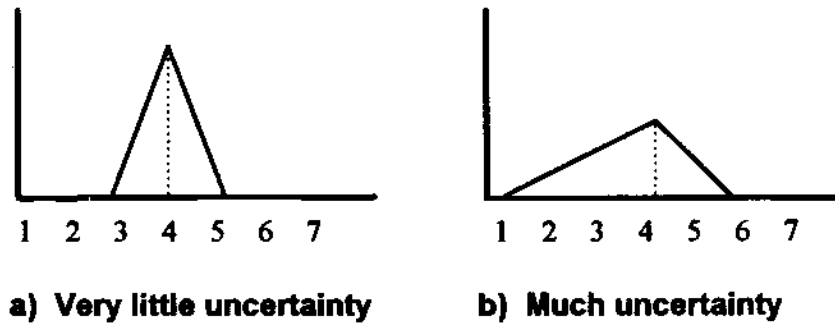


Figure 6. Distribution expresses assessor uncertainty

The assessors will be tasked with commenting on the reasons for assigning a certain scaled value. This information will be used to identify potential remedial measures and to evaluate the consistency of the results among different assessors.

2.3 The Assessors

The FLAIM II assessor must have experience operating either platforms and terminals, and have training on FLAIM II and HOF.

2.3.1 Qualifications

The quality of the FLAIM II results is critically dependent on the background, experience, and attitude of the assessors. The following assessor qualifications are proposed:

- a. Platform / terminal operations
- b. Fire and explosion training
- c. Safety auditing
- d. Human and organization factors

An important aspect of assessor qualifications is their aptitude, attitude, and motivation. It is very desirable that the assessors be highly motivated to: (1) learn about HOF and safety assessment techniques, (2) have a high sensitivity to safety hazards ('perverse imaginations'), (3) be observant and thoughtful, (4) have good communication abilities, and (5) have high integrity.

The assessor is expected to make assessments in five areas: (1) the condition of the structure, (2) the condition of the equipment, (3) adherence to and sufficiency of operating procedures, (4) performance of operating teams, and (5) influences of the

parent organization on platform and terminal loss of containment events. Sufficient expertise in the first three areas (structure, equipment, and procedures) is expected to be found in individuals having five to fifteen years of operating experience on platforms and terminals. Additional information in these first three areas, focusing on how poor structural and equipment maintenance, and procedural deviations have led to a loss of containment and subsequent fires and explosions, is incorporated into assessor training (see Appendix D).

The other two areas, HOF in operating teams and organizational influences, will make up a significant part of the training. Assessor experience with platform and terminal operating teams and organizational influences will enhance the HOF training, enabling them to better assess platform and terminal operations for HOF.

2.3.2 Training

The training (Appendix D) has two parts, the informational part and the practical exercise part. The assessor is the key to a quality assessment. An assessor with five to fifteen years of platform operating experience brings a base of knowledge and experience focused on structural, equipment/hardware, and procedures (Figure 7). Additional knowledge of how loss of containment leads to fires and explosions affects these three components is a part of the training (Figure 8), and furthermore, information on Human and Organizational Factors will be a part of the training as is outlined in Figure 9.

Structural
Equipment/Hardware
Procedures

Figure 7. Basic assessor knowledge

Structural	LOC
Equipment/Hardware	Fires and Explosions
Procedures	

Figure 8. Additional knowledge on loss of containment, fires, and explosions

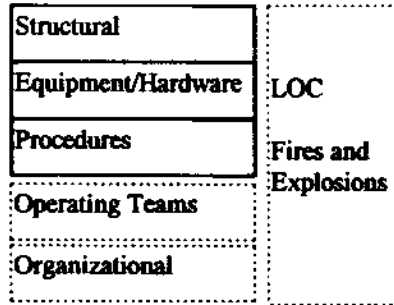


Figure 9. Primary training modules (dashed lines)

The dashed lines in Figure 9, provides an overview of several of the informational parts of training.

Other information provided during training are the methodology (described in the next section of this paper), and the overall concept of FLAIM II. Assessors will work through several “table-top” exercises using the FLAIM software.

The second of part training is the “hands-on” use of the computer software. Figure 10 shows how requirements mandated by regulators, company plans, and findings from previous research contribute to question development for FLAIM II.

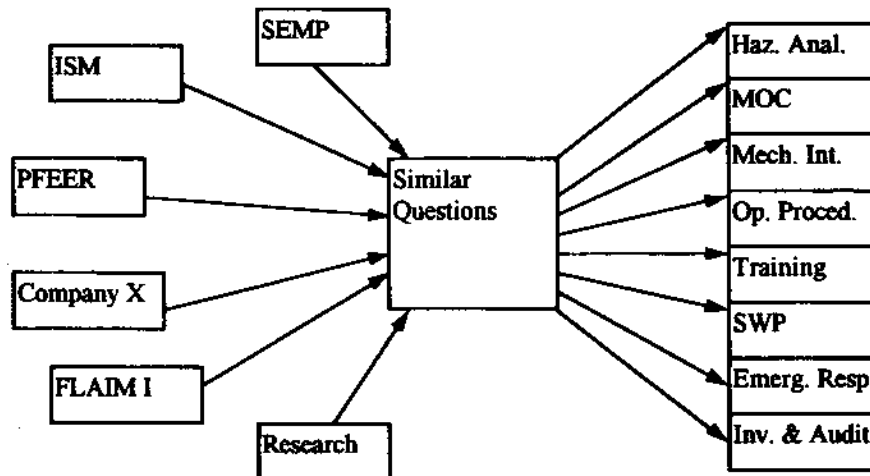


Figure 10. The relational data base system

A software demonstration using a simple platform as a case study will be shown to the assessors, and then they will assess another simple platform on their own. Following this, each assessment will be evaluated and assessors will be asked for feedback on

FLAIM II. The goal of hands-on training is to have the assessors become familiar with the software.

2.4 The Methodology

The FLAIM II evaluation process is organized into three phases : (1) background information development and initial assessment (onshore), (2) visiting the facility and observing operations (offshore), and (3) final evaluation (onshore) (Figure 11).

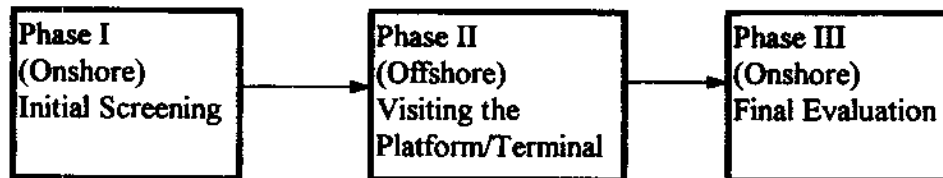


Figure 11. Phases of a FLAIM II evaluation

During the initial screening, information is gathered to identify “hot spots” (locations / operations having high likelihood and consequences of loss of containment events) and to make preliminary assessments. This information comes from both verbal briefings and written material. Verbal briefings by personnel from both the corporate office and the platform / terminal, followed by a question-and-answer period, provide insight into the organization. Written information, such as oil process flow diagrams, maintenance procedures, results from previous assessments and inspections, information on previous loss of containment events, and emergency action plans, are examined to determine hot spots and to familiarize assessors with the platform. During the initial phase, the preliminary assignment of scaled values for the questions are made.

The purpose of the second phase, visiting the platform / terminal, is to confirm information gathered during the first phase and to observe the actual operation of the facility. A typical visit will include a tour of the entire facility, followed by observing, at a minimum, the following three critical procedures: (1) maintenance, (2) emergency drills, and (3) shift changes. A tour will help familiarize assessors with the location of hot spots identified during phase one and perhaps reveal additional hot spots. Maintenance at hot

spots will be the first procedure focused on because poor or improper maintenance is the cause of many accidents on marine systems. The second procedure, emergency drills, focuses on how platform / terminal personnel respond to loss of containment events, because once it has started, humans must act either to bring the loss of containment under control or to escape. The third procedure, shift change, is observed to examine communication between platform / terminal operating crews and personnel. Of particular concern are communications between contract crews and platform / terminal operating personnel. As the visit proceeds, scaled values are assigned to all questions, and supporting information is gathered.

During the final evaluation phase, the evaluations and comments are re-examined, and the final scaled values are multiplied to compute a relative risk for each question. These values are then graphed (Figure 12).

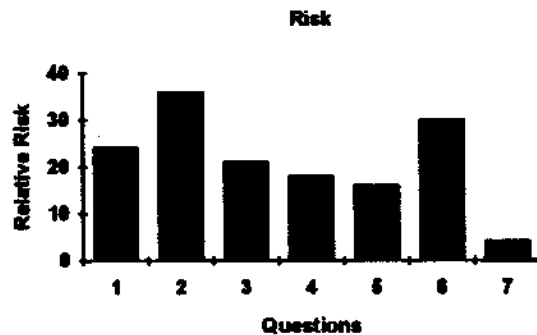


Figure 12. Relative risks for LOC questions

The highest relative risk factors are identified and the supporting information examined to make recommendations for reducing the risks. Risks can be reduced through reductions in likelihoods or severity of consequences, or through a combination of these. These recommendations are summarized in a final report on the assessment of the facility.

3.0 Testing

The testing of the FLAIM II process occurs in two phases. The first phase is the initial field test. Following the first phase, the FLAIM II process is updated using feedback and analysis of the first field test results. The second phase is the final field test.

3.1 The First Field Test

The goal of the first test is to assess whether the FLAIM II process is practical. The first test begins with the training of assessors, during which feedback is solicited to improve training. Next, the two teams of three assessors each are formed and a test matrix is set up (Figure 13).

Assessor Team	Platform #1	Platform #2	Marine Term. #1
1			
2			

Figure 13. Initial test matrix

The test assessment teams, as envisioned, are to be composed of a representative of: (1) the owner / operator of the facility, (2) a regulatory representative, and (3) an engineering contractor / classification society representative.

The test matrix consists of three marine systems, two offshore oil platforms and one marine terminal (see Appendix E for typical system candidates). Using the FLAIM II methodology, the first team will assess the first platform using the three phases:

(1) initial screening onshore, (2) visiting the platform offshore, and (3) final onshore evaluation. The time projected for each system assessment during this phase is four days: one day for the first phase, two days for the second phase, and one day for the final phase. A research associate will accompany the team to record assessor feedback on the training, the methodology, and the instrument. The teams will assess the three systems in any order, as long as both teams are not on the same system at the same time. The goal of this test phase is to determine the workability of the FLAIM II instrument. At the end of each assessment, feedback for the instrument's improvement will be solicited from the assessors.

3.2 The Interim Period

During the interim period, feedback from the assessors is collected and incorporated into FLAIM II. The system assessments are analyzed and revisions are made

to the instrument. The training, methodology, questions, and testing will all be reviewed during this phase with the goal of improving the FLAIM II instrument

3.3 The Final Test Phase

The goal of the final test phase is to check for FLAIM II's practicality, workability, and consistency. The final test phase will have improved training, methodology, and questions. This phase begins with the improved assessor training, and then proceeds to the assessment of another three marine systems, similar to the first field test matrix. The assessments, both scores and comments, are used to analyze the consistency of the instrument and the training.

4.0 Conclusions

FLAIM II is intended to fill a unique role in the safety assessment of marine systems. It incorporates three sources of information on Human and Organizational Factors into questions that will be used by trained and experienced assessors. The methodology developed is based on assigning scaled values for likelihood and consequence to determine a relative risk value for categories, with the highest relative risk categories targeted for risk reduction. The assessors also provide valuable information in the form of comments to reduce risk, and uncertainty in their assigned values. The training of the assessors is divided into two parts, the first informational and the second "hands-on" use of the computer program. The methodology consists of three phases, the one day initial onshore screen, the two day offshore visit to the platform, and the one day onshore final evaluation. The testing of the FLAIM II instrument has two phases, the first test and the final test. The test includes training, traveling to marine systems, and assessing the system. The goal of the first test is to check for FLAIM II's practicality and the goal of the final test is a consistency check. The interim period is used to improve all aspects of FLAIM II.

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6.0 Glossary

- Accident** - an occurrence that leaves a system damaged or defective.
- Cognition** - the capacity or mechanisms that lead to knowledge; those aspects of mental behavior involved in the diagnosis of events
- Commission error** - an error that results from an unintended action, excluding inaction; incorrect performance of a task or action
- Communication** - the capacity or mechanisms of information transfer between or among people
- Consequence** - the result of an event or action
- Conditional probability** - the probability of an event occurring given that some other event has occurred
- Decision making** - the activity of choosing one course of action among alternatives
- Dependency** - a relationship between the occurrence of one event (factor) and another event (factor)
- Diagnosis** - the attribution of the most likely causes of an abnormal event to the level required to identify these systems or components whose status can be changed to reduce or eliminate the problem; interpretation
- Error** - deviation for an intended or desired human or organization performance or any deviation from an intended result
- Ergonomics** - the discipline concerned with designing hardware, operations, procedures, and work environments so that they match human capacities and limitations
- Event tree** - a graphical representation of the logic of the interactions of intermediate events between an initiator and its identified consequences
- Failure** - any deviation from an intended or desired hardware, software, human, or organization performance
- Fault tree** - a graphical representation of the logic of the causes of failure of a specified event
- Hazard** - a feature of the environment that could be harmful or damaging to a system
- Hardware** - mechanical, structural, equipment, and other similar artifices
- Human errors** - actions or inactions by individuals that can lead an activity to realize a lower quality than intended; misadministrations; departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results
- Human factors** - any attribute of a situation or object that is due to the actions or attributes of one or more persons

Human performance - result of human behavior as measured against some goal or standard

Human reliability - the probability that the performance of a person or group of people will be successful or acceptable against the standard or goal of the performance

Human factors - a discipline concerned with designing hardware, operations, procedures, and work environments so that they match human capacities and limitations; any technical work related to the human factor in manned systems

Incident - an occurrence that interrupts the performance of a system rather than leaving a system damaged or defective

Influence - a causal factor for a specific event

Initiator - the occurrence that starts an incident or accident

Interaction - the relationship between the behavior of two systems or components to produce a combined consequence that would not occur if only the behavior of the individual system or component occurred

Knowledge-based behavior - behavior that requires one to plan actions based on an analysis of the functional and physical properties of a system

Lapse - an error in recall

Man-machine interface - the abstract boundary between people and the hardware or software they interact with

Mistake - an error in establishing a course of action

Model - a characterization or description of a system that is an abstraction that represents symbolically the way in which the system functions

Omission error - an error that amounts to an unintentional or unnoticed inaction; failure to perform a task or action

Organization errors - actions or inactions by groups of individuals that can lead an activity to realize a lower quality than intended; group misadministrations; departure from acceptable or desirable practice on the part of a group of people that can result in unacceptable or undesirable results

Perception - the capacity or mechanisms that lead to recognizing sensory input

Performance shaping factor - an influence on performance

Probability - a number between 0 and 1 that quantitatively ranks the likelihood or chance of the occurrence of a postulated event

Procedure - the formal realization of a task; verbal instructions or written actions

Probabilistic Risk Assessment (PRA) or Quantified Risk Assessment (QRA) - a rigorous and systematic identification of the levels of compromises in quality that could result from system operations and a quantitative assessment of the likelihood of such occurrences

Quality - fitness for purpose; freedom from unanticipated defects; meeting requirements of serviceability, safety, compatibility, and durability

Random - variability that cannot be predicted or its causes are unknown or its results have no discernible pattern

Reliability - the probability that the performance of some hardware, software, individual, organization, or their combination will be successful

Risk - the chance of a loss or damage; the frequency of an undesired consequence; the uncertainty of a hazard; the product of the likelihood of an event and the consequences of that event

Sequence - a chain of events that trace an initiating event to a specific consequence

Rule based behavior - behavior in which a person follows remembered or written rules

Skill - an ingrained ability or capacity toward specific action; the performance of more or less subconscious routines governed by stored patterns of behavior

Slip - an error in implementing a plan, decision, or intention

Software - information stored on paper, film, electromagnetic media, etc.

Stress - the physiological or psychological reaction to loads, burden, or other stressful influences on people; feeling of threat to one's well being; human response to a stressor (causes bodily or mental tension)

System - a group of entities consisting of hardware, software, people, organizations, or their combination that interact to produce joint behavior that can be measured against some goal or standard

Task - a series of human activities designed to accomplish a specific goal

Taxonomy - a classification or way to characterize and describe

Uncertainty - a lack in knowledge or a failure in being able to predict a postulated event

Appendix A - Article on FLAIM

Human Factors in Operational Reliability of Offshore Production Platforms: The Fire and Life Safety Assessment Index Methodology (FLAIM)

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Introduction

Following the 1988 *Piper Alpha* disaster in which 167 people lost their lives in industry's worst offshore platform accident, numerous inquiries and research efforts were set in motion. In the ensuing official investigation, Lord Cullen¹ recognized a principal change was needed in administering U.K. offshore safety regulations—a move away from prescriptive, mechanistic safety regulations to an approach based on comprehensive goal setting objectives that could accommodate, *inter alia*, the influence of human and organizational factors in managing safety. Within the United States, a similar movement is taking place—both onshore and offshore.

Recognizing the importance of addressing human factors in process safety management, OSHA's PSM regulations focus attention on the contribution of human factors in process hazard analysis. As pointed out by Flegler,² industry is now coping with the problem of how to

perform human factors analysis as a part of the mandated process hazard analyses required. Flegler notes that quantitative techniques, such as *human reliability analysis* (HRA) are even more cumbersome than many types of other quantitative analyses, and suffers from the same limitations of uncertainties due to a lack of specific data or human error probabilities.³

In the case of *Piper Alpha*, the Safety Management System, e.g., the means to integrate and execute those aspects of platform design and operations that directly or indirectly influence achieving safe operating goals (Figure 1) was found to be deficient in several respects. This led to the present requirement for a *formal safety assessment* or "Safety Case," based on *quantified risk assessment* (QRA) techniques, to be included as part of the overall platform's SMS.³

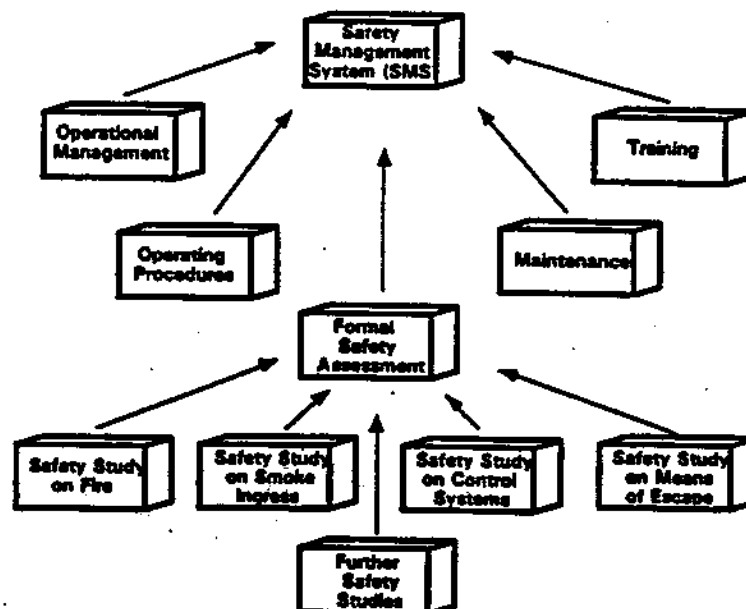


Figure 1 - Interpretation of Safety Structure Proposed in the Cullen Report

The Cullen inquiry of the *Piper Alpha* accident concluded that techniques based on QRA (also commonly known as PRA) should be used to assess major hazards and to evaluate the means to reduce risk of accidental events on life safety features, e.g., the integrity of personnel refuge areas, escape routes, embarkation points and lifesaving craft, etc.¹

However, as pointed out by the subsequent Fire and Blast Research Project's *Interim Guidance Notes*,⁴ it is considered either impractical or impossible to carry out a rigorous QRA due to a lack of sufficiently detailed knowledge of the systems and their expected performance characteristics, or the lack of accurate probability data of initiating events, and the large uncertainties associated with determining consequences. Limited knowledge of probability distributions and limited/incomplete event databases have been and continue to be long-standing obstacles to rigorous application of QRA offshore.

Meaningful data needed for performing rigorous QRAs on most U.S. OCS platforms is also lacking. The present database maintained by Minerals Management Service (MMS) has been recognized as lacking in several respects. A report by the National Research Council^{5,6} has recommended that MMS should develop a comprehensive system for collecting event and exposure data, calculating frequency and severity rates, analyzing trends, and performing several other functions necessary to produce usable data.

This problem is one of the driving forces that led to the development of FLAIM— a search for a means of integrating stochastic risk assessment approaches with deterministic and heuristic techniques to assess risk offshore— to identify deteriorating operations (both from a mechanical and management standpoint) and reveal emerging safety risks on older platforms. FLAIM's development sought to capture one of the main advantages of QRA— the application of a quantified and structured approach to enable decisions to be reached on a rational and consistent basis— but yet greatly simplifies the assessment procedure and eases the burden of performing such studies.

FLAIM is not intended to replace more thorough risk assessment techniques, however, but rather complement their usage when appropriate (and when meaningful data are available). FLAIM is primarily intended to provide a screening tool for platform operators and regulators to help them determine how to best improve existing safety management programs and direct limited resources for optimal risk mitigation.

Conceptual Basis and Development of FLAIM

Following the loss of *Piper Alpha*, the U.S. Mineral Management Service (MMS) requested the National Academy of Sciences' Marine Board to assist them in investigating alternative strategies for the inspection and safety assessment of OCS platforms, with a view towards improving operational safety and inspection practices.⁷ Considerable effort was made to select members of the working committee, known as the Committee on Alternatives for Inspection (CAI), who not only had both the requisite expertise in OCS operations and safety management, but also would bring a balanced viewpoint with respect to public interests in environmental protection and safety. CAI members reviewed the current OCS inspection

program and practices, appraised other inspection practices for "lessons-learned," including those of platforms in state waters as well as inspection practices in other industries (nuclear, etc.), reviewed MMS data bases and the OCS safety record, and developed evaluation criteria and alternative recommendations for consideration by MMS.

The CAI developed an inspection recommendation based upon developing *quantitative indices that characterize and measure the safety of individual offshore operations*. Several factors were identified that should be taken into account in developing sampling indices to characterize and measure platform safety, including:

- the occurrence of safety-related events onboard the platform
- the occurrence of near-misses which could have caused an accident
- the record of tests and inspections of safety equipment found in ill-repair
- evidence of slipshod operation, e.g., poor maintenance, poor housekeeping, poor record keeping, etc.
- the facility design, such as location and age
- evidence of lax safety attitudes of managers, supervisors, or operating personnel, e.g., the "safety culture" and awareness factor
- the overall safety record for all platforms operated by the operator
- the overall safety record for all operators with the region of operations

The CAI suggested that from such quantitative, facility-specific information, a safety rating could be developed for each platform and continually updated with new data. The data base would be kept up to date by requiring that all event reports and specified operator's inspection and test results be sent to MMS. Onshore review of records could then comprise a substantial part of the inspection and assessment process, and onsite inspections (offshore) could be accomplished in a much more efficient and informed manner based on prior analysis of the information in the data base.

Finally, the CAI stressed *the importance of management's safety culture* and suggested that MMS make explicit in its safety management and inspection philosophy the monitoring of safety attitudes of the operators essential, recognizing that subjective judgments will be involved in this process. However, the CAI pointed out that subjective judgments should not be a deterrent, but rather MMS inspectors and supervisors should be trained in techniques for and the importance of monitoring safety attitudes.

The CAI cautioned against the "compliance culture" in which some operators may perceive their responsibility and objective as to "simply pass inspection." CAI emphasized its belief that mere compliance with requirements/regulations *does not equal safety*, and that in practice and by law, the operators bear the primary responsibility for safety. MMS's responsibility is to find the best and most effective means it can devise to motivate operators to meet their responsibility.

FLAIM's conception is rooted in all of the foregoing CAI principles and findings. FLAIM's development was geared to meeting the identified criteria, in recognition of the need to fulfill a variety of functions to be successful. Foremost, it must be user-friendly, interactive, and pleasant to use—with the goal of *motivating platform operators* to monitor and manage an ever-change state of safety onboard their platforms, rather than represent a burdensome and arduous task that is both time consuming and overly technically demanding. It must promote safety performance accountability in an efficient and effective manner.

Further, FLAIM was designed to be adaptable for use to both specific applications as well as specific operators who, hopefully, will choose to use their own proprietary and confidential databases to identify those risk contributors of most significance to the particular operations under scrutiny. In this regard, FLAIM does not presuppose that the risk contributors and their corresponding weighting algorithms used in this original work are absolute or rigid, but rather provisions have been purposefully designed to allow users to select, add, and change the values used herein.

For example, FLAIM is intended to serve as the basis or framework for developing site-specific models suited for the particular area and nature of operations, facility design, reservoir characteristics, and service demands for any given platform. Therefore FLAIM incorporates features that both explain the logic used in its development and allows modification of factors and algorithms when deemed suitable for the user. FLAIM is intended as a tool for platform operators—to assist them in meeting their safety goals and responsibilities—using their own data-bases, knowledge, and experience, as well as those existing at large within industry to do so.

FLAIM's architecture was developed in recognition of the significant role that human and organization error (HOE) plays in promoting offshore accidents, while accounting for the fact that older topside systems, besieged by years of demanding service under harsh conditions, can be expected to have higher rates of mechanical/material related failures than their newer counterparts.

HOE related factors are rooted in design, construction, operational

maintenance, and operations of marine systems. *Over 80% of high consequence offshore accidents are attributable to some form of HOE, and 80% of these can be related to operational aspects of platform activities, e.g., 64% of high consequence accidents result from HOE during operations.*⁸ FLAIM identifies and permits the selection of known risk contributors to assess and quantify platform operational risks, placing heavy emphasis on safety management systems, their effective implementation, and the safety culture under which the platform is functioning. Given the substantial influence of HOE on platform risk and reliability, this paper will focus upon the human operational, management, and life safety aspects of FLAIM.

FLAIM's Architecture

FLAIM can best be described as a quantitative indexing methodology in which selected key factors relevant to fire safety and life safety are identified, assessed and assigned numerical (weighting) values. Risk contributing factors are thereby indexed and ranked using a weighting system algorithm, keyed to relative (comparative) risk, to yield a set of risk indexes, and an overall risk index for topsides facilities. For familiarity and ease of use, an academic letter grading scheme (A, B, C, D, F) based on a 4.0 grade-point scale was selected as the framework for assessing risk contributors. Refer to Appendix 2 for further detail on the specifics of the FLAIM algorithm.

Key topsides risk factors, identified on the basis of scenario analysis, expert opinion, and historical records, are selected and evaluated by the user together with provided or planned-for risk reduction measures. Life safety is assessed independently from fire safety, using risk factors specific to each, but accounting for their close interdependence. The adequacy of risk reduction measures and the overall platform *Safety Management System (SMS)* can be assessed by calculating the RIRA and SAMSA indexes. These indexes reflect provision of risk mitigating and safety management status of the facility. They are combined with fire safety and life safety indices in order to arrive at an overall *topside risk assessment index*.

Figure 2, *Primary Building Blocks of FLAIM*, and Figure 3, *FLAIM Assessment Procedure*, illustrates the way in which risk modules were incorporated in FLAIM's assessment and indexing model and their relationship. Figure 3 serves as an overall "road-map" to

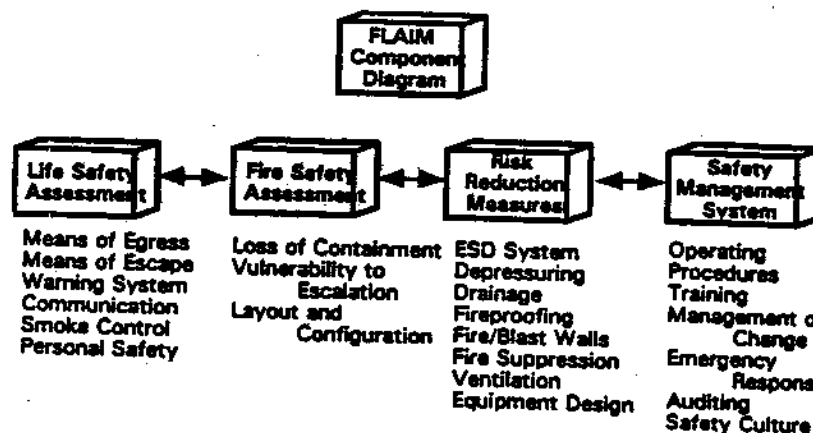


Figure 2 - Primary Building Blocks of FLAIM

most LOC events of significant consequence are not due to poor design, but rather stems from some form of human error,¹¹ e.g., personnel performing routine and/or non-routine tasks on pressurized hydrocarbon containing piping and equipment. For example, the CAI found that the act of opening a pressurized system for maintenance to be the third leading cause of fatalities in the GOM for the years of 1982-1986.⁸

Shortly after the *Piper Alpha* accident, the U.S. OCS experienced the loss of a production platform from a fire which also took seven lives.^{12,13} Human error was the direct cause for an uncontrolled release of hydrocarbons during a repair operation involving an 18 inch diameter gas riser.

The *Operational/Human Factors Assessment (OFHA)* module focuses on what is termed "front-line" operational aspects of platform activities that directly contribute to increased risk levels. Changes in operations may routinely occur, such as periodic workovers, wireline operations or other downhole and topsides activities that, in turn, temporarily increase the overall level of risk on the platform until

the job is completed. Errors involving operational activities are considered to constitute the single most important class of risk contributors leading to platform fires, explosions, and loss of life.

Many individual factors contribute to this problem, as identified by Moore and Bea,¹⁴ including fundamental deficiencies in organizational aspects of the management structure. In OFHA, FLAIM seeks to identify those normally encountered production activities which may involve either an inordinate reliance/dependence on human judgment to avoid serious consequences (direct-link couplings), or activities in which the risk of error is compounded by the complexity or multiplicity of the tasks involved, e.g., multiple simultaneous operations such as drilling, producing and maintenance involving hot work or startup of equipment. The OFHA risk assessment module contains approximately 167 questions covering five subcategories (Figure 4):

- *Maintenance and Repair Work (MARW)*
- *Multiple Operations Assessment (MULOPS)*
- *Operational Management Of Change (OPSMOC)*

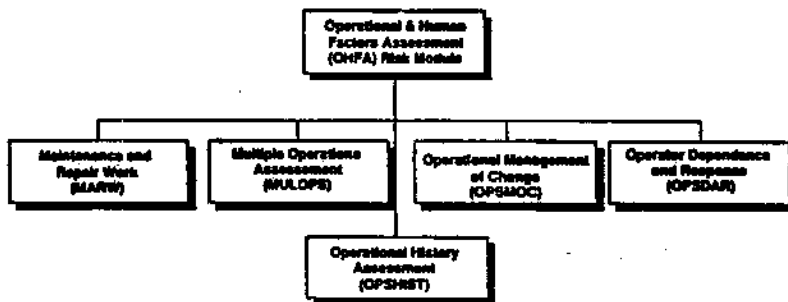


Figure 4
Components of OHFA Risk Module

- *Assessment Of Operator Dependence And Response (OPSDAR)*
- *Operational History (OPHIST)*

For example, MARW addresses operational risks during times when maintenance and repair activities are taking place on the platform— a time when many accidents happen. These activities include:

- major renovations/additions
- turnarounds
- routine maintenance/repair work involving equipment entry, line-breaking, and hotwork
- pipeline pigging/scrapper work
- downhole wireline work such as removing and testing storm chokes
- workover operations
- specialty work, such as pipeline riser retrofits/additions, control system modifications necessitating temporary bypass of safety shut-down functions, fire protection system work causing temporary impairment of the protection systems

Often times MARW activities involve "line-entry" or "vessel-entry" procedures whereby the risk of an LOC event is increased. Normal process control elements, pressure relief valves, emergency shut down valves, and other control and safety provisions may be placed in a bypass mode or be removed from the system, thereby increasing the potential vulnerability to an initiating event. Hot work involving welding, cutting, grinding, etc. is also commonly included, resulting in increased ignition risk.

During MARW, reliance on human intervention and judgment is greatly increased over that required for normal operations – both from a preventative and a response standpoint. Simply put, more things can go wrong, and there is a greater dependency on worker judgment to make the correct decisions. However, there is also a greater risk of error during such activities, especially so when non-routine operations are involved, job complexities are increased, and work crews may be diverse and unfamiliar with the facilities or inadequately trained in the particular operations taking place. The criticality of any particular MARW activity has been distinguished by Moore and Bea¹⁴ into two major categories: process critical and non-

process critical.

Process critical operations are considered to be those activities that involve vessel and/or line entry into hydrocarbon handling systems and equipment, e.g., operations posing an immediate risk of loss of containment. This includes all topsides process systems in which crude oil, natural gas, natural gas liquids (condensate) liquefied petroleum gases, and imported flammable liquids (methanol, glycol, aviation gasoline, etc.) are either processed, treated, handled, or stored.

In FLAIM, process critical operations as a group is further subdivided into three subgroups:

- process critical - HIGH (pressure exceeds 500 psig)
- process critical - MODERATE (pressure above 100 but less than 500 psig)
- process critical - LOW (pressure 100 psig or less)

Non-process critical operations are those activities that impact a platform's ability to respond to an LOC event, including fire and explosion, or that increases the risk of ignition should an LOC event occur. Any hot work activity not involving process critical activities would fall into this category. In addition, work that would require deactivation of any safety system, such as a fire or gas detection (as may be necessary during hot work), a fire pump, or a deluge system, is included herein.

In OFHA, FLAIM recognizes that platform operational risk levels are time dependent, varying in both the long term, e.g., emerging safety deterioration trends, and in accordance with the nature of daily operations. MULOPS assesses the frequency and nature of those simultaneous activities that produce short periods of high operational risk.

Simultaneous operations are, in general, significant risk contributors depending on the nature and number of simultaneous operations occurring; this is especially true whenever downhole work is in progress on live (capable of flowing) wells. Large platforms may have several contractor crews engaged in different construction/maintenance activities simultaneously, and while normal production and drilling activities are also taking place. This proved to be a significant factor leading to the *Piper Alpha* incident.^{1,14}

MULOPS seeks to evaluate the relative risk of simultaneous multiple operations by establishing their nature, relative proximity to each other, and the frequency of their occurrence. Simultaneous operations during production may include drilling, workovers, wireline operations, refueling of onboard fuel supplies, off/onloading bulk supplies, pig launching and receiving, and various construction and maintenance activities, such as installation of riser safety valves.

The extent to which operational safety and the control of emergency situations depends upon operator response is an important risk consideration. Platform process systems designed with protective systems that automatically sense and initiate corrective actions to developing emergency situations are apt to be less vulnerable to errors in human judgment or lack of prompt operator response. OPSDAR seeks to evaluate the extent to which the platform design and operational scheme places reliance on operator response and

judgment in order to safely shutdown topside systems and respond to LOC events.

Cognitive and sensory limits of operator response becomes increasing important in accident causation as the demands placed on operators increase. This problem is much the same faced by military fighter pilots who, compared with their immediate predecessors, have both a much greater array of sensory information to deal with as well as a much short time in which to arrive at correct decisions (due to higher flying velocities). The 1979 Three Mile Island nuclear plant accident was largely a result of a failure to properly sort out and recognize critically important information during the developing crisis scenario.¹⁵

OPSDAR uses a "what-if" scenario based approach to determine if emergency response plans are inadvertently placing too much reliance on operators performing critically important tasks or otherwise (overburdening) platform personnel to ensure safety. For example, OPSDAR asks if platform blowdown system valves are automated or if operators must manually open them to depressure system piping; are platform deluge systems automatically actuated or must operators manually open local control valves; are deluge systems provided or are operators expected to fight fires manually with hand-hose lines, etc.

FLAIM includes a component intended to identify endemic operational problems as may be evidenced by reoccurring accident events. OPHIST addresses the operational history of the platform and seeks to determine if certain types of operational related events are more prone to occur. This information is intended to distinguish between appropriate changes that may need to occur and those that may have already been implemented to rectify the root cause of such events.

Aiding in the assessment and management of the risk of personnel injury and death is a primary focus of FLAIM. The *Life Safety Assessment* (LISA) module identifies and assesses those risk factors directly impacting personnel safety and welfare. LISA is further broken down into two sub modules: LISAP, Life Safety Assessment - Platform, and LISAA, Life Safety Assessment - Accommodations. If a platform is not provided with living quarters (LQ), such as platform on which the crew is rotated out each day or work-shift via helicopter or service vessel, FLAIM forgoes the LISAA component addressing accommodation facilities life safety and only evaluates the overall life safety features of the platform (LISAP).

Production platforms in the Gulf of Mexico (GOM) have various size crews depending on the size and complexity of the platform. Many smaller platforms are normally unattended, whereas some platforms are normally occupied and may serve as central service facilities for other smaller nearby platforms. Unlike platforms in the North Sea, however, the crew size on platforms in U.S. waters is considerably smaller. The overall average number of personnel in attendance on GOM and Pacific production platforms is estimated to be 12 persons.⁸

LISAP is executed only if a platform is deemed to be "manned," e.g., a platform on which people are routinely onboard for more than

twelve hours per day.¹⁶ FLAIM incorporates occupancy criteria to trigger LISSA based on whether the platform has a LQ is actually and continuously occupied by at least five persons. This criteria is consistent with that adopted by the Panel on Seismic Safety Requalification of Offshore Platforms.¹⁷ However, FLAIM recognizes that some operators may want to adjust this discriminator according to their own risk management policies. LISA contains approximately risk assessment questions.

It is difficult to isolate all factors affecting life safety into a single risk module. Users of FLAIM will recognize the interdependence of the life safety assessment risk index on each of the other FLAIM assessment modules, and especially with regards to Layout and Configuration Assessment (LACA).

As already discussed, the Safety Management System (SMS) provides the means to integrate and execute those aspects of platform design and operations that directly and indirectly influence meeting safe operating goals. The *Safety Management System Assessment (SAMSA)* module contains those factors identified as being most prevalent in failures of the SMS. SAMSA seeks to assess the adequacy of management's ability to identify and respond to root-cause errors stemming from human and organizational factors, such

as those leading to the *Piper Alpha* loss. Bea and Moore¹⁸ have developed a taxonomy of human and organizational errors for marine related accidents. Preceded by early research by Paté-Cornell and Bea¹⁹ and Reason²⁰ the HOE taxonomy addresses both error types and underlying/compounding causes. An error classification has been identified by Bea and Moore and are subdivided into four general categories, all of which are subject to external environmental influences.

In FLAIM's SAMSA risk module, factors identified in the HOE taxonomy (and not previously addressed in OHFA) are accounted in the subcategories: *Management Systems (MASA)*, *Fire (Emergency) Preparedness (FIPA)*, *Safety Training (SATA)*, and *Management of Change Management Program (MOCMAP)*, as illustrated in Figure 5.

Note that MASA is further subdivided into four separate risk assessment sections: *Management Systems Safety Culture Assessment (SCULA)*, *Organizational Responsibility & Resources (OR&R)*, *Company Policies and Procedures (POLPRO)*, and *Accountability & Auditing (ACAU)*. Each of these components of SAMSA are considered to be interdependent and essential to achieving fire and life safety operating goals.

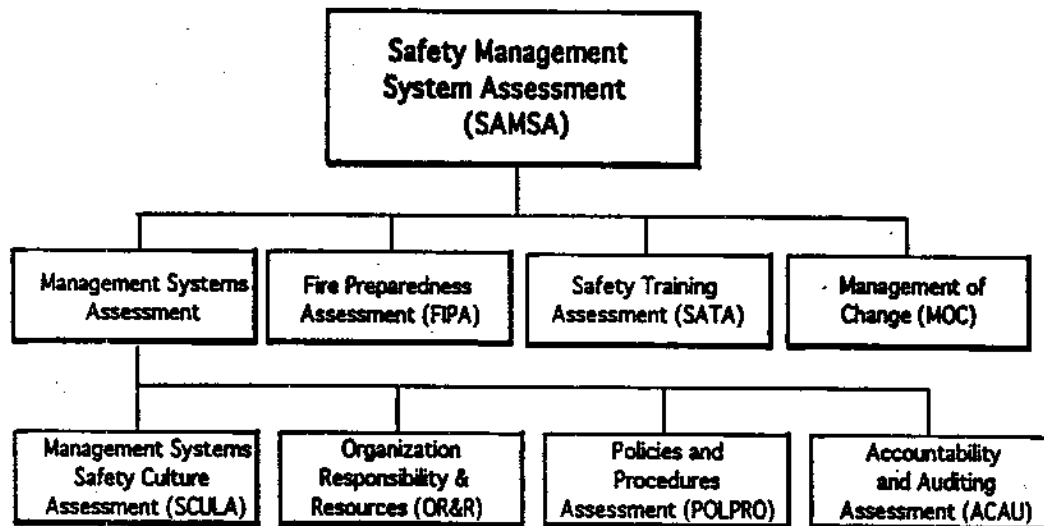


Figure 5 - Safety Management System Assessment Module

The four MASA components component of SAMSA form a synergism that are a compilation of the (fourteen) essential elements of *Total Quality Management (TQM)* as expounded by Deming.²¹ These elements are the sole responsibility of top management and can only be carried out by top management, they serve as direct indicators of management's awareness of and commitment to continued safe operations.⁸

The most essential element stressed by Deming²³ in his fourteen point approach to TQM is his last program element— creating a structure and environment in top management that is conducive to

continually cultivating and building upon on the other thirteen points, e.g., develop a "corporate culture" of quality that permeates down and throughout the entire organization.

Deming believed in the need to develop a "constancy of purpose towards improvement" in which management's philosophy embraces bold (new) concepts aimed at empowering the worker, creating organizational incentives encouraging and rewarding self-improvement, eliminating worker fear (to do the right thing) and removing barriers to improving quality and safety, e.g., imposed production quotas. The SCULA section of MASA, together with

OR&R (see below) and the other Management System components, identify and assess key indicators of management's awareness and commitment to these ideals.

As demonstrated by the current trend in the GOM, large offshore leaseholders (i.e., major oil companies) tend to sublet (farm out) older fields with declining production rates and rising maintenance costs to smaller operators who can continue to realize profitable operations due to lower overhead costs. The CAI Operations reported that in a five year period in the mid-1980's, the number of operating companies with less than six leases in the GOM increased more than 325%.⁷ This trend is continuing today as many large companies are abandoning their operations in the GOM in favor of overseas opportunities.

The CAI found that the safety implications of this trend is undocumented, but there are certain characteristics of small companies that may affect safety risks:

- small operators typically have no in-house safety staff and minimal technical engineering personnel to support field work or train field personnel in safe operations,
- small operators are heavily dependent on contract labor and expertise, and normally provide little or no onsite operator supervision,
- many small companies have limited "worry-budgets" (a term coined by R.G. Bea to denote resources for safety expenditures), and may tend to defer costly safety measures.

These considerations tend to make smaller operators more apt to adopt a "compliance culture" towards safety rather than moving forward with an aggressive, proactive SMS approach. *Organization Responsibility and Resources (OR&R)* seeks to identify weak safety culture environments by asking questions about: the company's safety and loss prevention staff relevant to the number of platforms being operated; its position in the organization and reporting authority; the percent of operating budget allocated to safety related activities, including training, maintenance, and testing of safety equipment; and the extent to which contract labor is employed to operate and maintain platforms, as well as the degree of supervision and training provided by the operator.

Another important component of an SMS is to which extent the operating company has committed its safety policies and practices to written instruction. Written instructions are the instrument by which safety policies, goals, and management's commitment are communicated throughout and beyond the organization, e.g., the means for articulation of the safety culture. FLAIM was developed with the recognition that attitude alone is not enough to elicit safe behavior.²² Without written policy goals and explicit instructions on how to achieve those goals, the course of platform safety goes uncharted. *Company Policies and Procedures (POLPRO)* asks if the platform operator has a written policy establishing definitive safety objectives, goals, practices and the means to monitor, measure, and improve meeting safety targets.

The POLPRO element of MASA accounts for the status of written,

up-to-date operating instructions for all topside systems and process components, including startup procedures, normal and temporary operations, emergency operations including emergency shutdowns (for each level of shutdown), and black-start restarts from complete shutdowns of all platform operations and power sources. Individual startup/shutdown and operating instructions for pumps, compressors, fired heaters, should be explicit to the machine in its "as-built" (as-installed) condition. As required by OSHA for onshore facilities, these procedures should contain information on occupational safety and health considerations.^{23,24}

A written Safe Work Practices (SWP) Manual should cover many routine tasks including: line and vessel opening/entry operations, lockout and tagout procedures, confined space entry, hot work and cutting operations, inerting and purging practices, heavy lifts and crane operations, sampling and sample connections, opening of drains and vents, use of personal protective clothing and gear, etc. The Permit to Work procedure should be clearly explained both in concept and in explicit requirements. In addition, accident investigation instructions and forms may be included in the SWP manual or provided as a separate document in the emergency response plan. These issues are addressed by the POLPRO component of MASA.

Emergency response plans are another important element included in POLPRO. Most platforms will already have written plans for oil spills and for emergency evacuation as required by MMS and the USCG. POLPRO seeks to assess the adequacy of these procedures and asks about the frequency of emergency response drills and the provision of improving written plans based on feedback from lessons learned in rehearsals.

Successful implementation of the platform's SMS depends to a large extent on the means used to measure progress in meeting safety goals and to effect improvements in program execution. Accountability is required to effect change and realize improvements. The ACAU element of MASA seeks to determine if the safety program is being effectively carried forward with the requisite level of management support and accountability necessary for meaningful implementation. This includes auditing of the safety assurance and written reports to management.

An important risk indicator in MASA is an operating company's "lessons-learned" program. ACAU asks the operator about the disposition of information collected in near-miss and accident reports. A pro-active approach taken in analyzing and learning from operational experiences, and then following through by communicating this information and revising company practices accordingly, is one indicator of a strong safety culture. Conversely, compliance with accidents report requirements as mandated by MMS OCS Orders and committing the information to a file cabinet without further thought is clear evidence of a "compliance mentality" as described by the CAI.⁸

The FIPA component of the SAMSA risk assessment module seeks to measure a operating crew's preparedness and ability to effectively deal with developing emergency situations. FIPA does not address hardware aspects of preparedness; these are accounted

for in RIRA. FIPA is the complementary component to RIRA and evaluates the human and organizational factors deemed critical to controlling a developing fire scenario.

The extent of human intervention necessary to successfully control a developing situation depends largely upon the platform design, its susceptibility to loss of containment events, provisions for automatic detection, control, and shutdown, and the platform's inherent vulnerability, or conversely, its robustness to resist thermal impact. There are two terms in "the equation" for assessing fire preparedness, each containing several variables.

The first term evaluates management's understanding of exactly what role the crew is expected to play in any given emergency situation. The assessment seeks to address issues of response expectancy with a view to determining whether or not an unrealistic reliance and dependency has developed on a crew's ability to respond.

For example, identification of critical manual tasks necessary for successful fuel-source isolation in a LOC event, when compared to concurrent demands for fire-fighting, communications, and general platform shut-down, may show an inordinate dependence on human response in some scenarios. Quite often, emergency demands placed on crew members tend to evolve and change in response to platform modifications and expansions. The cumulative effect may exceed reasonable response expectancies, but go unrecognized for lack of an emergency operability study.

The second term in the fire preparedness equation addresses the crew's preparedness and capability to carry out those essential demands placed on it under various emergency scenarios, assuming the demands are reasonable as evaluated above. This requires and assessment of the crew's knowledge and understanding of what is expected for a given situation, their ability and willingness to effect their duties, and the capability to demonstrate this through hands-on hypothetical training exercises for emergency situations.

For example, the operators at the Three Mile Island Nuclear Plant had been trained that the pressurizer on the pressurized water reactor was a valid representation of coolant inventory. Their training had not considered the possibility for a leak on top of the pressurizer, e.g., *their training model for emergency events failed to consider all possible event causes and consequences*. When the pressurizer leak occurred, the operator's diagnosis of the problem was based on an inaccurate model of what was actually happening - they interpreted a rise in pressurizer level as an indication of excessive coolant in the system, which caused them to dump coolant, eventually leading to a meltdown.²³

The *Safety Training Assessment (SATA)* component of the SAMSA risk module is intended to evaluate the overall level of formal personnel training and operator qualifications. Recognizing that HOE is the primary cause of offshore accidents, the adequacy of training at all levels throughout the organization is assessed - from an operational standpoint and risk aversion in the company's management culture.

Well trained operators, inspectors, maintenance personnel, and

supervisors are essential to workplace safety. Further, it is recognized that training must necessarily be viewed as a dynamic process, accounting for an ongoing effort to maintain personnel awareness and cognizance of a safety culture. Beyond this however, the overall attitude and culture of management must necessarily be assessed with regard to the inherent reward system of the organizational structure.

Training sessions must not only cover normal operating procedures and emergency response planning, but should also include safe work practices. This should include routine review of the work permit system requirements as well as specific training in each work practice, e.g., hot tapping, hot work, lockout/tagout, etc. If contract personnel are used to perform MARW activities, SATA seeks to determine if the contractor's personnel are adequately trained and qualified to perform their assigned duties, as well as being trained for emergency response.

The goal of risk management programs is to manage how risk may change over the operational lifetime of a platform, e.g., *the key to successful risk management is successfully managing change*. Both physical changes and personnel changes, and operational changes can greatly impact fire and life safety risks. In the recent past, however, the management of change has not been generally recognized as a factor that must be continually and systematically managed.

In the *Management of Change Management Program (MOCMAP)* section of the SAMSA risk module, FLAIM asks if the prerequisite elements of a MOC management program, as identified by API RP 75,²⁶ are established and implemented in written procedures. This should include the requirement for a hazards analysis of the safety, health and environmental implications of the proposed change, including its direct local impact and global ramifications to the overall risk level of the platform. Such an evaluation may be performed by using FLAIM's methodology to assess these impacts.

Screening Platform Risk Factors

FLAIM has been designed to accommodate the user in several ways. First, it allows the user to examine platform fire and life safety issues in increasingly higher degrees of analysis. The screening procedure follows the same general procedure established for structural requalification of offshore platforms proposed by Williamson and Bea.²⁷ Tier 1 is the initial screening procedure designed to assess the general state of platform risk with regard to both level of consequence and the likelihood of incident occurrence. Tier 1 consists of sets of questions that are considered to be basic but, at the same time, the most important questions relevant to overall platform operations and potential for loss. Depending of the results of initial screening, a Tier 2 or Tier 3 screening may be warranted for any given assessment under consideration.

Tiers 2 and 3 consists of supplemental questions intended to further delineate the state of operations and the relative risk-state of the platform. Tier 2 and 3 questions have been weighted at correspondingly lower values than those of Tier 1, and are increasingly more comprehensive and detailed. Consequently, as FLAIM is applied in higher screening levels, a more detailed level

of understanding and assessment of platform risk is derived.

Throughout the process, the user(s) performs two vital roles. First, the user checks and verifies the applicability of questions identified for each screening level in accordance with user preferences and experiences, e.g., FLAIM is interactive in both its content and in its application. Second, input to FLAIM is intended to represent a consensus of opinion, derived from a collective response from those individuals most familiar with the design and operation of the platform and its present exposure to loss. In this sense, FLAIM draws on industry's present familiarity with the HazOp procedure, e.g., Hazard and Operability Study, to ensure validity of response input, but without the cumbersome technical analysis procedures demanded by HazOp.

Questions have been developed reflecting offshore fire and life safety experiences, and professional expertise, case histories, industry recommended practices, regulatory requirements, and other relevant sources. All together, FLAIM contains over thirteen hundred questions which users can choose from and add to during the calibration procedure. Some questions have been identified as "red-level" questions, e.g., considered appropriate for inclusions regardless of platform specifics. These questions are automatically incorporated on the assessment worksheets unless the users intentionally delete their entry.

Default weightings for the questions have been assigned without regard to regional factors or unique considerations that may significantly influence the evaluation. In recognition of this, FLAIM has been specifically developed for the users to modify the weighting values and suggested tier level in order to account for unique design operating conditions. This is done during the initial calibration procedure by the user group.

Calibrating the Worksheets

Much like a hazard and operability study, FLAIM draws on the experience and knowledge of the users to calibrate the worksheets at the beginning of an assessment. Once the worksheets have been calibrated however, data input can be assigned to one or more persons e.g., the similarity to a HazOp session ends—the are not laborious group meetings needed to evaluate platform conditions.

The user group's tasks are 1) to reach a consensus on the level of detail warranted in the screening process (e.g., select an appropriate Tier level for the review), 2) select the appropriate questions relevant to the platform under consideration, 3) determine if any questions have a higher or lower relative importance (weighting value), and 4) for those questions in which a numerical range is involved, assign a value range to each answer selection provided in the question. The user(s) may also decide to modify existing questions or add new questions in order to customize the assessment process to conform with platform conditions and needs.

Upon completion of the calibration process, the risk assessments may be completed either onboard the platform or in the field office by one or more persons knowledgeable about platform design and operations.

Performing the Assessment

The session begins with the meeting facilitator loading and opening the FLAIM software package. The first window that appears after FLAIM is started is "Platform Identification Information." The user enters the platform's name, its location, block, lease numbers, etc. Next a window will appear asking whether a new platform assessment or modification of an existing platform assessment is to be performed. For example, for a first-time assessment the user clicks on "NEW;" FLAIM was designed to permit routine evaluations on a scheduled basis in order to detect symptomatic deteriorating trends as they may develop.

When the user reaches the "Fire and Life Safety Assessments Options" menu after inputting the preliminary information asked for, eight assessment choices are available corresponding to each assessment modules as described in FLAIM.

For a new assessment, the user begins with *General Factors Assessment* (GEFA), and then continues down the list until such time that all information has been inputted into each assessment module. FLAIM then calculates the overall fire and life safety index once all of the appropriate assessment modules have been completed, and also determines the difference any changes may make by calculating a differential risk index.

Summary and Conclusions

The cause and consequence of fires and explosions on offshore production platforms are extremely complex and highly dependent on events that may have only indirectly related precedents. Lack of comprehensive and meaningful statistical data and models on offshore system failures, human error, organizational factors, consequence analysis, etc. create a large uncertainty inherent in applying any predictive hazard analysis technique to a production platform.

FLAIM has drawn on many resources in an effort to combine deterministic and heuristic considerations into a unified approach for managing offshore fire and life safety risk. While FLAIM may be particularly helpful in identifying important considerations heretofore overlooked in the risk assessment process, it ultimately relies on the subjective probability and judgment of its users' input to assess relative states of risk.

It has been observed that objective probability, based on statistical data, is believed by everyone except by the statistician; whereas subjective probability, based on experience and judgment, is held in contempt by everyone except the evaluator performing the analysis.²⁸ The key to successful use of FLAIM lies in the selection and training of the assessors to ensure consistency and uniformity of evaluations. FLAIM was designed to permit quantification of a mixture of qualitative and quantitative responses to selected assessment questions. If there is not a clear understanding of what is meant by a particular qualitative descriptor, e.g., *high, frequently, low*, etc., then the validity of that input response is suspect.

FLAIM's design has sought to minimize this problem insofar as possible by frequent use of multiple choice questions that have

specified a value range selection. However, other questions necessarily ask for the users' general assessment using non-defined qualitative descriptors. To facilitate a general understanding of such terms and reduce possible errors due of a risk-communication nature, it is recommended that each user group define criteria for applications of these qualitative descriptors as part of the FLAIM worksheet setup process.

As part of FLAIM's implementation plan, it is recommended that all user group-leaders undergo a basic leadership orientation and training course (i.e., similar to a HazOp leader training course) that addresses issues of risk communication and the meanings of commonly used descriptors and criteria employed to characterize risk and the risk assessment process. User workshops designed to educate assessors and surveyors in application of the FLAIM software package is also suggested.

The quantification of HOE in the maritime industries has only recently begun to receive the serious attention of researchers. Ben and Moore²⁹ have made significant progress over the past five years in developing quantitative models and methodologies for examining HOE in the operation of marine systems. It is now generally recognized that only through improving the characterization and management of HOE risk factors can further strides be made to improve the offshore safety record. In this regard many opportunities exist for further research and development.

At present, there is insufficient data to develop meaningful objective probabilistic forecasts for offshore fires and explosions. It is believed that FLAIM can provide a basis for development of such data if used to assist accident and near-miss investigations. In this regard, it is recommended that further research be devoted towards developing a protocol and software interface with FLAIM to facilitate capturing vital information on platform accidents and near-misses. It is believed that such information could easily be incorporated into the existing structure of FLAIM's architecture in order to provide interactive access to new or existing proprietary databases.

Continued work is needed in refining and optimizing FLAIM; as mentioned in the introductory chapters, this will no doubt occur as part of its natural evolution through increased usage. However, it is also believed that a demonstration and validation study should be performed in the near future that involves several representative production platforms from different geographical locations, e.g., GOM, Pacific Region, GOA, etc. In this manner, FLAIM's utility and adaptability can be effectively tested and improved. In this regard, more attention is also warranted for developing a formal technique for updating FLAIM with a view towards continually improving reliability with each successive use.

The addition of an assessment module addressing life safety risk factors specific to those platforms handling hydrogen sulfide containing production fluids would be useful. In addition, further development of an economic analysis component of the software package would assist users in the decision making process.

Appendix 1: Risk Indexing Methodologies

FLAIM was developed with specific regard to the CAI's criterion for "valid precedents," and builds on concepts that have been successfully employed by major onshore petrochemical companies and fire safety authorities for over 25 years, using risk indices to measure and assess life safety and fire safety risks. The application of these techniques to offshore platforms was guided by principles established by the National Fire Protection Association for applying system safety techniques³⁰ as a means to reach safety goals.

Various indexing methodologies for safety assessment have been in use for many years, having their origin in the insurance underwriting industry where they are sometimes referred to as fire risk assessment schedules. Some of these approaches are well established and have been applied to the petroleum/petrochemical processing industries,³¹ such as the Dow Fire and Explosion Index³² as discussed below. Other indexing schemes, such as Muhlbauer's approach³³ for pipelines, are relatively new and remains to survive the test of historical validation. Several methodologies were reviewed in formulating FLAIM's model, including:

- The Dow Fire and Explosion Index³⁵
- The Mond Fire, Explosion, and Toxicity Index^{34,35,36}
- Pur's Method³⁷
- Gretener's Method³⁸
- Nelson's Fire Safety Evaluation System³⁹
- Muhlbauer's Risk Management Index for Pipelines³⁶
- DNV International Loss Control Institute's International Safety Rating System⁴⁰

Appendix 2: The FLAIM Algorithm

FLAIM's input data is requested in one of three primary forms: (1) binary, (2) qualitative "letter grades", and (3) numerical values. The following is an explanation of these input values.

Binary Input Data

The binary value system (β_{ij}) is presented by answering "Yes" or "No" (or "Good" or "Bad") to the presented questions. The input value returns a value of 0 or 1 dependent upon the assignment of the value to the answer (Equation 1). Any question that is to be answered "Yes" or "No" in the FLAIM spreadsheet program is followed by - "(Y/N)."

$$\beta_{ij} = \begin{cases} 0 & \text{if "Yes"} \\ 1 & \text{if "No"} \end{cases} \quad \text{or} \quad \beta_{ij} = \begin{cases} 0 & \text{if "No"} \\ 1 & \text{if "Yes"} \end{cases}$$

for question i, assessment j.

Letter Grades

The grade point structure follows along the line of the grade point structures used in academia. The grade points range from "A" to "F" and are assigned numbers based upon the same 4.0 point grading system used in many academic grading schemes. The algorithm automatically assigns a numeric value to the grade point input provided by the user in the spreadsheet (see Table

A2-1). Questions that directly use the grade point scheme in the spreadsheet are provided with a short description of what constitutes the selection of that grade. The grades are represented by $0 \leq \eta_{ij} \leq 4$ (risk assessment i , question j).

Numerical Values

Quantitative values (such as barrels of oil per day, millions of standard cubic feet of gas produced per day, size of operating crew, etc.) are numeric value inputs. The units prescribed for each input value is provided at the end of each question. This information is used in the assessment of the relative overall consequence level of the platform, as well as for evaluations of specific risk contributing factors.

Table A2-1- Grade point scheme for platform risk factors and corresponding numeric values

A - "Excellent" condition of the risk contributing factor upon the platform fire and/or life safety (4.0)
B - "Good" condition of the risk contributing factor upon platform fire and/or life safety (3.0)
C - "Fair" condition of the risk contributing factor upon platform fire and/or life safety (2.0)
D - "Poor" condition of the risk contributing factor upon platform fire and/or life safety (1.0)
F - "Bad" condition of the risk contributing factor upon platform fire and/or life safety (0.0)

FLAIM Weighting Structure

To maintain consistency with the grade point scheme, all default input values are considered to range between 5.0 and 1.0. This is equivalent to the concept of the number of "units" that an academic course is worth. The greater the unit value, the greater the relative importance of that factor to the grading scheme.

The weighting structure of FLAIM's algorithm has two types of value inputs (ω_{ij}) (risk assessment i , question j): (1) direct input value assessment of weighing values, and (2) indirect input value assessment, e.g., values generated as part of the algorithm. Direct inputs are provided by the user's assessment of the relative importance of that particular factor to fire and life safety on any given platform. For example, the relative importance of the ability of personnel to escape via the sea for a platform in the Gulf of Mexico (GOM) may be considered a more vital aspect of the overall risk management plan than that of a platform located in the Gulf of Alaska (GOA). Conversely, in areas where weather can be extreme, "safe havens" for personnel may create a greater need (and importance) for firewalls with high levels of fire endurance since escape by water may not be a viable option.

Indirect value assessments can be made through summing the binary input values (β_{ijk}) which are made up of sets of sub-questions. There can be between 2 and 23 sub-questions dependent upon the importance of the factor in question to fire and/or life safety.

Indirect value assessments are also functions of the numeric input values. These values are used to weigh the relative importance of fire and life safety risk. For example, if there is a small crew

contingent aboard the platform, there is a smaller overall risk of injury or loss of life to personnel than if there was a large operating crew. Or, for example, production rates (high or low) may have a great impact upon the loss of containment risk.

The FLAIM Algorithm Value Structure

The primary algorithm structure is in the form shown in Equation 2. This general algorithm structure is similar to that of the academic grading scheme shown in Equation 3. The *grade point average* (GPA) is determined by summing the product of the grades and credits for each course (total of p courses) and dividing by the total number of credits. This value is the GPA.

$$\eta_j = \frac{\sum_i \omega_{ij} \eta_{ij}}{\sum_i \omega_{ij}} \quad (2)$$

$$GPA = \frac{\sum_i Credit_i Grade_i}{Credit_i} \quad (3)$$

Table A2-2 summarizes the grading structure used for each value assignment type.

Numeric Value Range Assignments

The numeric value assignments have a pre-defined "value range" that determine the grading structure. Single-question numeric value assignments have direct value assignments. Multiple-question numeric value assignment questions use an averaging of values obtained from each sub-question. As already explained the user is asked to determine the range values that determine the grading structure based on the particular platform design and operation circumstances under scrutiny; FLAIM has been intentionally designed to allow either the user, or the consensus of a user's group,⁴¹ to "calibrate" the risk assessment process.

Binary Value Assignments

The binary input value assignments are given dependent upon whether the question has a positive or negative impact upon fire and life safety values. Multiple-binary value assignments are averaged over the sub-questions to provide an overall grade for that particular question.

Grade Value Assignments

Single grade value assignments are based directly upon the A-F structure described in Table 3. The multiple sub-question value assignments use the A-F grading scheme. Similar to the numerical and binary multiple sub-question value assignments a mean grade value is used by averaging the grade over the number of sub-questions.

Question Weighting Assignments

In accordance to Table A2-3, default values are assigned to the weight of each question dependent upon the level of the

Table A2-2 - FLAIM Algorithm Value Assignments

Numeric value assignments	Binary value assignments	Grade value assignments
<p>Single question value assignments</p> $\xi_{ij}(x) = \begin{cases} 4.0 & x < x_{ij}^1 \\ 3.0 & x_{ij}^1 \leq x < x_{ij}^2 \\ 2.0 & x_{ij}^2 \leq x < x_{ij}^3 \\ 1.0 & x_{ij}^3 \leq x < x_{ij}^4 \\ 0.0 & x > x_{ij}^4 \end{cases}$	<p>Single question value assignments</p> $\beta_{ij} = \begin{cases} 4.0 & \text{"positive impact" (Y / N)} \\ 0.0 & \text{"negative impact" (Y / N)} \end{cases}$	<p>Single question value assignments</p> $\epsilon_{ij} = \begin{cases} 4.0 & \text{if grade "A"} \\ 3.0 & \text{if grade "B"} \\ 2.0 & \text{if grade "C"} \\ 1.0 & \text{if grade "D"} \\ 0.0 & \text{if grade "F"} \end{cases}$
<p>Multiple sub-question value assignments</p> $\delta_{ijk}(y) = \begin{cases} 4.0 & y < y_{ijk}^1 \\ 3.0 & y_{ijk}^1 \leq y < y_{ijk}^2 \\ 2.0 & y_{ijk}^2 \leq y < y_{ijk}^3 \\ 1.0 & y_{ijk}^3 \leq y < y_{ijk}^4 \\ 0.0 & y > y_{ijk}^4 \end{cases}$	<p>Multiple sub-question value assignments</p> $p_{ijn} = \begin{cases} 4.0 & \text{"positive impact" (Y / N)} \\ 0.0 & \text{"negative impact" (Y / N)} \end{cases}$ $\rho_{ij} = \frac{1}{m} \sum_n p_{ijn}$	<p>Multiple sub-question value assignments</p> $\gamma_{ijn} = \begin{cases} 4.0 & \text{if grade "A"} \\ 3.0 & \text{if grade "B"} \\ 2.0 & \text{if grade "C"} \\ 1.0 & \text{if grade "D"} \\ 0.0 & \text{if grade "F"} \end{cases}$
$\delta_{ij} = \frac{1}{k} \sum_k \delta_{ijk}$		$\gamma_{ij} = \frac{1}{n} \sum_n \gamma_{ijn}$

assessment. Certain FLAIM questions have already been pre-determined as suggested red-flag or "red-level" questions. These questions have been deemed to be particularly important to the safe operations of any offshore platform. Weighted value assignments for these factors are assigned by the user, those questions identified of particular importance may be assigned weighting values greater than those assigned at the Tiers 1-3 levels. However, FLAIM also allows the user to reassign the suggested default value of any selected question. If the assigned value exceeds the Tier 1 level value of 5, FLAIM automatically designates the question to a "red-level" status.

Table A2-3 - Value Weighting Assignments According To Relative Importance

relative importance of Assessment to Fire or Life Safety	Assessment Level Assignment	Default [*] Assignment- ω_{ij}
Red-Level	Initial	User assigned
High	Tier 1	5 (5-4)
Moderate	Tier 2	3 (3-2)
Low	Tier 3	1 (2-1)

* Values in parentheses are value assignment ranges for each assessment level.

Factors from Tier 1 (initial screening) assessments are assigned the highest weighted values since they account for the most important

contributing fire and life safety factors specific to the platform being assessed.² More detailed Tier 2 and Tier 3 questions are weighted correspondingly lower to reflect their *relative importance to overall* fire and life safety. Though default values are assigned, FLAIM allows users to modify the value to reflect their preferences and experiences. Should a Tier 2 or Tier 3 factor be assigned a higher weight value comparable to that at a level higher than originally assigned, the user may reevaluate whether that contributing factor should be reassigned to a higher Tier level. At the user's discretion, these values may be changed to account for the relative importance of the question as determined by a consensus of the user group performing the analysis.

Individual FLAIM Assessment Grades

Equation 2 is used to determine the GPA for any assessment j (η_j). A grade value is assigned according to the question type. Each question is weighted according to its Tier level assignment except for the critical level where the weighted value is assigned by the users (τ_{ij}).

$$\eta_j = \frac{\sum_i^n \omega_{ij} \tau_{ij}}{\sum_i^n \omega_{ij}} \tag{2}$$

where

$$\eta_{ij} = \begin{cases} \xi_{ij} & \text{if question, i assessment j is single question num} \\ \delta_{ij} & \text{if question, i assessment j is question numeric} \\ \beta_{ij} & \text{if question, i assessment j is single question binar} \\ \rho_{ij} & \text{if question, i} \end{cases} \quad \omega_{ij} = \begin{cases} \tau_{ij} & \text{if "Red-Level"} \\ 5 & \text{if Tier1} \\ 3 & \text{if Tier2} \\ 1 & \text{if Tier3} \end{cases}$$

FLAIM's Overall Fire and Life Safety Index

To determine the platform's overall Fire and Life Safety Index a weighted sum of all risk assessment modules is made to determine the index value. Equation 4 is the weighted assessment used to calculate the overall Fire and Life Safety Index. The weighted

assessment procedures allows the user to take into account the overall relative importance on any single risk assessment module relative to each other, e.g., how GEFA, LOCA, VESA, LACA, OHFA, RIRA, LISA and SAMSA should be considered on a comparative basis.

$$GPA_{\text{overall}} = \text{Overall Fire and Safety Index} \sum_{j=1}^5 \sigma_j \eta_j \quad (4)$$

where $\sum_{j=1}^5 \sigma_j = 1$

FLAIM calculates the overall Fire and Life Safety Index using equal weighting among all risk assessment modules as a default condition. This is in recognition of the need to assess each module's relative weighting value based on the particular platform under consideration; not because of any implied level of equivalency. For example, on newer platforms the risk of LOC events due to mechanical failure may be judged to be relatively low, while the likelihood of a human error caused accident may be high due to simultaneous drilling, production, and construction activities. In this regard, it is important for the user to establish a uniform application of weighting values among groups of similar platforms in order to derive meaningful results from this procedure. It is suggested that operators can meet this objective by establishing their own application criteria that will ensure consistency and uniformity in the application of FLAIM.

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representing engineering, operations, maintenance and inspection, safety, etc. In this manner, both the range values and weights of critical questions may be determined as deemed appropriated for the specific region of operations and platform design factors.

⁴² The basic difference between red-level and Tier 1 questions is that the former are considered to be questions which are generally important to the operations of all offshore structures, whereas Tier 1 level questions may be specific to the platform being analyzed.

Appendix B Human and Organization Factors Definitions

<u>Human Factor</u>	<u>Definition</u>
Communication Ability	The ability to clearly transmit and receive information
Selection	How a person is chosen for a position.
Training Ability	The ability to learn a task
Educational Ability	The ability to assimilate and apply information from various sources
Limitations and Impairment	Physical and emotional hindrances
Organizational Ability	The ability to plan, prepare, organize, and adjust to changes
Experience	The amount of work in an industry and on a specific system, to avoid mistakes, slips, and violations
External Environment	The harshness of the work environment

(Source: Compiled from several sources and are listed at the end of Appendix B.)

Organization Factors and their Definitions

<u>Organization Factors</u>	<u>Definition</u>
Process Auditing	Monitoring, and when necessary, taking actions to correct deviations which lie outside of established norms
Culture	Cognitive framework consisting of attitudes, values, behavioral norms, and expectations shared by organization members
Appropriate Risk Perception	Acknowledging that known and unknown risks exists
Emergency Preparedness	Mitigating incidents through prior planning and exercises
Command and Control	The way decisions are made. Includes migrating decision making, redundancy, rules, seeing the "big picture," requisite variety, and alert systems
Training	Devotion to training through money, time, and trainee feedback about relevance
Communication	Ability to clearly and accurately transmit information throughout the organization
Resources	Availability and accessibility to resources

(Source: Compiled from several sources and are listed at the end of Appendix B.)

Operating Team Factors Comparison

Factor	SEMP	ISM	PFEER	Libuser/ Roberts	Bea & Moore	Boniface	NRC
1. Communications	O	P	X	P	X	X	X
2. Selection	P	X	X	X	X	X	X
3. Education	O	O	P	O	P	X	P
4. Limitations & Impairment	O	O	O	O	X	X	X
5. Organizational	X	X	X	X	X	X	X
6. Experience	P	O	O	X	X	X	X
7. Training	P	X	X	X	X	X	X
8. External Environment	O	O	X	O	O	X	X

X = Complete treatment

P = Partial treatment

O = No treatment

Organizational Factors Comparison

Topic\Program	SEMP	ISM	PFEER	Libuser & Roberts	Bea
1. Process Auditing	P	P	X	X	X
2. Culture	P	P	O	X	X
3. Risk Perception	P	P	X	X	X
4. Command & Control	P	P	X	X	X
5. Training	X	X	X	X	P
6. Communications	P	P	X	P	X
7. Emergency Prep.	X	X	X	O	O
8. Resources	P	P	O	P	O

Legend:

X = Complete treatment

P = Partial treatment

O = No treatment

References for Appendix B

1. American Petroleum Institute (API), "Recommended Practices for Development of a Safety and Environmental Management Program (SEMP) for Outer Continental Shelf(OCS) Operations and Facilities," May 15, 1993.
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4. C. B. Libuser and K. H. Roberts, "The Development of a Conceptual Model of Risk Mitigation," (submitted for publication), pp. 3-6.
5. W. H. Moore and R. G. Bea, "Management of Human Error in Operations of Marine Systems," Joint Industry Report, Final Report for the National Sea Grant College Program, National Oceanic and Atmospheric Administration, Department of Commerce, under grant number NA89AA-D-SG138, project number R/OE-17 through the California Sea Grant College, and in part by the California State Resources Agency, December 1993.
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7. National Research Council, Workload Transitions: Implications for Individual and Team Performance, 1st ed. National Academy Press, 1993.
8. R. G. Bea, Presentation on "Human and Organizational Factors in Marine Systems," given to oil industry representative as an update to research at University of California at Berkeley, Professor, U.C. Berkeley, Houston, July 11, 1995.

Appendix C - Basic Minimal Questions

Minimal BASIC MINIMAL QUESTIONS for FLAIM II (Includes FLAIM I questions, updated 28 May 1996)

Purpose: These statements are synthesized from different standards, company policy, and research. Assessors will assess platforms using these statements and a seven point answer scale, where 1 is not indicative of this company, to 7 is very indicative of this company.

Not Indicative of the Company				Very Indicative of the Company		
1	2	3	4	5	6	7

(Note: The term, Safety and Environmental Management Program (SEMP) will mean the same as the Safety Management System (SMS) and the Health, Safety and Environment (HSE) Program. The term, Company, will also mean organization and operator in these statement.)

(Note: The following is a key to the references: SEMP = API RP75, PFEER = HSE PFEER, HSEMS = ISO, ISM = ISM Code, Company "X" = a oil company, *Op Team* and *Organization* = Research, FLAIM = FLAIM I questions)

HAZARDS ANALYSIS

(def.: The company requires that a hazards analysis be performed, with the purpose of identifying, evaluating, and where unacceptable, reducing the likelihood and or minimizing the consequences of uncontrolled releases and other safety or environmental releases)

1. Hazard Analysis - The company's current "hazard analysis" is very thorough (Hazard Analysis API RP 14J/ RP 4C or similar) and includes:

- a. General Factors Assessment (FLAIM B1)
- b. Operational History (FLAIM B5.5)
- c. Fuel Factors (FLAIM B2.1)
- d. Well Bay Factors (FLAIM B2.2)
- e. Import/Export Risers (FLAIM B2.3)
- f. Platform Design Capacity and Operating Factors (FLAIM B2.4)
- g. Accommodations (FLAIM B6.1)
- h. Management Systems Safety Culture Assessment (FLAIM B8.1, B8.4)

(SEMP 3.3, 3.4, 3.5, 3.6; PFEER 5; HSEMS 3.4.4, 3.4.1; Company X #2; *Op Team* #7)

2. Hazard and Risk Reduction - The company has taken immediate steps to reduce hazards and risks.

(HSEMS 3.4.2, 3.4.3, 3.4.6; and Company X #2)

3. **Process Design Information** - The company has a simplified process flow diagram with acceptable upper and lower limits for temperature, pressure, flow, and composition. It is available and shows areas of high risks.

(SEMP 2.2, HSEMS 3.3.7.1.D2, PFEER 21, Company X #6)

4. **Mechanical and Facilities Design Information** - The company designs mechanical and facilities to meet applicable consensus codes and standards.

(SEMP 2.3, HSEMS 3.3.7.1.D3, PFEER 21)

5. *Hazard monitoring* - *The company monitors work processes and procedures related to hazards and corrects or improves them.*

(Organization #1)

6. *Risk* - *The company acknowledges known risks (by preparation and planning) and unknown risks (by training personnel to respond effectively to unknown risk and events - Crisis Management) risks. (Organization #3)*

MANAGEMENT OF CHANGE

(def.: The company has established procedures to identify and control hazards associated with change and maintain the accuracy of safety information.)

1. **Change in Facilities** - The company takes into account risks when changes in facilities are made.

(SEMP 4.2, HSEMS 3.5.4.I1, Company X #5, and FLAIM B5.3, B8.4)

2. **Change in People** - The company takes into account risks when changes in personnel and organizations are made (to include the use of contractors).

(SEMP 4.3, HSEMS 3.5.4.I2, ISM 6.3, Company X #5, and FLAIM B5.3, B8.4)

3. **Managing the Changes** - The company identifies and manages risks when there are changes in facilities, personnel, and legislation.

(SEMP 4.4, HSEMS 3.5.4.I3, Company X #5, and FLAIM B8.4)

4. **Pre-Start Up Review** - The company's management program requires that the commissioning process include a pre-start up review for new and modified facilities.

(SEMP 9)

MECHANICAL INTEGRITY

(def.: The company requires that 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' recommendations, or industry standards.)

1. **Quality Assurance Strategy** - The company considers risks when critical equipment are designed, procured, fabricated, installed, tested, inspected, monitored and maintained. (SEMP 8, ISM 10, PFEER 19, HSEMS 3.5.2, Company X #3)

2. **Mechanical Reliability** - The company regularly assesses, tests, and inspects critical equipment and technical systems which may contribute to high risk. This includes material compatibility for service conditions of erosion and corrosion. These critical equipment are examined for their general condition and historical reliability, and includes:

- a. Flammable Gas Compressors
- b. Reciprocating Compressors and Drivers
- c. Centrifugal Compressors and Drivers
- d. Pumps
- e. Electrical Equipment
- f. Fired Heaters
- g. Storage Tanks and Pressure Vessels
- h. Heat Exchangers
- i. Piping Systems and Components
- j. Wellheads and Risers
- k. Surface Safety Valves (SSVs)
- l. Subsurface Safety Valves (SSSVs)
- m. Instrument & Electrical Systems and Equipment
- n. Compressed Air Systems

(ISM 10.3, 10.4; PFEER 19.4, and FLAIM B2.5, B3)

3. *Repair parts are readily available.*
(Organization #8)

4. **Layout and Configuration** - The following items areas on a platform are laid out to reduce risk from fire and explosion:

- a. General Layout
- b. Fire compartmentation
- c. Locations of accommodation module
- d. Separation of Potential Fuel and Ignition sources
- e. Well Bay arrangements
- f. Arrangement of Process equipment
- g. Flares and Stacks
- h. Air intakes
- i. Emergency Shutdown stations and devices
- j. Emergency escape capsules/ Life-craft stations

(FLAIM B4)

OPERATING PROCEDURES

(def.: The company requires written operating procedures designed to enhance efficient, safe, and environmentally sound operations.)

1. **Content of Operating Procedures** - The company has procedures that address risks in the following operations: start-up, normal operations, temporary operations, simultaneous operations, emergency shutdown and isolation, and normal shutdown.
(SEMP 5 and FLAIM B8.1.2)

2. *The company's operating procedures are effective in minimizing risks and helpful in preventing loss of containment, fires, and explosions. Their procedures meet or exceed the requirements of industry regulations.*
(Organization #3)

3. **Periodic Review** - The company periodically reviews operating procedures for risks and to determine if procedures are simple, unambiguous and understandable (list of items which may need operating procedures included in references).
(SEMP 5.3 and HSEMS 3.5.3)

4. **Plan preparation** - The company has procedures for preparing plans and instructions for key marine system operations and assigns qualified personnel to this task.
(ISM 7)

5. **Operations and Maintenance** - During the operation of wells and facilities, the company ensures operations are conducted within established parameters (procedures, inspection and maintenance systems, reliable safety system and control devices, clean and tidy facilities, qualified personnel, and multiple operations).
(Company X #4 and FLAIM B5.2)

TRAINING

(def.: The company has established and implemented training programs so that all personnel are trained to work safely and are aware of environmental concerns offshore.)

1. *Resources* - *The company invests significant amounts of money and time to relevant and effective hazard prevention and response training.*
(Organization #6 and FLAIM B8.1.1)

2. **Personnel Selection and Training** - The company recruits, selects, places, assesses and trains personnel concerning hazards. Training is recorded.
(Company X #7, HSEMS 3.3.4, Op Team #2,3,4,5,6)

3. **Initial Training** - All personnel are given initial training as listed in the references. This training includes: Fire Fighting (API RP-14G)
(SEMP 7.2, HSEMS 3.3.4.2a,b,c)

4. **Safework Practices** - The company has the following safework qualification criteria for its personnel:
(SEMP 7.2.2, HSEMS 3.3.4.2e,f,g,h and FLAIM B8.3)

a. Safety and anti-pollution device training (API RP T-2 and 30 CFR 250 part O)

(HSEMS 3.3.4.2g and FLAIM B8.3)

- b. Crane operations and maintenance (APR RP 2D)(HSEMS 3.3.4.2I and FLAIM B8.3)
- c. Non-operating Emergencies (API RP T-4) (FLAIM B8.3)
- d. Well control training (API RP T-6, RP 59, if Hydrogen sulfide API RP 49 and 55) (HSEMS 3.3.4.2h and FLAIM B8.3)
- e. Operating and Maintenance training and on the job training.
- f. Hydrogen sulfide training if applicable (HSEMS 3.3.4.2e)
- g. Environmental protection and pollution control (guideline UKOOA "Environmental Training Position Paper") (HSEMS 3.3.4.2f,g,h)

5. Hazards communication training - The company ensures that hazards communication training for critical work instructions (e.g. hotwork, hot tapping, safe entry, lockout/tagout, and simultaneous operations), are provided to personnel who are regularly or occasionally assigned to SEMP tasks.

(HSEMS 3.3.4.2d)

6. Operations Training - The company trains operators to detect hazards (fire and accumulation of flammable gases), and to combat fire and explosion.

(PFEER 19, HSEMS 3.3.4, and FLAIM B5.4)

7. Competent examiners - The company assigns competent examiners, independent of the system, to conduct examinations related to hazards. The nature and frequency of examinations are specified in writing and are given before the start up of new or modified systems.

(PFEER 19, HSEMS 3.3.4)

8. Management Training - The company ensures that the senior person on the platform has been formally trained on hazard prevention and response.

(ISM 5, 6.1, 6.2, 6.4, 6.5, 6.6)

9. Periodic Training (SEMP 7.3) - The company ensures that refresher training on hazard prevention is conducted. It also ensures that periodic personal protective equipment usage is conducted.

(PFEER 18)

10. Communication Training - The company ensures that:

(SEMP 7.4, HSEMS 3.3.6, ISM 6.7)

- a. Changes in procedures are followed by training and communications before the facility is operated
- b. *Individuals are selected, trained, and exercised on clear communication skills (Op Team #1)*
- c. *Effective communication pervades the company (Organization #7).*

11. **Contractor Training** - The company ensures that the contractor's training is conducted at or above the company's training standards.
(SEMP 7.5)

12. **Designated Person(s)** - The company has designated a person(s) who has direct access to the highest level of management on hazard and risk
(ISM 4)

SAFE WORK PRACTICES

(def.: The company has established and implemented safe work practices that are designed to minimize the risk associated with operating, maintaining, modifying activities, and the handling of materials and substances that could affect safety or the environment.)

1. **Leadership** - The senior management of the company emphasizes the prevention of hazards and reduction of risks through its actions.
(HSEMS 3.1, Company #1, Organization #2, and FLAIM B8.1.2)

2. **Policy** - The company's hazard prevention objectives are effective.
(SEMP 6.1; ISM 1.2.2, 1.2.3, 1.4.1 and 2, ISM 2.1, 2.2; ISM 4; HSEMS 3.2, 3.3.1, 3.3.2, 3.3.3, 3.4.5, 3.5.1, 3.6.1; and FLAIM B8.1.2)

3. **Safe Conduct of Work Activities** - The company's safe work practices consider hazards and risks during the following (to include maintenance and repair work):
(SEMP 6.2 and FLAIM B5.1, B8.1.2)

- a. Opening of equipment or piping
- b. Lockout and Tagout of electrical and mechanical energy sources
- c. Hot work and other work involving ignition sources
- d. Confined space entry
- e. Crane operations

4. **Prevention** - The company has taken appropriate measures to prevent and reduce hazards, to include safe work practices, preventing uncontrollable release of flammable or explosive substances, prevention of ignition of such substances and atmospheres.
(PFEER 9)

5. **Control of Materials** - The company has procedures for handling toxic or hazardous materials in order to prevent hazards.
(SEMP 6.3)

6. **Contractor Selection** - The company obtains and evaluates information regarding a contractor's accident record.
(SEMP 6.4, HSEMS 3.3.5, Company X #8)

EMERGENCY RESPONSE

(def.: The company requires emergency response and control plans be in place, ready for immediate implementation, and validated by drills.)

1. Emergency Response Preparation - The company has emergency response and control plans in place for L.O.C., fires, and explosions; and are ready for implementation; and have been validated by drills.

(SEMP 10.1; ISM 1.4.5; PFEER 6,12; *Organization #4*, and FLAIM B8.2)

2. Hazards Review - The company has a systematic review and analysis procedure to identify foreseeable hazard.

(HSEMS 3.5.5 and FLAIM B8.1.2).

3. Emergency Action Plans (EAP) -

a. Loss of Containment, fires, and explosions are planned for in EAPs. The EAPs 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):

1. Emergency evacuation plan - USCG - 33 CFR 146.140

2. Oil, Gas and Sulfur Operations in the OCS - MMS - 30 CFR parts 250 and 256

3. Pipeline Emergency Plans - USDOT - 49 CFR 192 and 195

(SEMP 10.2, ISM 8, and FLAIM B6.2, B8.3)

b. EAPs include fire and explosions caused by Helicopter emergencies and identify associated emergency equipment (if applicable) (PFEER 7).

c. The actual persons responding to the fire and explosion have been consulted and have had the opportunity to revise the plan (PFEER 8).

d. Emergency planning and preparedness are conducted to ensure all necessary actions are taken for the protection of the public, environment, company personnel and assets from fire and explosions (Company X #10).

4. Command and Control Functions -

a. *The structure of the company's decision making process considers fires and explosion emergencies (Organization #5).*

b. An Emergency Control Center been established to deal with L.O.C., fires, and explosions (SEMP 10.3).

5. Training and Drills - The company has training and drills that are effective in testing plans and correcting weaknesses.

(SEMP 10.4, PFEER 8)

6. **Detection of Incidents** - Company measures are effective in detecting fires and other events which may require emergency responses.

(PFEER 10)

7. **Communications** - Emergency warnings for fires and explosions are (audible and where appropriate, visual) given to all persons in a system.

(PFEER 11) (PFEER 11.2 - types of visual and acoustic warning signals)

8. **Personnel** - The company has taken measures to protect persons from the effects of fire and explosion.

(PFEER 13, 14, 15, 16, 17, 18, 20 and FLAIM B8.2)

9. **Emergency Equipment and Systems** - The company has evaluated the following fire and life protection systems:

- a. Platform firewater systems
- b. Firewater distribution systems
- c. Firewater hose stations, hydrants, and monitors
- d. Fixed firewater spray/deluge systems & sprinkler systems
- e. Fire fighting foam systems
- f. Fixed and portable chemical fire suppression systems - gaseous agents
- g. Dry chemical agents
- h. Fire detection systems
- i. Combustible gas detection systems
- j. Alarm and communication systems
- k. Emergency power and lighting
- l. Emergency shutdown (ESD) systems
- m. Pressure relief and vapor depressing (blowdown) systems
- n. Liquid spill control provision
- o. Thermal robustness and passive fire protection systems
- p. Design for explosion protection

(FLAIM B7)

INVESTIGATION AND AUDIT

(def.: The company has established procedures for investigating all incidents with serious safety or environmental consequences and for auditing all of the above areas periodically.)

1. **Investigations Policy**- The company has procedures in place to promptly investigate and report all accidents to help prevent similar incidents.

(SEMP 11.1, ISM 1.4.4, ISM 9, HSEMS 3.6.5; Company X #9; HSEMS 3.6.4, ISM 1.4.3)

2. **Investigation** - Company investigations address the following:

(SEMP 11.2)

- a. The nature of the incident

- b. The factors that contributed to the incident and mitigation actions
- c. Recommended changes identified as a result of the investigation

3. Follow-up - The company distributes findings of an incident investigation to appropriate personnel and similar facilities. The company has procedures in place to ensure corrective actions are completed.
(SEMP 11.3, HSEMS 3.6.6)

4. Auditing system -

a. The company has an auditing system in place to ensure that audits for incidents are accomplished in intervals which do not exceed four years (SEMP 12.1, ISM 1.4.6, HSEMS 3.6.2, 3.7.1, and FLAIM B8.1.1, B8.1.3 [Safety Assurance Program]).

b. The company ensures that personnel carrying out these audits are independent of areas being audited. (ISM 12 and FLAIM B8.1.1)

5. Audit Reporting - The company has procedures in place to ensure that audit findings relating to incidents 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)

6. Documents - The company maintains document control.

a. Procedures are established to ensure the control of all documents and data relevant to incidents are:

- (1) available to all at relevant locations
- (2) changes to documents are reviewed and approved by authorized personnel,
- (3) obsolete documents are promptly removed,
- (4) documents are kept in an effective form and carried onboard systems
(ISM 11, HSEMS 3.3.7.2, and FLAIM B8.1.2)

b. A Safety Management Certificate, if applicable, has been issued for the system and is periodically verified (ISM 13)

c. Certificates of Exemption are not required for this system (PFEER 22).

d. The company maintains the following controlled documentation:

- (1) Environmental and location information,
- (2) Structural Information, and
- (3) Well design information (HSEMS 3.3.7.1D4, D5, D6)

7. Reviewing - The company's senior management, at appropriate intervals, review the hazard prevention and response measures.
(HSEMS 3.7.2)

Appendix D - Training Plan

Homework:

FLAIM II documentation sent to assessors before the 2 day training program to include:

1). Summary description of the project (goals, objectives, approach), 2). Summary description of the FLAIM II modules, 3) Background information on Human and Organizational Factors, 4). Flow diagram for the FLAIM II methodology, 5) Flow diagram for the relational data base system of FLAIM II, 6). List of the 'first level' questions in FLAIM II, 7) a summary of the assessment of likelihoods and consequences in terms of Risk, 8). a flow diagram of the phases of the assessment, and 9). an illustration of an application of FLAIM II assessment on a platform for loss of containment accident.

Training Day 1

0800 to 0815	Introductions (Paragon)
0815 to 0915	Video of Mobil - North Sea Piper Alpha (Paragon)
0915 to 1000	Discussion of the Video (Paragon, UCB)
1000 to 1015	Break
1015 to 1200	Human and Organizational Factors (Profs. Roberts and Bea)
1200 to 1300	Lunch
1300 to 1430	FLAIM II Project Goals and Objectives, Overview of FLAIM II Methodology, Assessment Phases, Scales, and Indexing (Hee)
1430 to 1445	Break
1445 to 1630	Walk through example application of assessment of platform A (Paragon)
1630 to 1700	Feedback on the day of training
1700	Adjourn

Training Day 2

0800 to 0830	Feedback on prior day's training
0830 to 1100	Walk through example application of assessment of platform B (Paragon)
1100 to 1215	Lunch
1215 to 1245	Brief for afternoon example, platform C, to be assessed by teams (Paragon)
1245 to 1545	Teams perform assessment of platform C using FLAIM II computer program (Paragon)
1545 to 1615	Review and discussion of assessment of platform C
1615 to 1700	Feedback on training and improvements to FLAIM II

Appendix E - Marine System Candidates

Test Platforms/Terminals (Example Candidates)

- P - 1) 4 Leg Gas/Oil 1980's Platform
- P - 2) 8 - 12 Leg Oil 1970's Platform, Shallow water
- P - 3) 8 Leg Gas Processing 1980's Platform
- P - 4) Deep water Oil and Gas 1990's Platform

- MT - 1) Richmond Marine Terminal

- MT - 2) El Segundo Marine Terminal