Marine Safety Council

PROCEEDINGS

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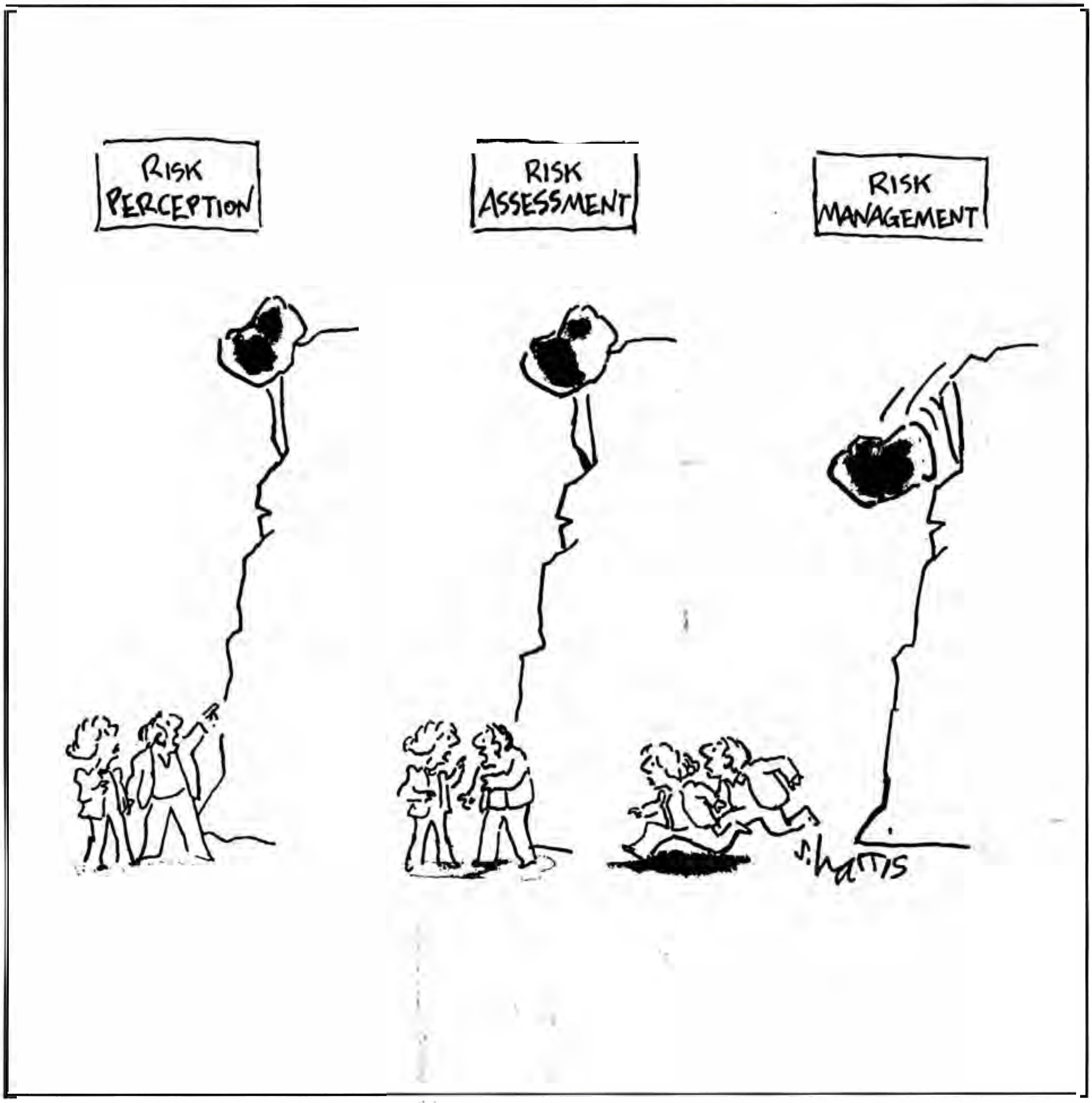
Risk Management in the Maritime Industry



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Front cover photo:
Matson Navigation Company's ship M/V R.J. PFEIFFER off Diamond Head, Hawaii

Back cover photo:
The RAVEN is the second double-hull VLCC owned by Mobil Shipping and Transportation Company.
The RAVEN entered service this summer.

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POINTS OF CONTACT
Cheryl Robinson, Editor
Voice: (703) 235-1604
Fax: (703) 235-1062
E-mail: Cheryl_Robinson/NMC@CGSMTP.USCG.MIL
World Wide Web:
http://www.dot.gov/dotinfo/uscg/hq/g-m/gmhome.htm

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Our 53rd Year

PROCEEDINGS

of the Marine Safety Council

April-June, 1996 Vol. 53, No. 2

RISK MANAGEMENT IN THE MARITIME INDUSTRY

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IN MEMORIAM

It is with deep regret that the Marine Safety Council notes the death of their former editor, **Ms. Betty Murphy** on June 25, 1996. Under her guidance, *Proceedings* grew from a 28-page black-and-white periodical to a 70+ page full-color magazine. Ms. Murphy, a lifelong resident of Bethesda, Maryland, served many years with the U.S. Navy. In 1990, she assumed the editorship of *Proceedings* and served through August 1995 when she retired.

MARINE SAFETY COUNCIL HAS NEW CHAIRMAN

Rear Admiral Paul Blayney serves as Chief Counsel of the U.S. Coast Guard and is also the new chairman for the Marine Safety Council. RADM Blayney's education at the Coast Guard Academy and Juris Doctorate degree from the Catholic University of America Law School prepared him well for a challenging and diverse career, emphasizing command and legal assignments. His operational experiences range from sea going tours including command of a Patrol Boat in Vietnam to Chief of Atlantic Area Operations, then based on Governor's Island in New York. He has served in many capacities in several Coast Guard commands, including (then) Group Muskegon on Lake Michigan, Section Command in Puerto Rico, Second District Commander covering the Western Rivers throughout 22 states in mid-America.

His legal assignments included tours at the base (Kodiak), district (Alaska) and regional (MLC-Atlantic) levels, as well as serving as special trial attorney with the Justice Department. As Chief Trial Judge for the Coast Guard, then Commander Blayney issues a ruling that was eventually tested in the Supreme Court (Solorio). His work resulted in simplifying issues of jurisdiction for all military Courts Martial.

RADM Blayney is a graduate of the Armed Forces Staff College and The Senior Seminar conducted by The Department of State. His awards include the Bronze Star with Combat "V" and the Legion of Merit.

RADM CARD SPEAKS . . .

By Rear Admiral James C. Card,
United States Coast Guard

RISK NOT, WANT NOT

The practice of risk assessment/management is not new. For example, whenever we drive our cars, we assess the risks of weather, traffic, and the car's mechanical condition, then "manage" the level of risk by slowing down, choosing a specific route, etc. We also recognize that errors (predominantly human error) may occur, and "buckle up for safety" to further reduce the risk should our "accident avoidance measures" fail.

In the maritime industry, we have long been assessing risk associated with safety. For the most part, though, our assessments have been implicit (hidden) within our decision-making processes. But as the complexity and rate of technological growth of our industry increases, we need to recognize, adopt and adapt many of the tools that have been developed to manage risk in a more formal and structured way.

The Coast Guard, within the context of our Business Plan for Marine Safety and Environmental Protection, requires Captains of the Port to assess the risks within their zones and assign resources accordingly To this end, we are currently testing various approaches to educate our personnel in risk application techniques, and will be providing field units with information and guidance on risk assessment tools. We're also crafting a strategic plan for implementing risk-based methods. Included in this strategic plan is the continued development and implementation of our Marine Safety Evaluation Program (MSTEP), addressed in detail in a separate article in this issue. This program is a key part of our regulatory reform efforts as it provides us with the ability to move toward risk-based regulations, all the while assisting in both technical decisions and program management determinations. MSTEP developments also directly support our position at the International Maritime Organization in the area of Formal Safety Assessments.

It's absolutely essential that we become more adept at systematically identifying and quantifying risk. A risk-based approach is critical to achieving a higher degree of marine safety and environmental protection within available resource constraints and without stifling competition or innovation.

Key to this approach is a recognition that people are vital to any process, and that steps to manage risk must include the human element. We cannot "engineer the human out of the system," nor can we account for all the potential modes of failure to make a system fail-safe. We must remember that people are not only part of the cause of most accidents, but are the best means of prevention as well. This approach requires inclusion of all the members of the port community (e.g., pilots, port authorities, vessel operators, state representatives, and environmentalists) in the risk process. In-turn, this should help us "to achieve the world's safest, most environmentally sound and cost-effective marine operations by emphasizing the role of people in preventing casualties and pollution," (or simply, Prevention Through People).

BY THE WAY...
EDITOR'S POINT OF VIEW

Proceedings magazine strives to keep you informed about all aspects of the maritime industry. Our theme for this issue is "Risk Management in the Maritime Industry." From articles on current developments to future trends, our goal is to put you in the best position to respond to the changing demands of the industry.

Risk management techniques and tools are shared worldwide in this issue. Sharing provides excellent examples of risk management in action—perhaps, even providing a few examples you can use in setting up your own risk management program. Sharing the benefits and techniques of risk management is another dividend of "Prevention Through People."

Our staff hopes you have received some new information and useful ideas. If you have any topics you would like to see in upcoming issues, send in your idea and we will do the rest. Suggested themes are only limited by your imagination.

A special thank you to all our readers!

Cheryl Robinson
Editor

Next Issue:
"How Technology is Affecting the Maritime World"
Upcoming Issues:
"Electronic Commerce in the Maritime Community"
"Safety Through Shared Lessons Learned"
"Partnerships/Alternate Compliance"

RISK MANAGEMENT IN THE U.S. COAST GUARD

Mr. Zbigniew Karaszewski, Program Manager at the National Maritime Center, is the Champion for this issue—"Risk Management in the Maritime Industry."

Zbigniew J. Karaszewski

The U.S. Coast Guard intends to capitalize on the advances made by the nuclear and chemical process industries over the past thirty years. In partnerships with the Gulf Coast Region Maritime Technology Center (GCRMTC) at the University of New Orleans, and the Center for Technology Risk Studies (CTRS) at the University of Maryland the U.S. Coast Guard (USCG) intends to meet its near and long term goals of establishing a risk-based approach to safety determination of all marine systems. This introduction outlines the intended objective and scope of the proposed effort championed by the USCG's Marine Safety and Environmental Protection Directorate, and its Risk-Based Technology Management Team.

Over the years the maritime industry is learning a harsh and discomforting lesson-that the benefits from technology must be paid for not only in money, but perhaps also in illness, injury, premature loss of life and environmental damage. Although the industry has some control over the level of risk to which it is exposed, reduction of risk often also entails a reduction of profits, thus posing a serious dilemma. The industry and regulators are required, with increasing frequency, to "weigh benefits against risks" when making decisions. Further, overpaying to reduce one set of risks may introduce offsetting or larger risks of another kind.

The urgent need to help society cope with problems of risk has led to the development of a new intellectual discipline, "Risk Analysis". The scope and pervasiveness of problems of risk analysis require a cooperative effort on the part of specialists from many fields. The Socio-Technical issues of risk assessment require the efforts of physicists, mathematicians, biologists, chemists, engineers, public policy experts, lawyers, political scientists, economists and psychologists. Specialists in decision-making attempt to coordinate this diverse expertise and organize it in a manner conducive to improved decisions and risk management. There is also a very strong need to utilize risk-based decisions in a clear and open way to communicate risk and encourage public support.

Risk is defined in most references as the possibility of suffering harm or injury. In the context of risk analysis, it is more appropriately defined as the potential for an adverse effect. Risk analysis is the process of evaluating a risk. There is consensus within the technical community that a comprehensive risk analysis consists of the following three major components: risk assessment, risk management, and risk communication.

Risk assessment is the use of information to define the potential safety threats resulting from exposure of individuals or populations to hazardous events, hazardous materials, physical agents, chemicals, and situations. While no risk assessment is devoid of value judgments, risk assessment should be an objective engineering/ scientific enterprise aimed at approximating the truth about a possible threat to humans or the environment.

Risk management is the process of weighing alternatives for controlling risks and selecting the most appropriate course of action. While risk managers may use information from risk assessments when making decisions, they may also consider information about engineering, economics, law, ethics, and politics.

Risk communication refers to exchange of information about risks. It includes the public perception of risk and conveying of risk messages in media ranging from radio and television to handouts at town meetings.

Ideally, risk assessment should provide systematic results to evaluate and manage technologies. It should answer whether evidence is sufficient to prove specific risks and benefits. Answers to questions about acceptability of risks, or when a risk situation merits regulation, clearly involve values. On the other hand, the information in the assessments of the risk level should be objective. Given answers to questions of acceptable risk, the question of acceptable evidence becomes scientific and not political.

Continued

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Within academic circles, a milestone in stimulating modern research on technological risk was the 1969 publication of Chauncey Starr's article in ***Science*** magazine, "Social Benefit and Technological Risk." This comparative analysis examined the voluntary nature of public exposure to risk and the willingness of society to trade-off risks for other societal benefits. It called for a rigorous approach to making these societal choices and an understanding of the true extent of technological risks. A landmark industrial risk assessment was the Reactor Safety Study of nuclear power plants. This effort, sponsored by the Nuclear Regulatory Commission, was headed by Dr. Norman Rasmussen of M.I.T. in the early 70s and greatly advanced a methodology for analysis of technology risk called Probabilistic Risk Assessment (PRA). While the use of PRA was initially resisted by many, it is now prevalent in many industries, especially the nuclear and chemical process industries.

The need for continued research on technological hazards was clear in the 1970s and Starr's publication led to a number of research efforts and a National Academy of Sciences workshop. Within the National Science Foundation, a program on Technological Assessment and Risk Analysis was established in 1977 and still exists in the Social Behavioral, and Economic Sciences directorate.

Conferences sponsored by the National Academy of Sciences, the National Science Foundation, and the National Academy of Engineering helped stimulate interaction among specialists in risk and hazard assessment in many disciplines. Professional societies (American Sociological Association, Association of American Geographers, American Nuclear Society, Society for Risk Analysis, International Committee for Research on Disasters, etc.) also regularly sponsored PRA sessions at their annual meetings. The American Society of Mechanical Engineers is now in the process of developing standards for the use of risk-based analysis and for regulatory decision making in such diverse areas as risk-based inspection, testing and risk-based maintenance. Increased public and regulatory concern with risks imposed by technological undertakings has focused attention on risk assessment as a tool for aiding in risk-based decisions. In some areas, risk analysis has been used quite effectively in both the assessment and management of safety.

The idea of science-based risk analysis is not new. The Environmental Protection Agency (EPA) has used techniques since the early 1970s to quantify the risk to human health or the environment from certain chemicals and substances, and has submitted many of its significant regulatory proposals to "peer review panels." Other Federal agencies apply similar procedures. The Nuclear Regulatory Commission (NRC) has also been a leader in the use of risk assessment in regulations since it issued the landmark Reactor Safety Study. Over the years PRA has played a major role in formulating and enforcing regulations at NRC. This has recently culminated in the issuance of quantitative and qualitative safety goals, and a Policy Statement (December 1994) to integrate PRA more formally into future NRC rules and regulations. The U.S. Coast Guard has its own share of contribution into the application of risk analysis, in marine industry. Dating back to 1978, CDR W. D. Snider of USCG made an attempt to apply risk considerations and systems approach in managing tank vessel safety. But it was not until 1994 that RADM Card endorsed the Marine Safety Evaluation Program (MSTEP) that the application of formal risk assessment finally began.

Objecting that the costs of many regulations outweighed their benefits to the public, criteria called for agencies to apply "sound science" (risk assessment and cost-benefit analyses) to their rule-making activities. Regardless of the success of the risk assessment bill awaiting Congressional approval, risk assessment will play a major role in the allocation of scarce public resources on issues related to health, safety, and environment.

If current Congressional trends persist, greater responsibilities for risk management will be passed down to the state and local jurisdictions. Consistent procedures will need to be developed for use at the federal, state and local levels, to assure fair, equal and consistent treatment and to see that unbalanced legislation does not create states with high risk tolerance and states with low risk tolerance.

It appears that our Coast Guard experience gained from developing MSTEP could allow for more aggressive risk-based approach to management of marine safety. To do this however, we must first determine what it makes will be consistent from one issue to another (with respect to risk) and from one Marine Safety Office to another.

The primary theme of the MSTEP's activities is that all engineering systems and technologies are similar in their basic structure. Whether mechanical, electronic, or chemical, systems can be defined in terms of their goals and functional requirements, and by the hardware, software and human interfaces required to implement the functions. Therefore, we believe that many of the risk assessment tools and techniques for the risk-based analysis of such complex systems, which have been developed by the researchers at the CTRS and GCRMTC centers or adopted from outside are relevant across the board. Such tools and techniques will be employed to assess technological systems, to explore the ways in which systems can fail, and to evaluate the risk implications of such failures. As such, since engineering systems can be systematically evaluated and their risk measured, regulations consistent with their risk can be devised. Risk management and other risk-based analyses can be performed by the USCG in cooperation with the centers and the industry. The centers will also serve as umbrella organizations to bring social, psychological, economic and public affair experts together to solve the multi-disciplinary issues that the US Coast Guard and marine industry would face. The centers can also act as independent mediators between regulators and the regulated industries. The independent and competent voice of the centers can help allay public concerns over risk issues over which regulators and the regulated industries may debate.

The Coast Guard will ensure that risk-based analysis has its place in regulatory reform and that the application of risk analysis tools does strengthens our long-standing commitment to safety and protection of the public and the environment.

" 'BE CAREFUL'! ALL YOU CAN TELL ME IS 'BE CAREFUL' ? "

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DOMINANCE OF REASON OVER INTUITION: EMERGENCE OF RISK-BASED REGULATION

Mohammad Modarres
Center forTechnology Risk Studies
University of Maryland
College Park, MD 20742-21225

Government regulations have become unreasonably complex. The complexity has been influenced by a combination of many factors, the most notable of which are vague laws, politics and the influence of interest groups. Despite their good intentions, some regulations control marginal risks at an exorbitant cost. Federal, state and local risk regulations are aimed primarily at reducing fatalities from cancers and accidents. While about 500,000 cancer deaths and 100,000 accidental deaths are observed each year in the United States, it turns out that only a small fraction of them are preventable by regulations. As high as 10% of cancer deaths could be averted by imposing regulations which completely eliminate the risk. While it is possible to avert some of these deaths, this may come at a prohibitively high cost. Regulations should be imposed when their societal cost is consistent with their risk reduction potential.

In the past, the public desire for extra protection against hazards (or more correctly perceived hazards) has influenced the U.S. Congress and in turn Congress has passed legislation that has created some very costly regulations (e.g., the Clean Air Act of 1990). It is clear that regulations don't come for free—the society ultimately pays for them in form of higher product prices, higher taxes, loss of global competitiveness, and lower income. The net effect of some costly regulations is a reduction in the gross national product. It has been estimated that regulations cost the American people about $500 billion per year, about $100 billion for the Environmental Protection Agency's regulations alone. Accordingly, control of regulations should be an important goal of a fiscally responsible society. In this article I will examine the role of using a formal risk-based approach for devising regulations.

Because of economic concerns, the U.S. Congress has been responding to pressure for greater use of risk assessment. This pressure has included ads and lobbying from major corporations, scientists, engineers and lawyers. Recently Supreme Court Justice Stephen Breyer in his book *Breaking the Vicious Circle* has advocated a greater use of risk assessment in our regulatory process. Major legislations under review by the House and the Senate would require significantly greater reliance on risk-based regulation by the Federal Government.

Quantitative Risk assessment, especially probabilistic risk assessment, can play a central role in the development of risk-based Federal regulations. Progress in the field of risk assessment, especially probabilistic risk assessment, has been enormous. The field hardly existed two decades ago, but now it is ready to make meaningful contributions to the analysis of risks and risk-control strategies (*e.g.*, risk management and regulations). A great advantage of risk assessment is that it brings calculations out into the open, encourages informed dialog, and can greatly improve public confidence in the process.

There are many types of governmental regulations. They cover a broad range of areas such as financial, environmental, health and safety. One underlying reason used in most legislation and regulations — "protect the consumer from unreasonable risk" — is derived from old English common law. This, in turn, has put the responsibility on each agency to decide what is reasonable and what is unreasonable. In this paper I only consider safety and health related risk assessment and regulations.

THE CONCEPT OF RISK AND RISK ASSESSMENT

Risk can be described as the potential for a loss. The loss may be in the form of tangible assets, morbidity or fatality. The risk (that is the potential of loss) is either considered qualitatively, or it is viewed quantitatively. Qualitatively, the risk is referred to situations or events associated with a potential loss, without any attempt to measure the degree or likelihood of the loss. Quantitatively, the potential for loss may be measured through the probability (or frequency) of an event leading to a loss, multiplied by the amount of loss (this essentially yields "expected loss".) *Risk assessment* is the process of calculating the probability or frequency of the loss, and *probabilistic risk assessment* is risk assessment done in conjunction with an assessment of the probability of events leadning to the risk. The risk can be assessed for losses incurred by an individual, a group of people, or by the society as a whole.

CURRENT METHODS OF DEVISING REGULATIONS: DOMINANCE OF INTUITION

Current legislative charters given by Congress to the regulatory agencies often state general and vague objectives. In the absence of clear objectives and tangible measures for testing regulatory objectives, the Federal Government has created regulations which are vastly inconsistent among agencies, and which are often inconsistent within an agency. Typically, regulators identify potential risks and alternative methods for controlling them. Information on these risks and possible regulatory management options is then gathered and decisions are made—often on a case-by case basis and qualitatively without much public participation and formal risk assessment. This resulted, especially during the 1980's, in a prevalence of regulations which impose larger costs for smaller benefits as compared with previous decades.

This large and inconsistent body of regulations can do much harm to society, too. Consider the growth of regulations in the past three decades in terms of the pages of federal regulations. Figure 1 describes this growth. The growth is much faster than the observed improvements in the health and safety of the public during the same period (for example as measured by rate of reduction in the number of accidental deaths) for the same period.

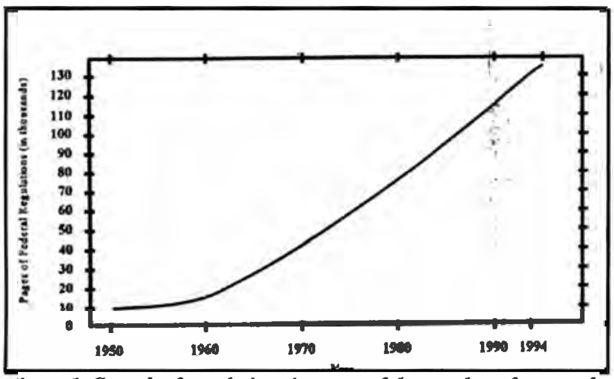

Figure 1. Growth of regulations in terms of the number of pages of the Code of Federal Regulations

According to Samuelson the cost of regulation is estimated at about $500 billion per year today ($100 billion for EPA regulations alone.) While the ultimate purpose of regulations is to improve health and safety of the people and thus improve the quality and quantity of people's lives, there is a legitimate question as to whether this money could be better spent to achieve the same result. For example, is it more effective to spend money on research to discover causes of cancer or to develop find better treatments for cancer? That is, to take a preventive-corrective role as opposed to a protective-reactive role. The rate of return on investment is much higher for health and safety research, education and training as compared with some marginal regulations.

Consider advances in electrical systems, computers and transportation systems. They have improved people's quality and quantity of life significantly. Conversely, costly marginal regulations have reduced the GNP because of higher product prices and lower wages, thus eroding the quality and of people's lives. The late Berkeley sociologist Aaron Wildavskey argues that when people get richer, they live healthier and safer livers because they can afford to buy healthier and safer products. As such, costly regulations that reduce the standard of living may be more harmful to society.

Some regulations are based on skimpy data and conservative assumptions. For example, in a rule under consideration by OSHA to ban smoking in most buildings, except in especially ventilated areas, OSHA assumes that a fifth of workers face uniform smoke exposure over a 45-year career. However, most people work less than 45 years and even fewer are exposed to uniform smoke. These conservative assumptions have often led to unreasonable risk estimates and the creation of marginal and costly regulation.

Consider the charter that Congress has given the Nuclear Regulatory Commission (NRC). This charter givers a vague and broad mission to the NRC of protecting the health and safety of the public from unreasonable exposure to radiation. In turn the regulatory philosophy employed by the NRC, is the so-called "defense in depth". This approach, while only indirectly related to nuclear plant risk, has been the basis for design and implementation of NRC rules and regulations. This concept, essentially provides a qualitative risk-reduction approach, without having any formal relation to the risk or risk acceptance criteria. This has resulted in regulations with widely different risk reduction capabilities.

Recent studies, including an example that I will discuss later, have shown that while some regulations based on the defense in depth approach appear to reduce plant risk and are risk-consistent with each other, others marginally impact the plant risk. Recognizing these problems, the NRC has been a

Continued

pioneer in using probabilistic risk-based techniques in devising regulations. For example, recent publication of the NRC Policy Statement on "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities," the so-Backfit Rule and "Safety Goals for Nuclear Power Plants" encourage a greater use of risk assessment in NRC regulations. Still, not all NRC rules are consistent with their risk prevention ability, and they are even less consistent with other regulatory agencies such as Environmental Protection Agency (EPA), Mine Safety and Health Administration (MSHA), National Highway Traffic Safety Administration (NHSTR), Federal Aviation administration (FAA), Food and Drug Administration (FDA), and Occupational Safety and Health Administration (OSHA). The consistency of some NRC and EPA rules will be compared later in this paper.

CURRENT TRENDS IN THE U.S. CONGRESS

A compromise regulatory reform bill as part of the Contract with American to limit new regulations for one year and a subsequent plan to reform regulations stresses the need for more rational ways of regulating risks. Another bill that requires use of risk assessment (as of April 7) still awaits Senate approval. While it is too early to measure the impact of these bills, Congress appears to favor the use of risk assessment and cost-benefit analysis for enacting and revising government regulations. Some recent, more specific legislation such as H.R. 4306 requires EPA to establish a risk assessment program within the administrator's office with clearly defined guidelines to coordinate related activities across federal agencies.

INCONSISTENCIES IN THE CURRENT BODY OF REGULATIONS

In order to better appreciate inconsistencies among regulations, it is important to first examine risk statistics and risk reduction strategies.

ACTUAL STATISTICS ON RISK AND THE ROLE OF REGULATIONS

Figure 2 ranks the top ten causes of death in the United States and compares 1985 and 1993 data. Regulations can reduce some cancers and accidents. We know that the only certainty in life is death; the uncertain part is when and how this eventuality happens. So, when we talk about risk of death, we are really talking about risk of early or premature death. There are three major

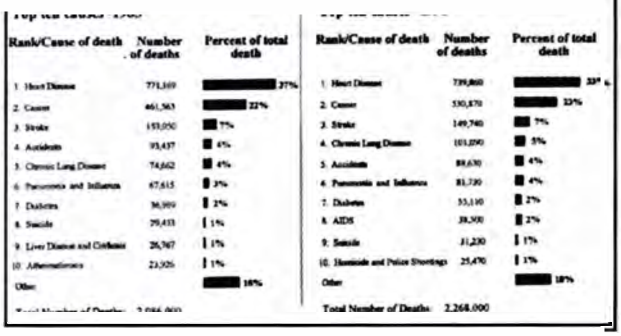

Figure 2. Top ten causes of death in the U.S. in 1985 and 1993 [7]

Cause	Annual Rate (deaths per million)
Asbestos exposure in schools	0.005 to 0.093
Whooping cough vaccination (1970 to 1980)	1 to 6
Aircraft accidents (1979)	6
High school football (1970 to 1980)	10
Drowning (ages 5 to 14)	27
Motor vehicle accident, pedestrian (ages 5 to 14)	32
Home accidents (ages 1 to 14)	60
Long-term smoking	1200

Table 1. Estimate of risk from verious causes (Source: Mossman, Bignon, Corn, Seeton and Gee, "Asbestos: Scientific Developments and Implications for Public Policy," 247 Science 294 (1990)]

Cause	Odds
Breast Cancer (at age 60)	1 in 500
Breast Cancer (at age 40)	1 in 1,000
Car crash	1 in 5,300
Drowning	1 in 20,000
Choking	1 in 68,000
Bicycle crash	1 in 75,000

Table 2. Risk of dying from selected causes

Nature of Risk Exposure	Cause of Death
Smoking 1.4 Cigarettes	Cancer, heart disease
Spending 1 hour in a coal mine	Black lung disease
Spending 3 hours in a coal mine	Accident
Living 2 days in New York or Boston	Air pollution
Traveling 10 miles by bicycle	Accident
Traveling 300 miles by car	Accident
Traveling 10000 miles by jet	Accident
Having chest a X-ray taken in a good hospital	Cancer caused by radiation
Living 50 years within 5 miles of a nuclear plant	Cancer caused by plant emissions

Table 3. Risk exposures that increase chance of death by 1 in 1,000,000 per year

ways by which risk statistics are compared and presented. They are: individual probability of an event leading to the risky outcome, that is, risks per-person per-year; societal frequency of occurrence of an event, that is, number of events per large population of people per year; and amount of hazard exposure that causes a given outcome at a given level of probability (or odds). The outcome may be fatality, morbidity, or economic consequence. Tables 1-3 show examples of these three of risk presentation.

Table 4 estimates the contribution of various

Factor or Class of Factors	Percent of all Cancer Deaths	
	Best Estimate	Range of Estimate
Tobacco	30	25 - 40
Alcohol	3	2 4
Diet	35	10 - 70
Food additives	< 1	?
Reproduction and Sexual behaviors	7	1 - 13
Occupation	4	2 - 8
Pollution	2	< 1 - 5
Industrial products	< 1	< 1 - 2
Medicines and medical procedures	1	0.5 - 3
Geophysical factors	3	2 - 4
Infection	10	1 - ?
Unknown	?	?

Table 4. Proportion of cancer deaths attributed to different factors [Source: r. Doll and R. Peto, "The Cause of Cancer," 1256 (1981)]

factors to cancer deaths. The data indicates that only a small portion of these factors can be influenced by imposing regulations. Cancers caused by food additives, occupation, pollution, and industrial products appear to be most amenable to regulations. They contribute less than

Age	Black Females	Black Males	White Females	White Males
15-24	1. Homicide 2. Accidents 3. Cancer	1. Homicide 2. Accidents 3. Suicide	1. Accidents 2. Cancer 3. Homicide	1. Accidents 2. Suicide 3. Homicide
25-44	1. Cancer 2. AIDS 3. Heart Disease	1. AIDS 2. Homicide 3. Accidents	1. Cancer 2. Accidents 3. Heart Disease	1. Accidents 2. AIDS 3. Heart Disease
45-64	1. Cancer 2. Heart Disease 3. Stroke	1. Heart Disease 2. Cancer 3. Stroke	1. Cancer 2. Heart Disease 3. Chronic Lung	1. Heart Disease 2. Cancer 3. Accidents
65 and older	1. Heart Disease 2. Cancer 3. Stroke	1. Heart Disease 2. Cancer 3. Stroke	1. Heart Disease 2. Cancer 3. Stroke	

Figure 3. Leading causes of death for different population groups in 1992 [7]

ten percent of cancers (or about 50,000 deaths per year).

Various risks may not uniformly expose members of society. For example, Figure 3 shows the risk of death based on gender, race and age. This figure compares the three top killers for specific groups of people. The regulations should, therefore, consider the heterogenous effect of risks.

Political, economic, and educational status of a society collectively influence life expectancy. For example, consider the life expectancy in the U.S. which has been rising steadily and now stands at about 75 years. This is comparable to other well-to-do, highly educated democratic countries such as Western European countries, Japan and Australia. However in Eastern European countries life expectancy stands at about 72 years. Life expectancy is 67 years in Central America; 64 years in Turkey, Brazil, and Thailand; 59 years in Iran, India and Egypt; about 45 years in most central African countries; and only 38 years in Afghanistan. The data underline the importance of education and economics on prolonging life. In fact according to Cohen the highest risk factor in a society is "Living in Poverty."

EFFECTS OF RISK

An event may directly affect a person, for example by causing a cancer or resulting in bodily injuries. The risk may indirectly affect a recipient, for example through loss of jobs, epidemics, or lack of resources. Similarly, regulations to prevent or minimize such risks may have direct or indirect influences. For example, as was noted earlier by Aaron Wildavsky, the money spent on reducing risk lowers people's buying power thereby diminishing their ability to buy healthier and safer products. In fact according to this theory, the growth of families below the poverty level in the U.S. should lead to higher mortality at earlier age.

Regulations should try to address both the direct and indirect effects of each risk as compared to other risks. For example, when Congress considers nuclear power related legislation, it appears prudent to not only consider direct risks of nuclear power as compared to other sources of energy such as oil, gas and solar, but also indirect effects such as costs (or risks) associated with securing a supply of fuel. While difficult to quantify, I expect that the expenses incurred by the American tax payers during the Gulf War of early 1991 whose primary objective was to maintain a credible supply of crude oil, should be considered as an indirect cost of relying on fossil fuels when considering energy alternatives.

Continued

COMPARING REGULATIONS

In order to demonstrate inconsistencies in regulations, lets compare some risks. Since there are formal methods for comparing risks, I will first start with some established methods for this purpose.

METHODS OF COMPARING RISKS

Cost-Benefit

Cost-benefit analysis is a methodology that evaluates a regulation in terms of its net costs (i.e., the cost of averting risk given that the regulation is adopted and the cost of implementing the regulation) as compared with the net gain which resulted from reducing or averting the risk. A drawback of this approach is the difficulty in placing a monetary value on risks (*e.g.*, fatalities) and indirect costs and benefits.

Life Expectancy

Life expectancy is another powerful measure for expressing and comparing risks or regulations. In this case the loss of life expectancy (LLE) due to a given risk can be used for comparison. The LLE shows the statistical mean (average) of one's lifetime shortened by the risk under consideration. Conversely, the effectiveness of a regulation can also be measured by the gain in life expectancy (GLE). Quantification of LLE and GLE are subjective, but this approach provides one of the most useful methods for communicating risk issues. For example, Table 5 shows the LLE values associated with various risks. As pointed out earlier, the highest LLE in the U.S. belongs to "Living in Poverty".

Activity or Risk	LLE (days)
Living in poverty	3500
Being male (vs. female)	2800
Cigarettes (male)	2300
Being unmarried	2000
Being black (vs. white)	2000
Working as a coal miner	1100
30-lb overweight	900
Grade school dropout	800
Suboptimal medical care	550
15-lb overweight	450
All accidents	400
Motor vehicle accidents	180
Occupational accidents	74
Married to smoker	50
Drowning	40
Speed limit: 65 vs. 55 mph	40
Falls	39
Radon in homes	35
Firearms	11
All electricity, nuclear (UCS)	1.5
Peanut butter (1 Tbsp./day)	1.1
Hurricanes, Tornadoes	1
Airline crashes	1
Dam failures	1
All electricity, nuclear (NRC)	0.04

Table 5. Loss of life expectancy (LLE) averaged over the exposed population due to various risks [Source: "Nuclear Energy Option," B. Cohn, Plenum 1990]

Willingness to Pay

Another method for comparing and analyzing risk is "willingness to pay" to reduce our risks. This method is sometimes used to arrive at a value of life. This value of life is especially important when performing cost-benefit analysis. It may be immoral and even inhumane to place a value on one life. However, we have to realize that while every life if precious, there are limited resources and knowledge available to prevent all premature deaths or to completely clean the environment. So, a premature loss of life is not preventable for everyone. One can only spend money where best effects can be expected. In order to calculate the willingness -to-pay (e.g., how much people would unconsciously pay to avert a premature death), one may examine the risk taking behavior of an average person in the society. For example, consider an example related to getting a Pap smear test for cervical cancer. A Pap smear costs about $30 and has a 1 in 3,000 chance of saving a woman's life. Thus, for every $90,000 spent (3000 x $30= $90,000), a life is saved. About 50% of insured women of susceptible age chose to be tested regularly. As such, the other 50% have unconsciously concluded that their life is not worth $90,000. Willingness-to-pay values ranges from a few thousand dollars up to several million dollars, depending on the nature of risk.

Cost-Effectiveness

Similar to the concept of risk-effectiveness, cost-effectiveness compares the cost of implementing a regulation or an alternative method of risk reduction. Summarizing the cost-effectiveness results of Morrall, seventeen health and safety rules extend a life to a normal level for less than $1 million in regulatory costs. Almost all were issued before 1986. However, 18 regulations extend a life at a cost of more that $25 million. Most of these have been issued after 1986.

Consider a cost-effectiveness comparison method described by the U.S. Department of Transportation. Current risk reduction programs (regulations) are estimated to save 79 lives per year with improved traffic signs (at a cost of $31,000 per life saved); 13 lives per year with improved lighting ($80,000 per life saved);

Regulation	Year Issued	Health or Safety	Agency	Baseline Mortality Risk per Million Exposed	Cost per Premature Death Averted ($ millions 1990)
Unvented Space Heater Ban	1980	S	CPSC	1,890	0.1
Aircraft Cabin Fire Protection Standard	1985	S	FAA	5	0.1
Auto Passive Restrain/seat Belt Standards	1984	S	NHTSA	6,370	0.1
Steering Column Protection Standard	1967	S	NHTSA	385	0.1
Underground Construction Standards	1989	S	OSHA-S	38,700	0.1
Trihalomenthane Drinking Water Standards	1979	H	EPA	420	0.2
Aircraft Seat Cushion Flammability Standard	1984	S	FAA	11	0.4
Alcohol and Drug Control Standards	1985	H	FRA	81	0.4
Auto Fuel-system Integrity Standard	1975	S	NHTSA	343	0.4
Standards for Servicing Auto Wheel Rims	1984	S	OSHA-S	630	0.4
Aircraft Floor Emergency Lighting Standards	1984	S	FAA	2	0.6
Concrete and Masonry Construction Standards	1988	S	OSHA-S	630	0.6
Crane Suspended Personnel Platform Standard	1988	S	OSHA-S	81,000	0.7
Passive Restraints for Trucks and Buses (Proposed)	1989	S	NHTSA	6,370	0.7
Side-impact Standards for Autos (Dynamic)	1990	S	NHTSA	NA	0.8
Children's Sleepwear Flammability Ban	1973	S	CPSC	29	0.8
Auto Side Door Support Standards	1970	S	NHTSA	2,520	0.8
Low-altitude Windshear Equipment & Training Standards	1988	S	FAA	NA	1.3
Electrical Equipment Standards (Metal Mines)	1970	S	MSHA	NA	1.4
Trenching and Excavation Standards	1989	S	OSHA-S	14,310	1.5
Traffic Alert and Collision Avoidance (TCAS) Systems	1988	S	FAA	NA	1.5
Hazard Communication Standard	1983	S	OSHA-S	1,800	1.6
Side-impact Standards for Trucks and MPVs (Proposed)	1989	S	NHSTA	NA	2.2
Grain Dust Explosion Prevention Standards	1987	S	OSHA-S	9,450	2.8
Rear Lap/shoulder Belts for Autos	1989	S	NHSTA	NA	3.2
Standards for Radio Nuclides in Uranium Mines	1984	H	EPA	6,300	3.4
Benzene NESHAP (Original: Fugitive Emissions)	1984	H	EPA	1,470	3.4
Ethylene Dibromide Drinking Water Standards	1991	H	EPA	NA	5.7
Benzene NESHAP (Revised: Coke Byproducts)	1988	H	EPA	NA	6.1
Asbestos Occupational Exposure Limit	1972	H	OSHA-S	3,015	8.3
Benzene Occupational Exposure Limit	1987	H	OSHA-S	39,600	8.9
Electrical Equipments Standards (Coal Mines)	1970	S	MSHA	NA	9.2
Arsenic Emission Standards for Glass Plants	1986	H	EPA	2,660	13.5
Ethylene Oxide Occupational Exposure Limits	1984	H	OSHA-S	1,980	20.5
Arsenic/Cooper NESHAP	1986	H	EPA	63,000	23.0
Haz Waste Listing for Petroleum Refining Sludge	1990	H	EPA	210	27.6
Cover/Move Uranium Mil Tailings (Inactive Sites)	1983	H	EPA	30,100	31.7
Benzene NESHAP (Revised: Transfer Operations)	1990	H	EPA	NA	32.9
Cover/move Uranium Mil Tailings (Active Sites)	1983	H	EPA	30,100	45.0
Acrylonitrile Occupational Exposure Limit	1978	H	OSHA-S	42,300	51.5
Coke Ovens Occupational Exposure Limit	1976	H	OSHA-S	7,200	63.5
Lockout /Tagged	1989	S	OSHA-S	4	70.9
Asbestos Occupational Exposure Limit	1986	H	OSHA-S	3,015	74.0
Arsenic Occupational Exposure Limit	1978	H	OSHA-S	14,800	106.9
Asbestos Ban	1989	H	EPA	NA	110.7
Diethylstilbestrol (DES) Cattlefeed Ban	1979	H	FDA	22	124.8
Benzene NESHAP (Revised Waste Operation)	1990	H	EPA	NA	168.2
1,2 - Dichloropropane Drinking Water Standard	1991	H	EPA	NA	653.0
Haz Waste Land Disposal Ban (1st 3rd)	1988	H	EPA	2	4,190.4
Municipal Solid Waste Landfill Standards (Proposed)	1988	H	EPA	< 1	19,107.0
Formaldehyde Occupational Exposure Limit	1987	H	OSHA-S	31	86,201.8
Atrazine/alachlor Drinking Water Standard	1991	H	EPA	NA	92,069.7
Haz Waste Listing for Wood Preserving Chemicals	1990	H	EPA	< 1	5,700,000.0

Table 6. Risk and cost-effectiveness of selected regulations [Source: The Budget for the Fiscal Year 1992 - Table C-2, page 370]

Continued

119 lives with guardrails ($101,000 per life saved); 28 lives with median barriers ($163,000 per life saved); 75 lives with channeled turn lanes ($290,000 per life saved). The average cost is about $150,000 per life saved. Clearly the consistency of a new regulation within the DOT can be compared with these data. A diametrically different statistic may be observed in EPA and NRC programs where average cost per life saved is several million dollars. For example, the EPA's regulations dealing with air pollution control equipment for coal-burning plants require installation of sulfur scrubbers, which corresponds to spending an average of $1 million per life saved. Other regulations of EPA may correspond to as high as $5 million per life saved. The regulations of the Consumer Product Safety Commission amount to an average of about $2 million per life saved.

A 1972 recommendation by the Office of Management and Budget suggests that nuclear power plants install safety systems at a cost of $8 million for every statistical life saved. The NRC regulations correspond to an average of about $4 million per life saved. For controlling normal radioactive emissions, it has some regulations which cost as much as $100 million for one statistical life saved.

Psychometric Analysis

The public's perception of risk for most activities and situations is inconsistent with the actual risk. Since the public influences Congress and hence the development of regulations, one should closely examine and consider the public bias over certain risks. Psychometric surveys have been performed to measure the degree of bias.

For example the general pu lic has a tendency to undertake voluntary risks (*e.g.*, flying, smoking, rock climbing) that are about 100 times more likely to cause harm than an involuntary risk (e.g., being hit by a car, or developing poor health by being a passive smoker). Conversely, an involuntary risk which has a probability or frequency of occurrence of about 100 times smaller than an involuntary risk may be viewed equally risky by the general public. Major factors influencing the public view of risk are: controllable vs. uncontrollable, natural vs. artificial, new vs. old, immediate effect vs. delayed effect, known effects vs. unknown effects, and ordinary (a few affected by the risk) vs. catastrophic (many affected by the risk).

OBSERVING INCONSISTENCIES

The best way to understand the significance of a risk or a risk decision is to compare it with other highly familiar risks. In this section some comparison results are presented using the techniques discussed earlier.

The Office of Management and Budget (OMB) has used a cost-effectiveness approach to compare selected regulations. The results are shown in Table 6. The risk effectiveness of various regulations according to this table may vary as much as a factor of one-million. That is, one can expect that members of society may end up paying on the average one-million times more for certain government imposed regulations to achieve the same risk reduction result (i.e., the cost to avert one premature death in our society) as other regulations. This is certainly unwise. Another way to interpret this table is to assume a fixed value of life and determine which regulations meet this level and which ones impose "too much" burden on society. For example, if an agency is willing to spend $1 million to avert one death, then the first 17 regulations in Table 6 are consistent with this criterion.

Another observation from the OMB ranking is that while there are major differences between the cost-effectiveness of various regulations, it seems that safety regulations appear to be more cost-effective than health regulations. On the average, regulations designed to avert cancer deaths are 8000 times more costly per life saved than safety regulations. Also, it appears from these data that the government agencies overestimate the likely effectiveness of health regulations.

Problem Area	Agency Concerned	Base Case Policy Option	Alternative Policy Option	Per Life-Year Saved*
Highway safety	NHTSA	Status quo	Mandatory passive belts	$88
Smoke Detectors	CPSC	Status quo	Mandatory, in sleeping rooms only	1,300
Stationary Source Air	EPA	Pre - 1970 conditions	1970 Clean Air Act	3,800
Highway Safety	NHTSA	Status quo	Alcohol Safety Action Project	2,000
Saccharin	HHS	Status quo	Ban	8,500
Highway Safety	NHTSA	Pre - 1966	1966 Motor Vehicle Safety Act	6,300
Highway Safety	NHTSA	Unsafe Fuel Tank	Safer fuel tank	17,000
Smoke Detectors	CPSC	Mandatory, in sleeping rooms only	Mandatory in all rooms	32,000
Carcinogens in Water	EPA	100 mcl rule	50 mcl rule	390,000
Vinyl Chloride	OSHA	55 ppm	1 ppm	490,000
Benzene Emission	EPA	No control	97% control	480,000

* Per life-year saved for net additional cost of alternative policy option

Table 7. Comparison of per life-year saved of selected regulations [Source: Graham and Vaupel, "The Value of Life: What difference does it make?" Risk Assessment]

Since the cancers usually strike older groups of the society as opposed to safety risks which more uniformly affect people of any age group, it would be more appropriate to compare the cost-effectiveness based on

Standard	Limit	Annual Risk
10 CFR 20 (Workers)	5 rem/yr (0.05 Sv/yr)	2E-3
10 CFR 20 (Public)	100 mrem/yr (1 mSv/yr)	5E-3
10 CFR 61 (LLW)	25 mrem/yr (0.25 mSv/yr)	1E-3
40 CFR 190 (Uranium Fuel Cycle)	25 mrem/yr (0.25 mSv/yr)	1E-3
40 CFR 191.03 (Workers) (Repository Operations)	[illegible]	[illegible]
40 CFR 191.15 (HLW ind. prot. std.)	25 mrem/yr (0.25 mSv/yr)	1E-3
40 CFR 191.16 (Groundwater port. std.)	4 mrem/yr (0.25 mSv/yr)	2E-3
40 CFR 141 (Drinking Water)	4 mrem/yr (0.25 mSv/yr) 20 pci ^{226}Ra/l (0.7 Bq/l) 30 pci U-nat/l (1 Bq/l) 300 pci ^{222}Rn/l (11 Bq/l)	2E-6 1E-6 2E-6 3E-6
Reactor Safety Goal	0.1% Increase	2E-6 to 5E-7

Table 8. Comparison of selected NRC and EPA ragulations [Source: "Questions Concerning Regulatory Requirements for High-Level Water Depository." Memorandum for Commissioner Curtis from james Taylor, August, 1992]

the cost per life-year saved. Table 7 shows a comparison of some other regulations from this point of view.

A similar comparison outlined in Table 8 shows risk significance of some NRC and EPA rules aimed at controlling radiation. The EPA radiation standards are generally more restrictive than the corresponding NRC rules. These inconsistencies underline an imbalanced cost of implementing regulations. A more important question is the effectiveness of these regulations in saving lives. Consider the transportation regulations. Injury and fatality rates have declined significantly over the past several decades per passenger mile traveled by automobiles and commercial air transport systems. Most of this decline, however, may not be attributed to governmental regulations. Some claim that most of the decline has been influenced by technology, consumer demands and legal liabilities rather than by regulations *per se*. This example also highlights the importance of using a performance-based regulation where possible instead of prescriptive regulations. Because of economic incentives and knowledge of the risks, the best and most effective regulation would be a performance-based regulation.

SOURCE OF INCONSISTENCIES

As discussed earlier, the regulatory system often does not rationally prioritize the health, environmental and safety risks. Breyer claims this is because of people's irrational reactions to risk (*i.e.*, wrong public perception), Congress' attempt to regulate risk directly through detailed statutory instructions, and the uncertainties and irrationalities of our technical regulatory methods. Together, Breyer affirms that these three phenomena reinforce one another to create a "vicious circle". In sum, they diminish public trust in regulatory institutions and thereby inhibit more rational regulations. Clearly, public perceptions influence Congress, Congress influences public perception through its press reports and other activities, and both influence the response of regulation to perceived problems. Breyer claims that since people's views, politics, and the media are hard to change, the only hope is to change the regulatory process.

EMERGENCE OF RISK-BASED REGULATION (RBR): DOMINANCE OF REASON

Since society has very limited resources for reducing risks, a rational being has no choice other than using a prioritization scheme. If risk reduction measures such as regulations are designed, implemented and enforced on the basis of their risk reduction abilities, we can better manage risks and most effectively use our scarce resources. The process by which risks are prioritized and risk reductions measures are made consistent with their risk reduction potentials is called risk based regulation (RBR).

While RBR examines and ranks risks and regulation from a societal point of view, regulatory agencies must find ways to regulate such risks in a cost-effective manner. Some use cost effectiveness measures to compare alternative risk management techniques. Others rely on what is known as "performance-based regulation". That is, the regulatory body simply prescribes criteria (often tangible measures in the form of safety goals, or self-imposed limits) by which the effectiveness of risk aversion efforts is measured. The industry then decides on the most effective means to achieve the goals or limits. In this case, no risk management method is prescribed. The combination of risk-based and performance based regulatory approach provides a rational and powerful method for distributing scarce resources and obtaining the best results.

Since RBR compares and ranks risks and alternative regulatory measures, it requires a reference plane. This topic is discussed in the following section.

RELATIVE VERSUS ABSOLUTE RISK REFERENCE PLANE

Conceptually RBR requires establishing an acceptable level or risk, or a risk reference index. For example one attempt may be to find a trivial level or de

Continued

minimis risk, beyond which expenditures to improve the risk exposure should be avoided. Another approach may establish a level consistent with readily accepted everyday risks. Yet another may employ psychometric analysis along with other methods.

Risk-based analysis may be based upon one of the following options:

1) A limit may be placed on the frequency or probability of occurrence of an event or hazard condition

2) A limit may be placed on the individual risk of early death, or delayed death due to cancer

3) A limit may be placed on the overall societal risk of early or delayed death

4) A limit may be placed on the cost-effectiveness of risk reduction methods

5) A risk-aversion limit may be applied to infrequent risks involving a large number of deaths or other major consequences.

In establishing these limits it is prudent to take into account societal bias about certain classes of risk, without letting it drive the final decision. The so-called NRC quantitative safety goals may be viewed as establishing these levels. For example:

1) The risk to an individual in the vicinity of a nuclear power plant, of fatality resulting from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed

2) The risk, to the population in the area near a nuclear plant, of cancer fatalities resulting from nuclear power plant operation should not exceed one-tenth of one percent (0.1%) of the sum of cancer fatality risks resulting from all other causes.

Clearly, these two reference levels are relative measures for de minimis risk limit-the first one is an individual risk limit and the second is a societal risk limit. As such, if a cure is found for all kinds of cancer, then these safety goals assumes that any nuclear plant would be safe. Therefore, other absolute risk measures may be required to augment relative risks. For example, other levels could be established based on reactor and containment performance measures as follows:

1) Consistent with the traditional defense-in depth approach and the accident mitigation philosophy requiring reliable performance of containment systems, the overall mean frequency of a large release of radioactive materials to the environment from a reactor accident should be less than 1 in 1,000,000 per year of reactor operation.

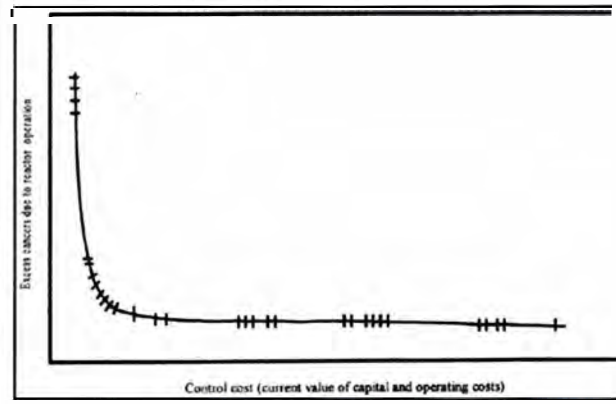

Figure 4. Risk reduction versus cost in a light water reactor [Source: Environmental Protection Agency, "Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle," Vol. 1 (EPA, 1976)]

2) The frequency of core damage should be less than 1 in 10,000 per year of reactor operation.

At the institutional level one may compare risk-effectiveness of alternative options instead of relying on performance-based measures. This can be done on a relative basis, or it can be performed based on an absolute plane of reference. Consider Figure 4. On a relative basis, the "knee" of the curve determines the best choices. Where there is a tolerable cost per life saved value (or its equivalent such as probability of individual or societal cancers), it can be used to locate alternative control strategies that come close to this criterion.

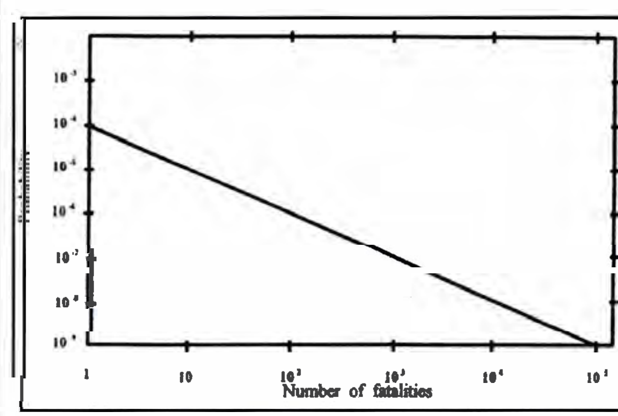

Figure 5. A criterion for delayed death risk in a cumulative form

Another way to promulgate a risk-based regulation is to establish risk vs. probability curves. For example, for fatality risks, a decision criterion similar to the one shown if Figure 5 can be used. This method is used when no consideration is given to the cost of regulation. That is, the objective is solely to avoid certain risk outcomes. For example, this figure assumes that the individual probability of death should always be less than 1 in 10,000 (which is the smallest accidental death rate in the U.S. and pertains to girls 10-14 years old, and is less than 1% of the total annual individual death rate.) The probability and number of fatalities are assumed to be a linear function of each other. This can, however, be adjusted for cases where the relations may not be linear. For example, when large number of fatalities are possible (*i.e.,* the risk is considered catastrophic), a lower acceptable individual probability of death should be used.

Figure 6 shows another application of this concept to regulations for launching radioactive or nuclear reactor powered space missions. This figure shows the acceptable risk level for radioactive dispersal on earth

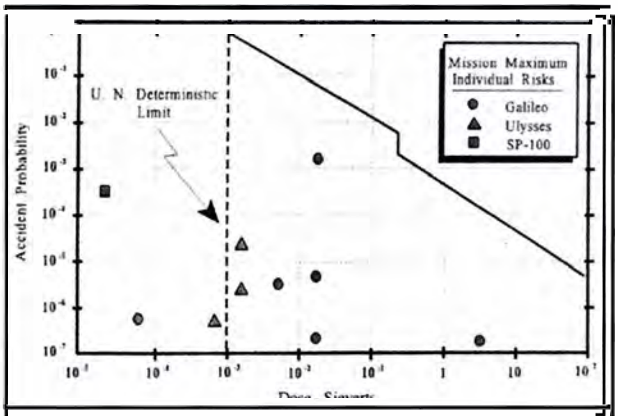

Figure 6. Constant risk limit curve ($5x10^{-5}$ fatalities/year)

(due to launch accidents or reentry into the atmosphere.) Risk imposed by some recent launches are compared with this criterion.

SOME EXAMPLES OF RBR (PROBABILISTIC RBR)

Two examples of risk-based regulation are discussed in this section. One concerns regulations for establishing exclusion zones for sour gas pipelines in the Province of Alberta, Canada, and the other involves allowed outage time for safety equipment in a nuclear plant.

SOUR GAS REGULATION

In this case, the risk profile of a gas pipeline was determined based on the frequency of occurrence of gas release events, the amount of gas exposure to a hypothetical person at various distances from the pipeline, and the health effect data which calculates the likelihood of death given the exposure amount. The combination of these factors yields a risk profile similar to the one shown in Figure 7. An individual risk acceptance criteria (reference level) was developed

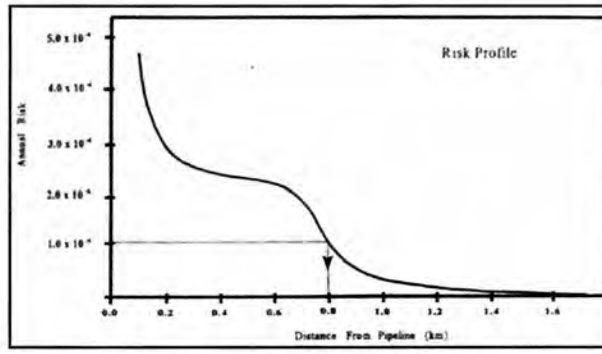

Figure 7. Risk distance curve for the sour gas pipeline

based on an absolute level beyond which the risk is considered negligible. This threshold was 1 in 100,000 or frequency of death per person per year. To correct for societal impacts (in this case catastrophic risk), the risk acceptance criteria chosen for urban areas was 1 in 1,000,000. This has yielded the following typical regulations in the Province of Alberta:

1) For sour gas pipelines with a capacity of gas release of 300 m or less the minimum separation distance is the easement for the right-of-way (usually 15 meters).

2) For sour gas pipelines with the potential to release gas of more than 300 m^3 but less than 2000 m^3 the minimum separation distance is 0.1 km for a permanent dwelling, and 0.5 km for an urban center or rural public facility.

SAFETY SYSTEMS IN NUCLEAR PLANT

A major benefit of performing risk analysis is to rank the risk significance of various events, components, and human elements that affect risk and not the absolute risk imposed. Such knowledge allows us to spend measured resources to achieve the highest risk reduction and control. Figure 8, for example, shows a comparison of the relative risk significance of some safety systems in a nuclear power plant. This clearly points out the importance

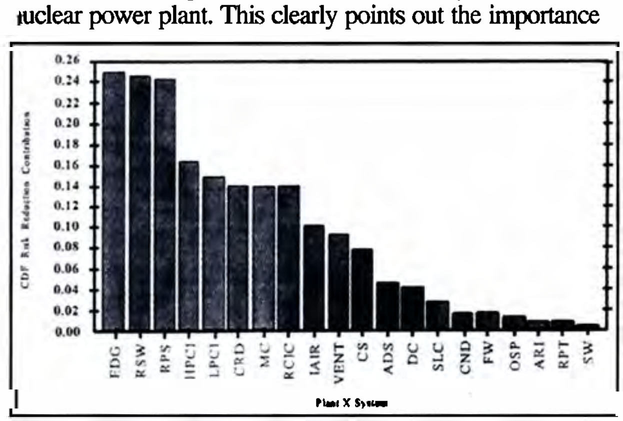

Figure 8. Core damage frequency (CDF) risk reduction contribution

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of RBR. This is, while the defense in depth approach has provided adequate safety, some safety features have been overemphasized. The RBR concept puts a more balanced approach to regulating nuclear plants and reduces the cost. New regulations, improvements, maintenance and testing requirements, and performance criteria should be made consistent with the risk significance of these systems. Indeed some regulatory decisions by the Nuclear Regulatory Commission, such as inspection, modifications in plant technical specification, and maintenance requirements, consider such risk significance ranking.

HOW SOCIETY CAN BENEFIT

Society cannot and should not be expected to maintain consistency in demanding protection against risk. In fact, society has always preferred zero risk. People, however, may not be well informed about the risk of various activities. For example, it is not unusual to see a person exposing herself/himself to excessive ultraviolet sun radiation while worrying about living close to a nuclear power plant. Therefore, it is the regulatory agencies who should make rational decisions such that the interests of all individuals (especially the silent majority) in the society are maintained.

Morrall asserted that it is the "fear of cancer" which has led to a disproportionate cost-effectiveness of several regulations. Therefore, it may make more sense to shift the cost of ineffective regulations to cancer prevention and treatment methods that offer much higher benefit-cost ratio: namely, public education for reducing major contributors to cancer (smoking and diet), and for finding more effective treatment methods. Socioeconomic studies closely correlate any increase in the Gross National Product (GNP) with some corresponding decrease in mortality risk. For example, one estimate indicates that for every 1% increase in GNP, the mortality risk would be expected to reduce by 0.05% (*i.e.*, a reduction of 1000 deaths per year in the U.S.). How does risk analysis fit into the larger context of national priority-setting and international competitiveness? Risk analysis, cost-benefit, and cost-effectiveness can play a major role in this direction, but they are merely methodologies for analysis. As Breyer states common sense and judgement are more important ingredients in the political process to determine, prioritize and devise regulations. In all cases, we should place the interest of the society as a whole first.

As Jefferson said, "I know no safe depository of ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with wholesome discretion the remedy is not to take it from them, but to inform their discretion by education."

The public should realize that risks cannot be eliminated, they can only be managed. They should also realize that tolerating certain risks may result in a better economic future and less risk (by affording safer products, and accessing better health care). Such enlightenment can lead to a better and more consistent body of regulations.

CONCLUDING REMARKS

Regulations have good intentions, but some can do more harm to the society than good. As L. Lave puts it "...the time has come to recognize the complexity of regulating risks and banish such simplistic approaches. In this sea of risks, which are to be ignored and which to be reduced? Risk analysts have much work to do before satisfactory risk regulation can emerge. However, two principles would be of enormous help today: (1) Ignore minimal risks and (2) balance risks against benefits and control costs where risks are negligible."

Risk analysis should be used as an effective way of estimating and selecting the best risk management alternatives. The analysis should be probabilistic and should give a best estimate result as well as a range of uncertainty for the results. Congress should require various federal agencies to coordinate their risk analysis efforts to develop consistent regualations. While risk assessment is a relatively new subject, much research and development is still needed to realize its full potential. Universities, the industry and the Government should join forces to overcome these shortcomings.

It appears that other means such as better education (for example to reduce smoke related cancers and improvements in diet) may be much more cost-effective than some marginal regulations. Smoking and diet together contribute more than 65% of cancers. This is not to claim that regulations should not exist. On the contrary, regulation is necessary, but only when if effectively reduces risks.

I conclude with a quote from the noted 495 BC Athenian statesman Pericles who stated: "We Athenians ....take our decisions on policy or submit them to proper discussion: For we do not think there is an incompatibility between works and deeds; the worst thing is to rush into action before the consequences have been properly debated. We are capable at the same time of taking risks and of estimating them beforehand. Others are brave out of ignorance; and when they stop to think, they begin to fear. But the man who can most truly be accounted brave is he who best knows the meaning to what is sweet in life and what is terrible, and then goes out to meet what is to come."

RISK ANALYSIS OF CHEMICAL BARGING AND OFFLOADING OPERATIONS

J.K. Liming, PLG, Inc.

Until 1991, the Unocal corporation had been shipping anhydrous ammonia by truck and railcar from its Hedges terminal in the tri-cities area of Washington State to a terminal at Central Ferry. The Central Ferry terminal is approximately 85 miles up the Snake River from Hedges (Figure 1), and is a distribution center for ammonia fertilizer to farmers in the region.

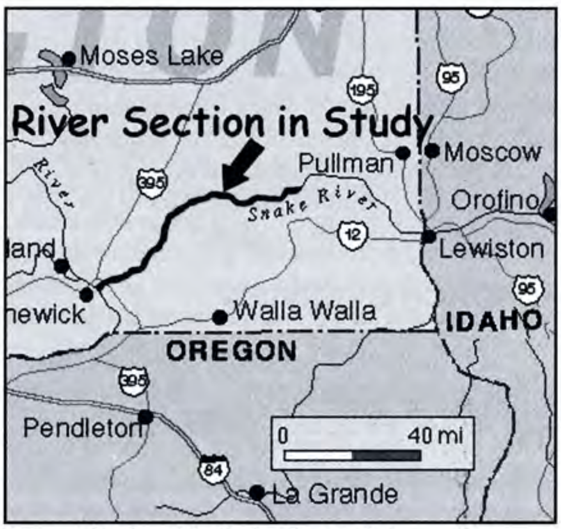

Figure 1. Section of the Snake River studied.

Because of the risks perceived by the parties associated with the Central Ferry operations regarding the truck and railcar modes of shipment, Unocal proposed an alternative. This alternative involved shipping the ammonia on barges up the Snake River and off-loading it at an expanded and improved Central Ferry terminal. Unocal believed that this was a more efficient means of transporting the ammonia and that it entailed even less risk than their current mode of shipment via truck and railcar. To quantify the risks of the barging and offloading operations, Unocal contracted with PLG, Inc. to conduct a risk assessment study.

The purpose of this article is to summarize the objectives, approach, and results of this study. This article also presents some observations about communicating this information to persons who are not familiar with the concepts and techniques used in probabilistic risk assessments.

The two primary objectives of the study were:

- To assess the risks to the Snake River fish species from the proposed Unocal operations.
- To define actions that could preclude or mitigate the consequences of any ammonia spills into the river associated with the proposed Unocal operations.

The focus on the fish species in the river was dictated by the fact that these fish represent a primary resource to the Indian tribes in the region. Follow-on studies are anticipated to address additional risks posed by the dispersion of ammonia released into the atmosphere.

SCOPE OF ANALYSIS

The scope or "boundaries" of the risk analysis were defined as follows:

River Section. From the Hedges terminal at the confluence of the Columbia and Snake Rivers up river approximately 83 miles to the Central Ferry terminal.

Spill Sources/Contributors. Personnel actions, equipment malfunctions, and/or events from external sources (e.g., collisions caused by other vessels) that can lead to ammonia spills from the ammonia barges or from offloading operations at the Central Ferry terminal.

Dispersion Modeling. The range of flowrates, temperatures, and water chemistry properties associated with the river during the proposed spring and fall transportation periods.

Fish Species. All fish species resident in the Snake River with emphasis on the six species for which toxicological data were available.

Date Sources. Information from 18 organizations was used to provide data on barge-related accidents, the characteristics of the Snake river and its fish populations, and the potential sources of personnel and equipment problems that could lead to ammonia spills. Key information was obtained from the U.S. Coast Guard and the U.S. Army Corps of Engineers.

RISK MEASURES

Since the focus of the study was on the impact of the proposed Unocal project on the fish species in the Snake River, the original intent was to use the probability of killing various numbers of each of the fish species per year as an overall measure of risk. However, the state and federal agencies involved in this study pointed out that the population of each species could not be realistically determined with any degree of accuracy. They requested, therefore, that the selected measure be limited to the probability that the ammonia barging and offloading operations would lead to spills that exceeded a lethal dose for each fish species.

Furthermore, the agency personnel recognized that there was limited information on the toxicological effects of ammonia on the fish found in the Snake River. The risk measure was then limited to the probability that the proposed mode of ammonia transportation and handling would result in leaks that were lethal to the fish species for which toxicological data were available. Since these species were among the more important resources in the river and since they covered a broad range of sensitivity to ammonia concentrations, it was considered to be reasonable by the fisheries experts that the results would adequately represent the effect on all species.

The risk measure was then separated into two distinct parts: one that pertained to the likelihood and magnitude of spills, and the other to the consequences of these spills on the selected fish species. The risk measure for the first part was the probability of having spills of various magnitudes. For the consequence part, the measure was the distance downriver from the spill site that each of the selected fish species would encounter a lethal concentration of ammonia.

With respect to the spill occurrence probabilities, the probabilities were computed only for selected spill magnitudes (i.e., spill masses.) These were determined from analysis of potential scenarios that could lead to a spill; e.g., barge collision leading to release of the full ammonia cargo, hose rupture during ammonia offloading leading to a spill that continues for 11/2 hours until the operators can initiate a secondary method of shutdown, etc.

For the consequence part of the risk measure, it was assumed that the spill would occur close to the Central Ferry terminal. This approach was considered conservative since it permitted calculation of the greatest downriver distance within which lethal concentrations could be expected. The validity of this assumption stems, in part, from the fact that the average flow, temperature, and chemical characteristics of the river are fairly constant throughout its length.

APPROACH OVERVIEW

The scenarios that can lead to spills are shown on the master logic diagram in Figure 2. It was determined through analysis that the scenarios associated with loss

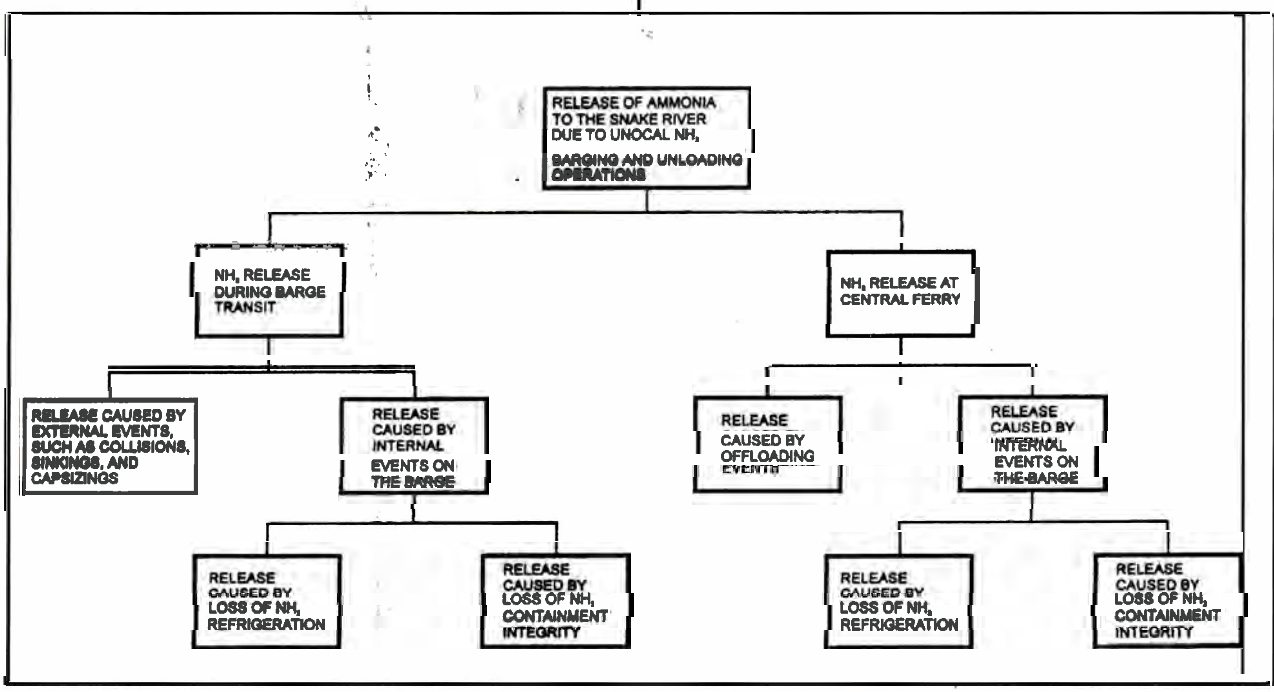

Figure 2. Master-Logic Diagram for Central Ferry Ammonia Barging Risk Assessment

of ammonia system refrigeration would not lead to spills onto the river. Therefore, the four possible categories of spills for this project were

Release from barge resulting from externally-caused events; e.g., collisions, capsizing, etc.

Spills from loss of ammonia system integrity on the barge while in transit.

Spills from loss of ammonia system integrity on the barge while at Central Ferry but not offloading.

Releases that can occur during ammonia offloading operations.

For each scenario, an estimate was developed for the most severe spill that could reasonably be expected. For example, a review of the barges and the types of accidents that could occur along the waterway indicated that the full ammonia cargo (2,400 tons) could be released in a collision. The magnitude of spill from loss of ammonia system integrity (about 1 ton) was determined from a review of the system design and an evaluation of potential failure modes and protective shutdown provisions. The magnitude of a spill from offloading operations (about 100 tons) was based on consideration of the time to implement a backup mode of shutdown following failure of the operator to implement the primary shutdown action. The process of estimating the frequency of occurrence of these spills was tailored to the manner in which they could be propagated. For example, the approach used for the external events scenario was based on the number of planned barge trips, the historical incidence of barge accidents along the Snake River, the relative number of cargo losses associated with these barge accidents, and an engineering comparison between the cargo containment system of the ammonia barges and the barges that had experienced cargo damage. The equation for this estimate is presented below:

$$F = B \times I \times C \times S$$

where:

F = frequency of ammonia releases into the Snake River caused by external events.

B = average number of barge trips per year for the 2 barges (6 to 10 per year).

I = relative frequency of barge incidents per barge trip (10 incidents; 13,214 trips; mean frequency = 1 incident per 1321 trips).

C = relative frequency of cargo loss damage from a barge of generic design, given that a barge incident occurs (1 occurrence; 10 incidents; mean frequency = 1/10 incidents.)

S = relative frequency of a 2,400-ton ammonia spill from the ammonia barges, given that a cargo damage incident occurs (mean frequency =1/2 generic cargo losses).

To develop risk estimates for the loss of containment system integrity, a fault tree analysis was performed to asses the probability of the spill occurring because of equipment failures and/or operator actions. For the spills due to offloading operators, an event tree was developed to define the specific sequence of events leading to the spill, and fault trees were developed to define the specific equipment failures and/or personnel actions of concern.

In all cases, a combination of historical data and engineering analysis was used to obtain the quantitative estimates. PLG's RISKMAN software package was used to propagate the uncertainty in these estimates through the analysis and to generate the output probability distributions.

With respect to the analysis of the impact of these spills on the selected fish species, two major activities were conducted: one estimated the dispersion of the ammonia downstream of the spill site, and the other addressed the fish and the potential impact of potential ammonia toxicity levels. The dispersion analysis employed a water chemistry model and a dispersion model with conservative assumptions on the input parameters.

The fisheries analysis involved an assessment of the available data on the fish species reported to be in the Snake River, an evaluation of toxicological data on representative fish species in the river, and a comparison between the predicted ammonia concentrations and the fish toxicity levels.

The results of these analyses were presented in terms of the ammonia concentrations as a function of time and distance downriver from the spill site, and of the acute toxicity thresholds for each representative species as a function of the distance downriver from the spill site. These results were computed for three spill quantities noted above (2,400 tons; 100 tons; and 1 ton), and for the combinations of transportation season water temperatures (spring, 8°C; and fall, 18°C) and flow conditions (average and low).

RESULTS SUMMARY

The results of this risk assessment study consist of the following:

The probability distributions and their characteristic values of the frequency of occurrence of spills for spill quantities of 2,400 tons; 100 tons; and 1

Continued

ton anhydrous ammonia.

The maximum distance downriver from the spill site that the seven representative fish species would encounter a lethal concentration of ammonia.

Figure 3 shows the cumulative probability curve for one of the key spill scenarios, *i.e.*, a loss of the full contents of the barge due to collision, capsizing, or grounding (2,400 tons). This curve is representative of the curves for the other three spill scenarios; *i.e.*, loss of part of the ammonia cargo from problems resulting in a loss of containment system integrity during transit, while at Central Ferry, and loss of part of the ammonia inventory during offloading operations (100 tons). These curves show the probability (or confidence) that the frequency of occurrence for the defined spill scenario will be less than the specified values. For example, Figure 3 indicates that there is a 95% probability that the loss of the total ammonia inventory of 2,400 tons is expected to occur less often than once in 455 years.

Figure 4 shows a representative curve for the predicted ammonia concentrations compared to the acute toxicity thresholds for the fish using the 2,400-ton spill. Similar curves were developed for the other spill scenarios noted above. This curve shows that for the spring conditions of low flow and a water temperature of 8°C, all of the fish species would receive acute doses of ammonia within about 7 kilometers (about 4 miles) of the spill. Also four of six species would see acute levels out to about 16 kilometers (about 10 miles).

The overall results for the scenarios of interest are presented in Table 1. This table identifies the spill category and provides a brief description of each category, the amount of ammonia estimated to be spilled in each scenario, the median frequency of occurrence from the scenario probability distributions, and the toxicity threshold range from the spill for the representative species.

RECOMMENDATIONS AND CONCLUSIONS

A number of recommendations were made for actions to be taken for ensuring that the results would not be invalidated by a violation of the analysis ground rules. For example, the types of recommendations that were generated by this study included the following:

Equipment. Install an automatic ammonia detection and offloading process shutdown system at Central Ferry.

Procedural. Request the U.S. Army Corps of Engineers inspect for boulders near the Ice Harbor dam prior to the spring and fall ammonia transportation periods.

Personnel. Implement a comprehensive ammonia barging and offloading procedure training program to include annual recertification.

Planning. Establish an emergency plan for the barges and the Central Ferry terminal, including definition of an ammonia spill committee to guide emergency activities.

The primary conclusion from this risk assessment project was that the risk to the fish species in the Snake River from the proposed project is not significant if the procedures and precautions assumed in the analysis are followed.

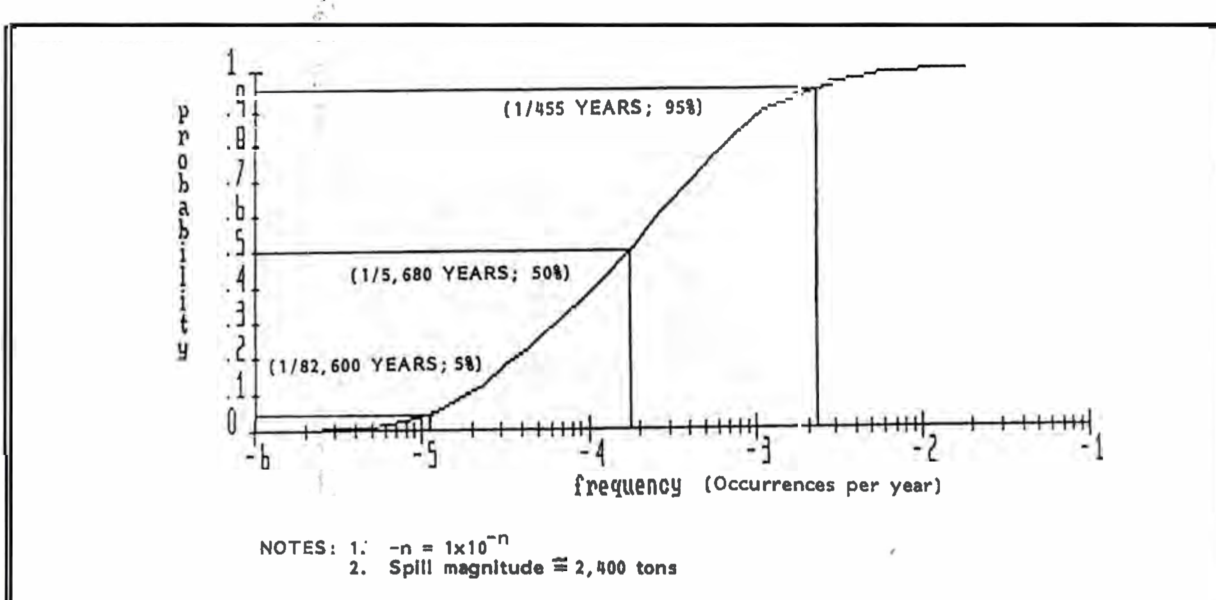

Figure 3. Cumulative Probability Function for Total External Events Frequency

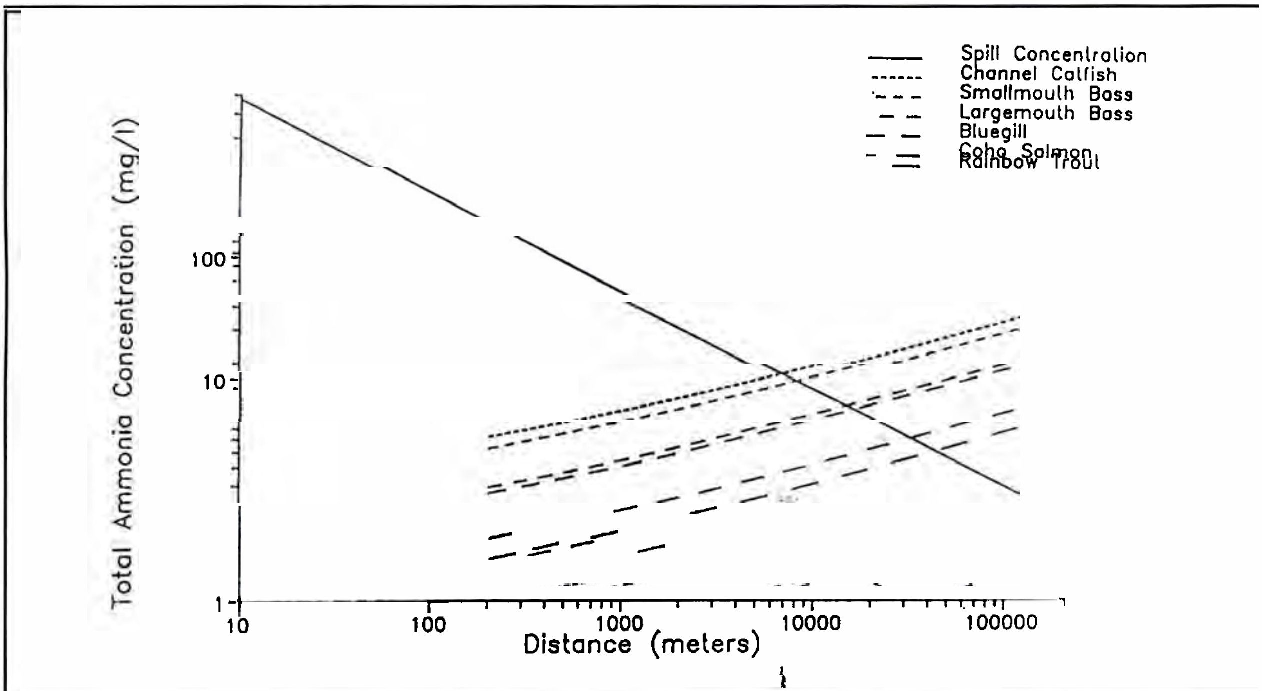

Figure 4. Predicted Ammonia Concentrations from a 2,400-ton Surface Spill (Low Flow Conditions, 8°C) Compared to Acute Toxicity Thresholds for Fish

Ammonia Spill Scenario Category	How? (scenario description)	How Much? (tons)	How Often? (median frequency)	*Impact on Fish Species (lethal r[illegible]e in kilometers)* Fall (low flow)	Spring (average flow)
During Barge Transit External Hazards	Barge Collisions, Capsizing, and Groundings Causing a Surface Spill	2,400	1 Event Every 5,680 Years	98.0 to 14.0	18.5 to 3.3
Internal Hazards	Loss of Ammonia Containment Integrity Causing a Surface Spill	1	1 Event Every 97 Years	<0.03	<0.03
At Central Ferry Offloading Hazards	Ammonia Spill during Offloading Causing a Surface Spill	100	1 Event Every 10,600 Years	0.90 to 0.23	0.32 to 0.09
Internal Hazards	Loss of Ammonia Containment Integrity Causing a Surface Spill	1	1 Event Every 47 Years	<0.03	<0.03

Table 1. Summary of Central Ferry Risk Assessment Results

Continued

RISK ANALYSIS TO REDUCE PETROLEUM SPILLS
RISK BASED ALLOCATION OF PETROLEUM SPILL RESPONSE RESOURCES

W. C. Gekler, PLG, Inc.

In 1990, a cooperative organization of petroleum industry owners/operators initiated a quantitative risk analysis (QRA) of facilities that could cause petroleum spills in the Cook Inlet region of Alaska. The primary objectives of the QRA were to identify the sources of risk at each activity and to identify any added spill response resources that were deemed necessary to achieve the desired level of protection, *i.e.*, reduce the risk.

All operations in each facility that could have a spill of at least 25 barrels to the waters of Cook Inlet were considered in the analysis. Using this criterion, 36 facilities were selected for analysis. They included 15 offshore platforms and associated submarine pipelines, 7 onshore production facilities, 2 refineries, 5 terminals, 3 onshore regulated pipelines, 3 docks, and various tankers and barges that are used to transport crude and petroleum products in the Inlet.

Facilities and activities of organizations that were not members of the cooperative (e.g., cruise ship lines) were also considered. However, it was concluded that these organizations did not contribute any unusual oil spill resource requirements.

The team first evaluated the existing spill response equipment, training, and personnel. Then, using the spill scenarios defined for each facility, the team identified recommended changes for spill response at the level of protection desired by the cooperative. Each lead facility operator was queried on experience with existing spill response equipment and personnel. Emphasis was given to identifying equipment, equipment location, and the organizational responsibilities necessary to meet recently enacted State of Alaska requirements on spill response; e.g., cleanup of 50,000 barrels of crude oil in the first 72 hours.

A particularly challenging aspect of the evaluation of spill response capability was the unique marine environment that exists in Cook Inlet. The Inlet has large tidal changes (20 to 25 feet) and associated tidal currents as high as 7 or 8 knots (8 to 9 mph). It is subject to severe arctic storms, almost complete ice coverage, and limited daylight in the winter. The strong tides result in tidal rips that become laden with debris washed into the inlet by rivers feeding the inlet. These rips and the associated debris have been known to turn oil spills into a mixture referred to as a "mousse." This mousse has been removed from the water by track-mounted shovels or back hoes mounted on barges.

TECHNICAL APPROACH

The flow of activities in the assessment is shown in Figure 2. The initial steps were:

- Define the spill scenarios at each facility; i.e., the sequence of events that can lead to oil spills into the Inlet waters.
- Estimate the spill scenario frequencies using Cook Inlet experience and experience for similar activities in other parts of the world.
- Identify spill response resources needed to meet Alaska regulations.

Subsequently, the expected need for each resource by each facility was estimated based on the size and frequency of spills. Thus, the spill response or emergency management requirements were defined within the context of a quantitative assessment of the oil spill risk. Any changes in the locations, quantities, or types of spill response resources could be evaluated by assessing the impact of the change on risk from spills into the Inlet.

Conversely, if a lower level of risk was desired for a facility, the spill scenarios that demanded the most resources were easily found. Then, equipment design or procedural changes could be defined to reduce the likelihood and/or magnitude of spills from the facility. This latter information was then used to reallocate requirements for spill response resources.

It is important to note that the historical frequency of large oil spills into the Cook Inlet was very low. Furthermore, many of the low-likelihood, large-volume spill scenarios that were considered in the QRA had not occurred.

To implement the QRA approach pictured in Figure 2, facilities expected to exhibit similar spill scenarios were grouped together and then a "lead"

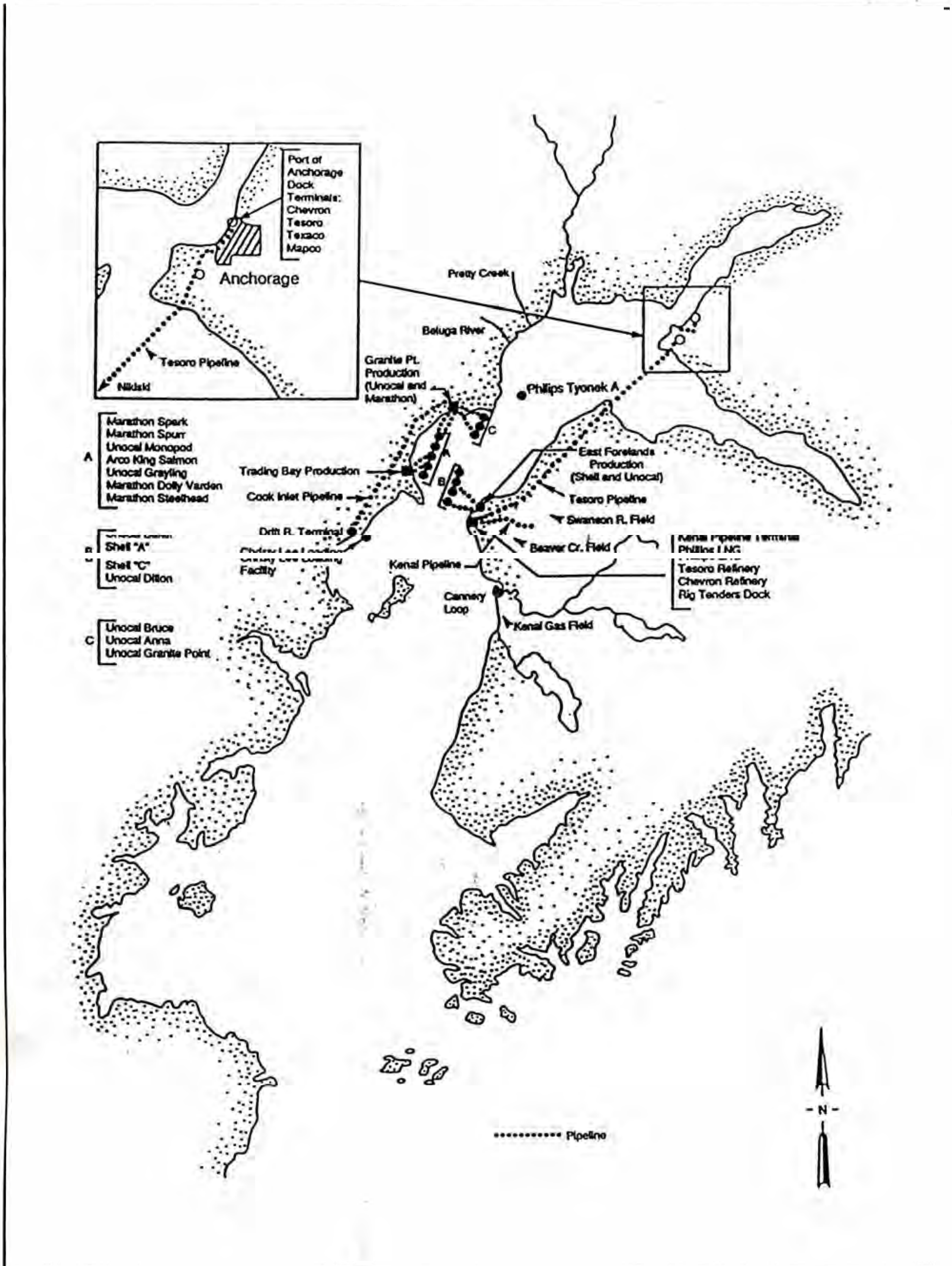

Figure 1. Location of Petroleum Facilities

Continued

facility was selected for each group. Each lead facility was then given a detailed evaluation to establish various spill scenarios that it might experience. The evaluation included a review of design documentation; Spill Prevention, Control, and Countermeasures plans; spill contingency plans, spill history; and a facility visit. Out of these evaluations, the team developed spill scenarios and identified the spill response resources that would be required at each lead facility location for satisfactory response to anticipated spills.

SPILL SCENARIO EVALUATION

A typical spill scenario evaluation sheet is shown in Figure 3 for a tanker carrying crude. As indicated in Figure 3, the size of spill in each scenario was given as a range. To define the spill response resources, the maximum spill size estimated for each scenario was used. While larger spills are possible they were judged to be extremely unlikely on worldwide experience.

Using the scenario evaluations, a summary of scenarios with spill sizes greater than 25 barrels was prepared. Figure 4 is a graphical presentation of all such scenarios. In Figure 4, the frequency is given as years between spills, and the maximum spill size estimated for each spill is recorded by the point plotted at the appropriate spill frequency for each lead facility.

It is important to note that a range of spill sizes occurs at any given spill frequency (or the years between spills increases). Also, frequency does not necessarily decrease as spill size increases, i.e., big bad events are not necessarily less likely. Another important observation from this plot is that ships and barges were the primary sources of large spills of either crude or petroleum product under the ground rules of this analysis.

Maximum spill sizes were of particular importance since they became the basis for defining spill response resource requirements. This approach was adopted since the frequency data showed that response (and the resources used in the response) would have to be capable of responding to the maximum credible spill size even though, in most cases, the spill size would be much smaller.

The frequencies assigned to the maximum spill sizes in Figure 4 were determined by the frequency of all possible spill sizes for the scenario, not the frequency of the largest spill size anticipated in the scenario. This approach is consistent with the regulatory philosophy that requires mobilization of a capability to clean up large spills even though experience has shown that most

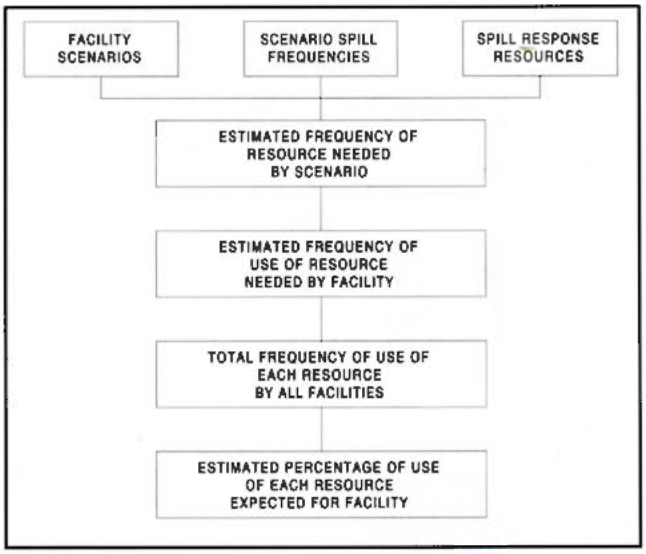

Figure 2. QRA Sequence

spills have been minor (less than 25 barrels). An analogy is sending multiple fire engines to a small fire since the fire may grow if not contained.

SPILL RESPONSE RESOURCES

The spill response resources were selected to ensure adequate response under the regulatory requirements established by the State of Alaska. To simplify the assignment of spill response resources, the spill scenarios were broken into size ranges and locations as shown in Table 1. Then, spill response equipment groups needed for the spill scenario sizes and locations were identified. Table 2 lists boats and skimmers assigned to each spill response group. Similar tables were prepared for pumps, portable recovered oil storage capacity, oil containment booms, and miscellaneous equipment such as portable generators.

The resource evaluation identified existing equipment, equipment on order, and new equipment identified in the ORA that should be assigned to each group. Most of the existing equipment was located in one central location at Nikiski. Some additional equipment was also located in the port of Anchorage and at the Drift River Terminal.

Personnel resources for spill response were also evaluated. At the time of the analysis, manning for spill response was provided first by employees of cooperative members, and if additional resources were needed, by

SPILL SCENARIO CHARACTERIZATION

Facility:	Tankers
Scenario Number	1
Source	Crude Cargo Tanks
Source Volume or Flow	Approximately 460,000 bbl.
Spill Cause(s):	Collision with another vessel.
Spill Duration:	Several hours to several days.
Mitigating Factors:	Collision Avoidance systems on tankers and collision avoidance practices by crew while in Cook Inlet waters
Volume to Water:	
Typical:	17,000 bbl
Maximum:	51,000 bbl
Minimum:	< 25 bbl
Basis for Estimate:	
Typical:	Two-thirds of one cargo tank.
Maximum:	Two-thirds of three cargo tanks.
Minimum:	Less than 25 barrels.
Years between Spills	170 years (frequency =5.9 x 10-3 spills per years)
Basis for Estimate:	Cook Inlet experience indicates two major or significant spills in the inlet. There have been 2,288 port calls at KPL dock since 1971. It is estimated that another 500 calls have occurred at Rig Tenders. If it is assumed that there has been and equal amount of port calls at Drift River and Anchorage combined, the spill frequency in Cook Inlet is 2 spills in about 5,600 port calls or 3.6 x 10-4 spills per port call. U.S. experience indicates 0.65 spills per 10 barrels or for one port call by a 460,000-barrel tanker, a spill frequency of 0.65 x 10 x 4.6 x 10 = 3.0 x 10 spills per port call. Use U.S. experience for estimate of overall spill frequency or 3.0 x 10 spills per port call. U.S. experience also indicates that 32% of vessel spills result from vessel collision. However, Cook Inlet experience shows no collisions for major vessels. Therefore, it is judged that fraction of vessel spills from the collisions with other vessels is less likely and is set at .15. The current and expected port call rate for crude tankers such as Chevron California at KPL dock is 130 calls per year. Overall spill frequency for crude tankers, such as Chevron California coming to KPL dock, is estimated to be 3.0 x 10 x 0.15 x 130 =5.9 x 10 spills per year from vessel collisions or 1 spill every 170 years at projected tanker traffic rate.
Equipment and Materials for Response (location):	CIRO Resource Groups I, IA, IV, and V.
Comments:	Delivers crude oil to refineries located in Kenai.

Figure 3. Typical Spill Scenario Evaluation Sheet

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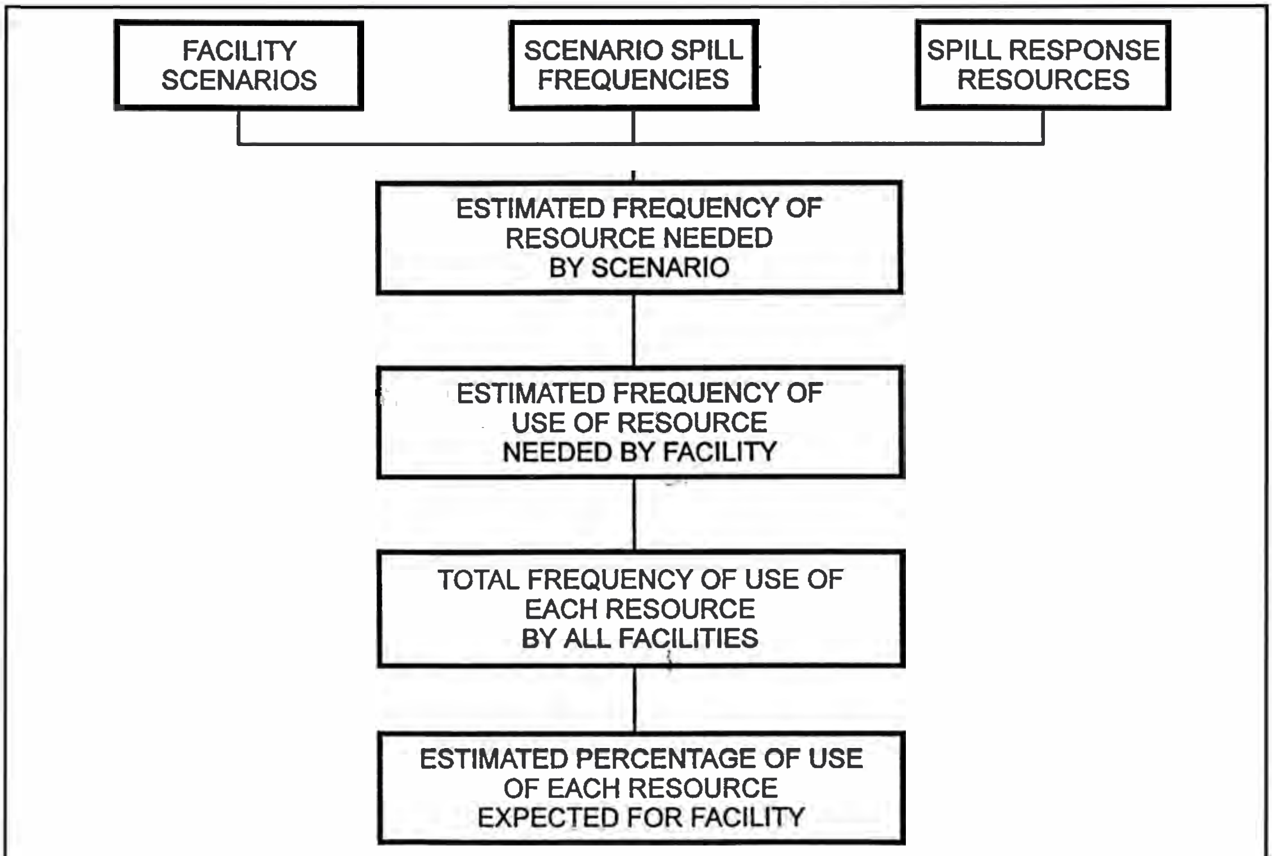
Figure 4. Recurrence Interval for Each Lead Facility Spill Scenario



contractor personnel. All these personnel were receiving training, but the training was limited in scope and efficiency. Recommendations were made on increasing the types and frequency of drills. These recommendations were considered necessary to ensure that resources recommended by the QRA could achieve the desired level of risk and regulating response. Training was performed by all personnel but was limited in scope and frequency.

CONCLUSION

This assessment demonstrated that the QRA technical approach provides a sound basis for identifying spill response resources to achieve desired levels of risk. More specifically, information and analysis requirements for the QRA provide a very effective basis for identifying emergency response requirements. For example, it was determined that emergency response requirements for large oil spills were expected to arise primarily from ship and barge activity. This conclusion is consistent with actual experience both in Cook Inlet and elsewhere. Spills from

Table 1. Resource Groups Required versus Quantity of Oil Spilled

Quantity Spilled (bbl)	Resource Groups
Less than 25	None
25 to 420	I (IA for platforms) or II
420 to 840	I (IA for platforms) and II
840 to 12,000	I (IA for platforms), II, and IV
More than 12,000	Additional storage capacity from barges of opportunity. This is not a cooperative-owned or cooperative-operated resource group. Its costs would be covered by the spiller.
At a Dock or Pier	II plus the above resource groups appropriate for the quantity spilled.
For a tanker or Barge Spill	IV plus the above resource groups appropriate for the quantity spilled.

Table 2. Boats and skimmers assigned to spill response groups

Resource	Quantity in Response Group I	IA	II	III	IV	V	VI	Total Needed	Total Available	Total To Obtain*
Boats										
• 140 to 210 foot contracted response vessel with outrigger booms and capability to tow	1							1	1	0
• Platform workboat with capability for dispersant system installation and boom deployment		1						1	0	1
• 30 to 40 foot boom deployment boat with 175-hp engine and V-hull			6					6	2	4
• 20 to 30 foot boom deployment boat with 100-hp engine and V-hull (31-foot CIRO workboat)	1	1						1	1	0
• 10-foot Hurricane rigid hull inflatable boat								0	2	0
• 8-foot prams							3	3	3	0
• 12-foot Jon boat								0	1	0
Skimmers										
• Desmi-250, or equal	2	1	3					6	2	4
• Walosep W4, or equal			3					3	0	3
• Transrec 250, or equal				1				1	0	1
• Rope mop machine			3					3	4	0
• ODI skimming system								0	1	0
• Outrigger Weir Skimming system								0	1	0

*Based on May 1990 inventory for major equipment items and 1989 inventory for other items.

other activities may be more frequent, but they are generally much smaller. Thus, the challenge to spill response resources is primarily associated with shipping activities.

Based on evaluation of all of the spill scenarios identified in the risk analysis, it was recommended that:

Significant additions to the existing spill response resources be provided to enable adequate recovery of potential spills considered in the QRA. These changes are illustrated by Table 2 for boats and skimmers.

Redistribution of the existing and recommended resources be performed using both present locations and new locations in order to meet regulatory response time lines. Figure 5 shows the location of the resource groups recommended by the study team.

The assessment also showed that the QRA provided a mechanism for evaluating the impact of changes in spill control equipment and practices at each facility on spill response requirements. For example, as some members of the spill response cooperative reviewed the assessment, they identified and implemented measures to reduce spill frequency or size. Therefore, their contribution to meeting the overall spill response requirement was reduced. Measures that were taken to reduce risk included use of locks and checklists to ensure that drain valves are closed when not in use, construction of permanent diversion dams to keep an oil spill from entering the inlet, and procedures to reduce the time to detect leaks.

In addition to identifying recommended changes in the types, quantities, and locations of response resources, the assessment recommended changes in operation of the spill response organization to improve the effectiveness of spill response resources. They included:

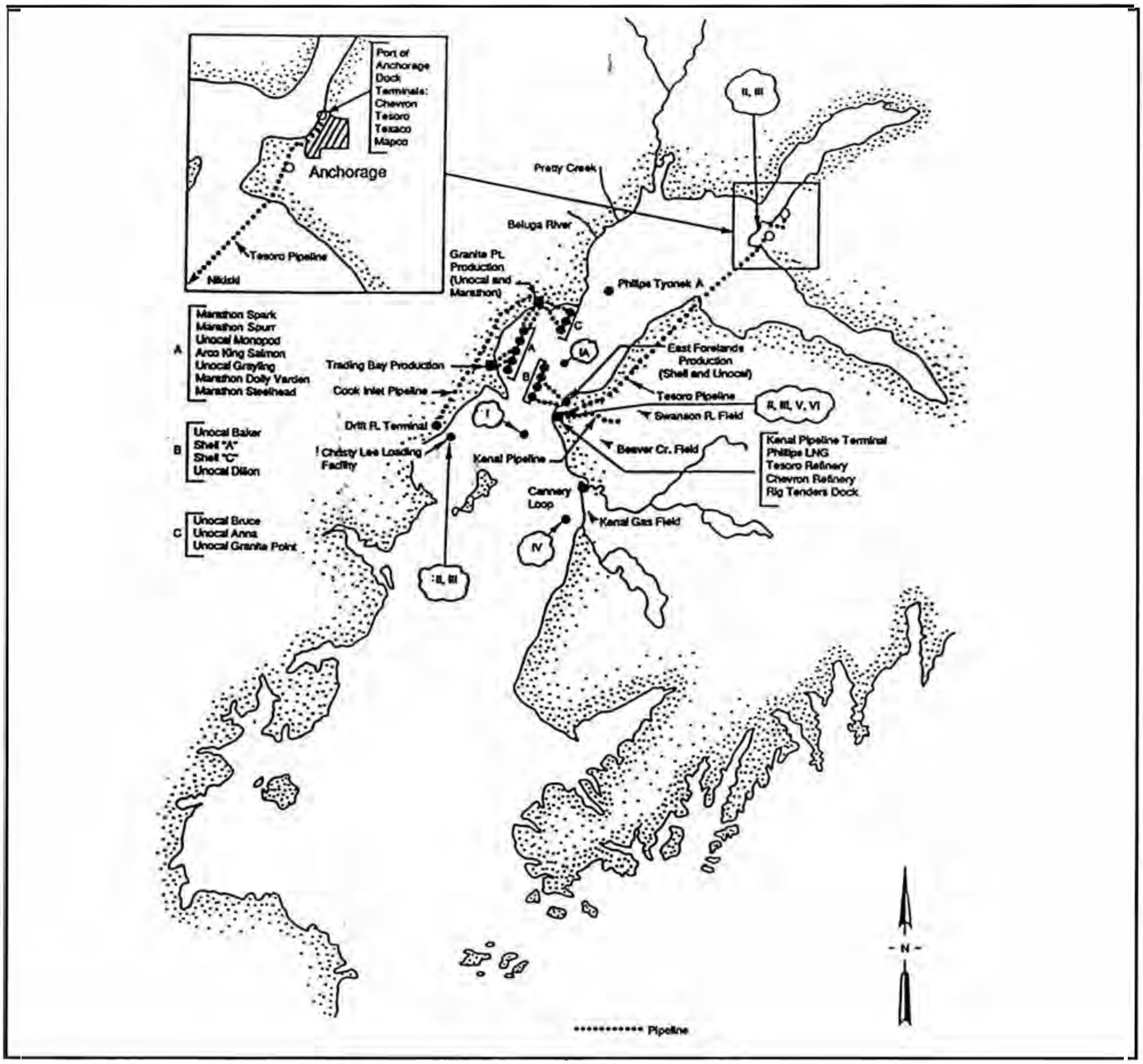
- Improvements in planning training exercises to ensure that training goals are accomplished.

Continued

- Improvements in equipment reliability to ensure that trainees have confidence that equipment will perform in an actual emergency
- Improvements in the realism of spill response training by devising exercises that are typical of a wide range of spill scenarios.
- Preapproval of in situ burning and dispersant application under predetermined climatic conditions when spill response equipment is unable to function; *e.g.*, spill in broken ice.
- Use of standardized electronics and communication equipment.
- Arranging for use of fishing vessels as backup response vessels.
- Arranging for additional backup capacity for recovered oil storage when responding to very large spills.

In summary, this QRA provided an objective basis for cooperative members to identify sources of petroleum spills and the resources needed to respond to these spills. It also provided an equitable basis for funding the resources recommended for responding to potential spills after each participant had implemented risk reduction measures. Most importantly, the risk analysis provided a "living" risk-based allocation of oil spill response resources as changes occur in the petroleum industry activities of Cook Inlet.

Figure 5. Recommended Location of Oil Spill Response Resources



RISK ASSESSMENT OF SMALL FISHING VESSEL TRAP NET OPERATIONS

Todd Schauer, Barry Romberg, Changben Jiang, and
Armin W. Troesch

This paper describes a means by which the capsize risk associated with various fishing vessel operating conditions can be evaluated. Rather than relying on the static restoring moment curve as the primary criteria for vessel safety, modern nonlinear systems analysis is applied to the problem of extreme nonlinear rolling in random beam sea. While the method is quite general and not limited to small vessels, it is illustrated with a specific application involving Native American trap net fishing on the upper Great Lakes. General trap net operations, as practiced by Native American fishermen and women in the Grand Traverse Bay region, are presented in detail. The most significant characteristic of trap net operations is the heel induced during net deployment and net lifting. The increased risk to the vessel, in terms of the increased probability of capsize is qualified for various heel angles and various sea states. A significant advantage of the capsize analysis method presented here is its ability to investigate quickly the effects of many parameters (e.g., trap net line tension, wave height, and/or wave period) on a nonlinear dynamic system without having to resort to extensive simulation studies.

INTRODUCTION

The rights of Native Americans to hunt and fish in the Great Lakes region were established through treaty agreements with the Federal government in the 1800s. In the twentieth century, commercial fishing and later sport fishing, in addition to the inadvertent introduction of foreign exotic species such as the sea lamprey and alewife, have placed tremendous pressure on the native commercial fishery. One consequence has been challenge to and an examination of Native American Treaty-fishing. In order to resolve long-standing disputes, the Bay Mills Indian community, Sault Ste. Marie Tribe of Chippewa Indians, and the Grand Traverse Band of Ottawa and Chippewa Indians, and the State of Michigan and Federal government, with input from various sport fishing organizations, established the 1985 Consent Agreement (GLIF&WC, 1991). A result of the agreement, which is dedicated to the conservation and enhancement of valued fish stock, is the proposal to evaluate trap net fishing as an alternative to the traditional Native American gill net fishing method. The gill net is allegedly indiscriminate in the fish it catches, and because of the basic design of the gill net, fish are alleged to almost always be dead when extracted from the nets. The groups opposing gill net fishing claim that the inadvertent harvest of fish such as Lake Trout is depleting a large sport fishery. The trap net, a more complex and expensive fishing system, is designed to hold fish alive until returned to the water, thus potentially preserving sport and commercial fish stocks.

Depending upon the technique of the individual boat crew and the boat size, there can be significant operational differences between trap netting and gill netting. The trap nets are usually taken in over the side, producing a steady heeling moment. In addition, the deployment of the trap net requires the vessel to be fixed in a particular orientation, possibly heeled, for periods of up to two hours. During the deployment phase, reorientation of the vessel may not be possible without completely disconnecting from the trap net lines. Conversely, gill nets are generally draped transversely across the deck, or taken over the bow, producing little change in the vessel's upright position. Nearly three-fourths of the Tribal boats engaged in net fishing are small, trailered boats of 16 feet (5 m) to 25 feet (7.6 m) in length. In these small vessels, the overturning moment of the trap net lines affects a significant heel bias, and the trap netting operation may present an additional safety hazard in rough weather. The goal of the work described in this paper is to arrive at quantitative estimated of the possibly increased capsize risk due to various operational conditions.

It should be emphasized here that Treaty-fishing is a complex and sometimes disputed topic. The State of Michigan, the U.S. Fish and Wildlife Service, the Chippewa-Ottawa Treaty Fishing Management Authority and three 1836 Treaty Tribes have invested considerable time and resources on jointly resolving this issue. In addition to the difficult technical problems, there are sociological, economic, and political aspects as well. With these other, primarily nontechnical, factors influencing the ultimate outcome of the dispute, this paper will in no way endorse a particular course of action or advocate one fishing system over another. The authors' intent is to describe a methodology, based upon first principles, that will allow for the quantitative determination of risk levels for the various hull and fishnet configurations. Given an accurate technical evaluation of the different options, the interested parties may then use this information in their deliberations and arrive at a more informed decision than otherwise may have been available.

TRAP NET FISHING

This section describes the technical and operational aspects of the Native American trap net fishery on the Great Lakes with a primary focus on stability considerations for the subject vessels. The research was conducted by the faculty and students of the University of Michigan, Department of Naval Architecture and Marine Engineering with logistical support provided by the Grand Traverse Band (GTB) Biological Station of Ottawa and Chippewa Indians and the U.S. Fish and Wildlife Service. The primary data was collected in Sutton's Bay, Michigan, near the site of the GTB Biological Station. The technical analysis was completed for two vessels. The first is the Harry Robert, a 27 foot (23 m) vessel presently being used for trap net fishing by GTB fishermen and women. The second is a 22 foot (6.71 m) vessel recently delivered and simply named Schafer boat after its builder. (See Figures 1 and 2, respectively). Of relevance to this paper are trap net fishing operations with specific concerns for the normal working loads experienced by the fishing vessels. Measures of stability have been calculated for each of the above based on the working loads observed. The

Figure 1. Trap net boat HARRY ROBERT

stability results are presented in the following sections.

DESCRIPTION OF FISHING BOATS

Trap nets when compared to gill nets (widely used by the Native American fishery) are larger and more complicated and thus the boats required to operate the trap nets are larger and more complex than the typical gill net boat (C-OTFMA, 1990). With the increased size and expense of operation, the normal catch of fish is increased as well and the results is that more is required of a trap net boat. These additional requirements include an open flat deck for setting and lifting the net, a winch

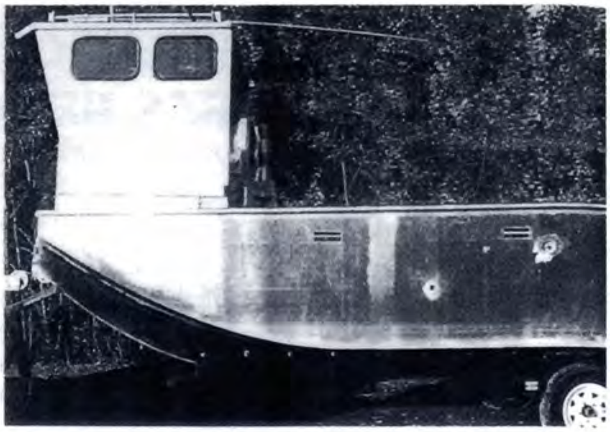


Figure 2. Trap net boat SCHAFER

for conducting net operations, an enclosed deck with fish hold for handling the larger catch, adequate structural strength to handle high transverse winch loads, and adequate stability to conduct operations with higher net loads and more weight on deck. The two boats involved in this research, i.e., Harry Robert and Schafer, were designed to be trap net boats and the analysis in this paper will evaluate the stability of these boats while they conduct these operations. Body plans for the two vessels are shown in Figures 3 and 4 and the principals particulars in Table 1.

The typical trap net boat is a fairly flat-bottomed boat with hard chine and a high freeboard. These boats have a small cockpit forward to allow for a maximum amount of deck space for conducting net operations. (See Figure 5). In addition, there are no obstructions aft on the boat since during operations net, anchors, and

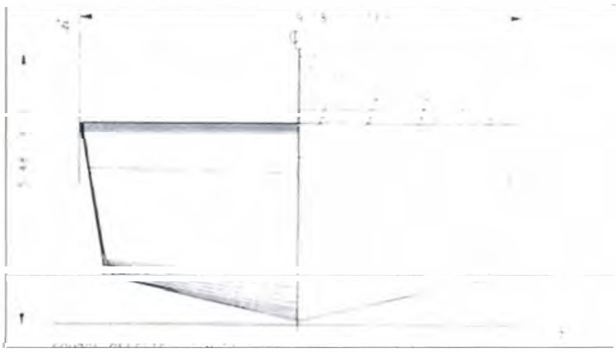


Figure 3. Body plan for HARRY ROBERT (LBP-25.2 ft)

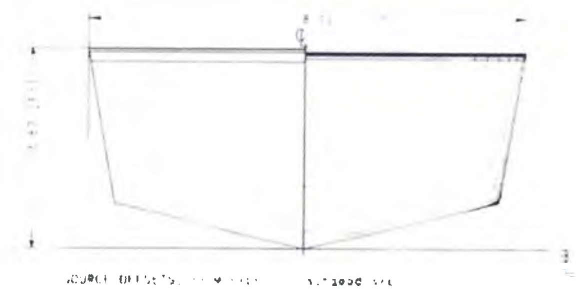


Figure 4. Body plan for SCHAFER 9LBP 21.9 ft)

Characteristic	*Harry Robert*	*Schafer*
Length (LOA)	27 ft (8.23 m)	22 ft (6.71 m)
Beam	9 ft (2.74 m)	8 ft (2.44 m)
Draft	1.45 ft (0.442 m)	1.2 ft (0.366 m)
Freeboard	2.8 ft (0.853 m)	2.6 ft (0.792 m)
Displacement (crew and nets)	8300 lbs (36 900 N)	6000 lbs (26 900 N)
Displacement (crew and fish)	9200 lbs (40 900 N)	6900 lbs (30 700 N)
Roll natural period	2.2 sec	2.4 sec

Table 1. Vessel characteristics for HARRY ROBERT and SCHAFER

Figure 5. Relative size of HARRY ROBERT and SCHAFER

lines under tension must be slid off the back of the boat. For this reason an inboard/out drive engine is a major advantage over an outboard motor.

DESCRIPTION OF TRAP NET FISHING OPERATIONS

Trap net operations can be divided into three categories:

(1) setting the net in the spring at the beginning of the season; (2) lifting the net to take in a catch; and (3) pulling the net in the fall end of the season. Each of these operations represents a complex progression of steps which requires skillful operators and which places a variety of different loading conditions on the boat. Before discussing the three operations in detail, the basic trap net will be described.

As seen in Figure 6), the trap net is a complicated combination of net, anchors, floats, and line. The net consists of a long lead net and "wings" that direct the fish into the "tunnel" and then into the "pot" where they are held until the net is lifted. The nets are categorized by the height of the net off the bottom and typical sizes are 20-40 feet (6.1-12.2 m). A typical 30-foot (9.1 m) net with all required setting gear has a dry weight of approximately 800 pounds (3500 N). Trap nets of this size are usually set in 90-120 feet (27.4-36.3 m) of water.

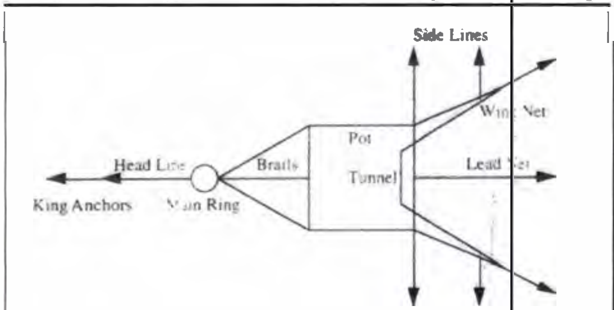


Figure 6. Schematic of trap net components (plan view)

SETTING THE NET

The first step is to set the lead net (approximately 1200 feet (366 m) long). (See Figure 7.) This is done by setting a king anchor which is attached to the end of the lead net and motoring the boat forward while the net pays out over the stern of the boat. When the full length of lead net is out, the head line is attached to the net end and the two king anchors for the headline are set.

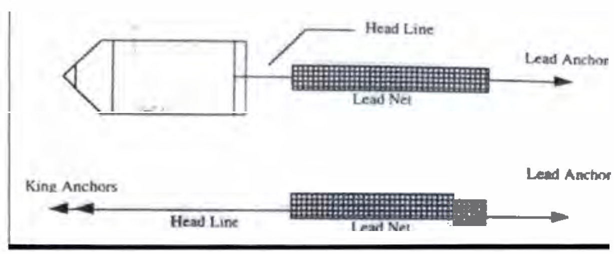


Figure 7. Schematic of setting lead nets

The boat then returns to the headline end of the lead net which is marked with a buoy and lifts the end of the net to the surface with the winch to prepare for the setting of the "wings " and "pot".

Approximately 20 feet (6.1 m) to 30 feet (9.1 m) of net is brought on board and tied off to the boat and the winch is then used to place moderate tension on the net

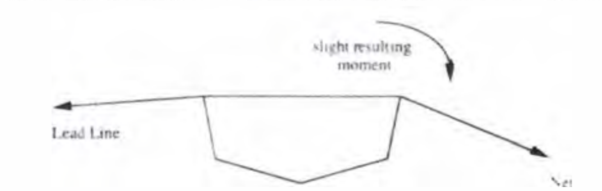


Figure 8. Schematic of boat position during wing net setting

Figure 9. HARRY ROBERT during wing net setting

Continued

and headline. The boat essentially sits perpendicular to the net and headline at this point and experiences side forces pulling out on each side of the boat. (See Figures 8 and 9.) The trap net boat remains in this configuration for approxi-mately 90 minutes while the remainder of the net is set.

The next step is the "wings". Here the procedure may vary depending on the crew and boat. Some fishermen use a smaller skiff with outboard motor to assist in this, others do not. With a skiff, anchor is attached to the end of each wing net and one at a time the skiff pulls the net off the primary and drops the anchor when it is tight. (See Figures 10 and 11). There are six anchors attached at various locations to the wing nets that are set by the skiff. The purpose of the anchors is to hold the wing nets in position and under tension. While the skiff is setting the wings, the trap net boat

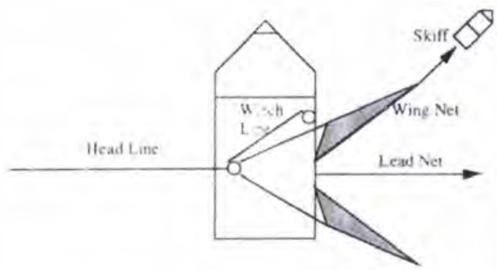


Figure 10. Schematic of setting of wing nets

Figure 11. HARRY ROBERT and skiff setting wing nets

experiences a variety of torques that tend to spin the boat away from perpendicular to the headline. There is very little heeling moment placed on the trap net boat however. If a skiff is not used, the wings are set by tossing the anchors out of the trap net boat marked with buoys. When the net is set loosely, the crew return with the main boat to each anchor to put more tension on them.

Once the "wings" are in position and anchored, the "pot" is then set. This requires a new cross deck line configuration of the trap net boat. (See Figure 12.) The winch is used to tension the headline on the port side of the boat while the pot net pays out to starboard. Once the

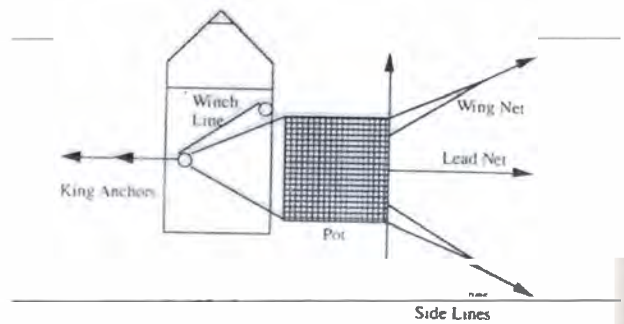


Figure 12. Schematic of setting pot

brails are over the side, the net is ready for final tensioning.

In the tensioning stage, the main ring attaching the headline to the pot lead lines is fixed in a cross deck fashion to the port side of the trap net boat. The winch is then used to tighten the headline over the port side until heavy tension is obtained. A stopper is then placed to hold the headline snug while the loose end of the headline is removed from the winch and tied to the main ring. Once the headline is secure to the main ring, the ring is freed from the side of the boat and the stopper is released. Finally, the headline is slid off the stern of the boat and the net is set. It should be noted that during the tensioning process, the heeling moments are quite small since the tensioned lines extend from each side of the boat and cancel each other's heeling effect. There is an overall downward force on the boat which is related to in net setting.

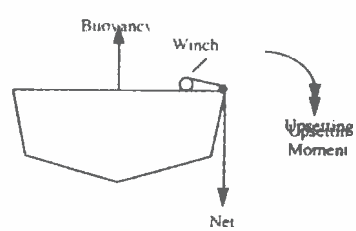


Figure 13. Schematic of forces during net lifting

PULLING THE NET

The pulling procedure was not observed but was discussed in length with the GTB fishermen. The setting process is essentially reversed but pulling the net back on board requires a different technique. A large hydraulic reel is placed either on a side gunnel or amidships on deck to retrieve the net. The reel sizes vary from 3 to 6 feet (0.9-1.80 m in diameter). (See Figure 15.) The concern with this part of the operation is that the weight of the net will be high off the deck and will combine with the heeling moment of reeling in the net to

Figure 14. SCHAFER during net lifting

possibly result in an unsafe stability condition. Further investigation and observation of the procedures are required before any definitive conclusions can be made, however.

FIELD MEASUREMENTS

The Harry Robert was the trap net vessel of primary observation and experimentation. the vessel loading data was obtained through monitoring actual fishing operations and is presented here. In additional, an inclining experiment and a roll decrement test were also conducted.

A protractor inclinometer was used during fishing operations to observe angles of heel for different steps of the operations. To translate heel angles to line tension the ships' GZ curve must be known. The GZ curves of both the Harry Robert and the Schafer boat for the loading conditions encountered during the observations are shown in Figures 16 and 17. Using curves similar to this in conjunction with the ships' displacement and heel angles during times of operation, a calculation of heeling moment and associated line tension can be made. For example, if the displacement of the Harry Robert during "lifting" (Figure 13) is 7550 pounds (2300 N), then the

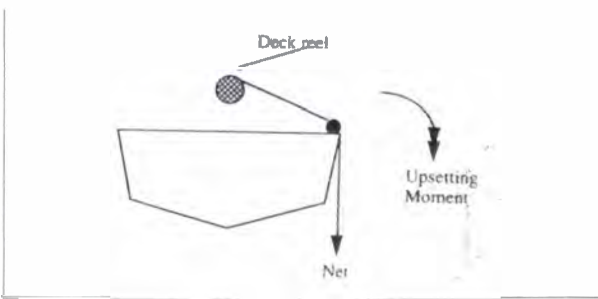


Figure 15. Schematic of forces during net pulling

righting moment at 6.5 degrees is approximately 3780 foot-pounds (5125 N-m). For a net line moment arm qual to half beam, i.e., 4.5 feet (1.37 m), the line tension then can be estimated to be 840 pounds (3740 N). This line tension is independent of vessel and can be assumed to act, under similar conditions, on any trap net boat creating a bias angle.

In general, a bias angle could be equated to any steady moment induced by external forces (e.g., wind, mean wave drift force, or total line tension). Since the wind was light during this experiment, it had little effect and was neglected. The waves induce a time varying heel angle oscillation which amounted to 0.5-1.0 degrees during the observations made on the Harry This time dependent wave motion had an effective mean of zero. It was assumed, therefore, that the total observed angle was due to net line tension.

Setting the net took approximately two hours. As described in the previous section, the operation consisted of: setting the lead anchors and net, setting the wing anchors, and tensioning the net. The first step, setting the lead anchors, took approximately 30 minutes and exhibited no significant stability problems. The second step, setting the wing anchors, took approximately 45 minutes and required the vessel to remain at a constant heading held by the headline. (See Figure 9.) Heel angles observed during this phase were only 1-2 degrees so reduced stability was not a major concern. It then took approximately 15 minutes to arrange the rest of the net for launching. After the net was launched, it was tensioned with the winch.

It is this phase of setting operation that puts the vessel at significant risk. Heel angles were observed only to be 2-3 degrees but the vessel has loads that pull symmetrically on the beam that prohibit the hull from reacting to incident waves. This condition is a risk more for the inability of the vessel to maneuver and escape in an emergency than it is for stability considerations associated with large heel. Due to the side forces and line attachments, there is a period of approximately 10 minutes where the fishing boat is locked into a position as shown in Figure 18.

The lifting part of the trap net operations took approximately 25 minutes. It was during the first five minutes of this phase that the vessel was at the highest risk. As shown in Figures 13 and 14, the net must be hoisted to the water surface so it can be emptied. The amount of heel is directly proportional to the number of fish and the amount of sea growth in the net and the speed at which it is lifted. For the lifting operations observed, the mean heel angle was 7 degrees for the largest net and the largest catch. During these five minutes, the boat was subjected to wave forces that

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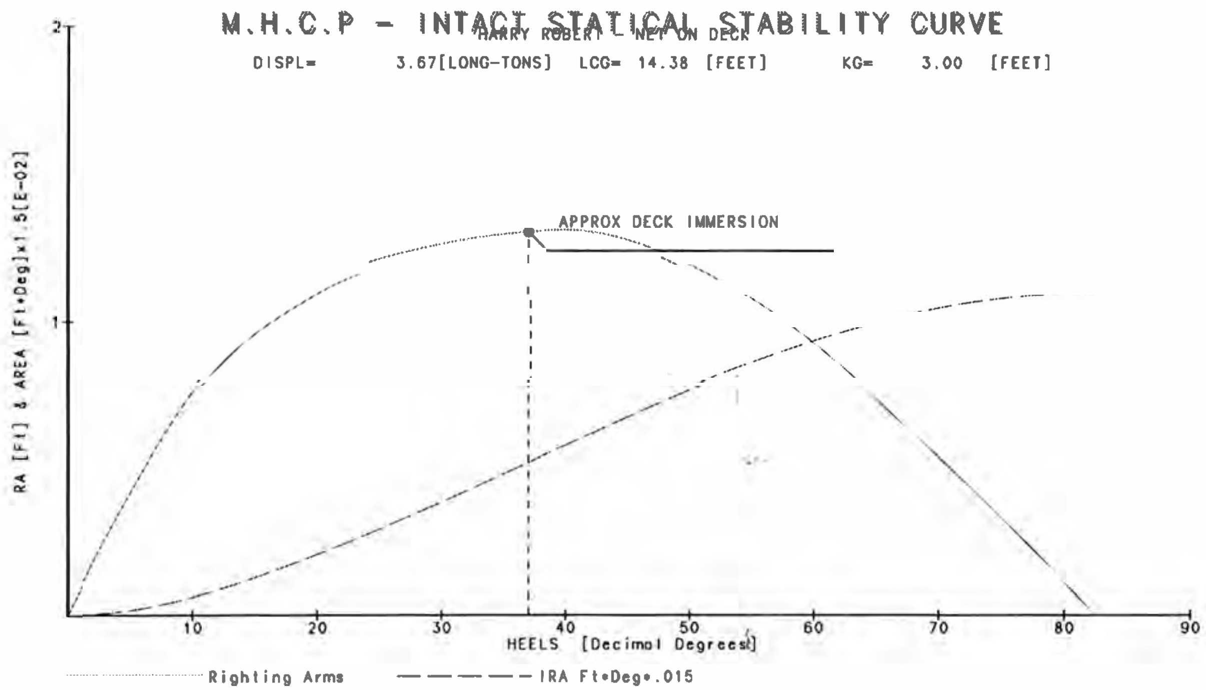

Figure 16. Righting arm curve for HARRY ROBERT

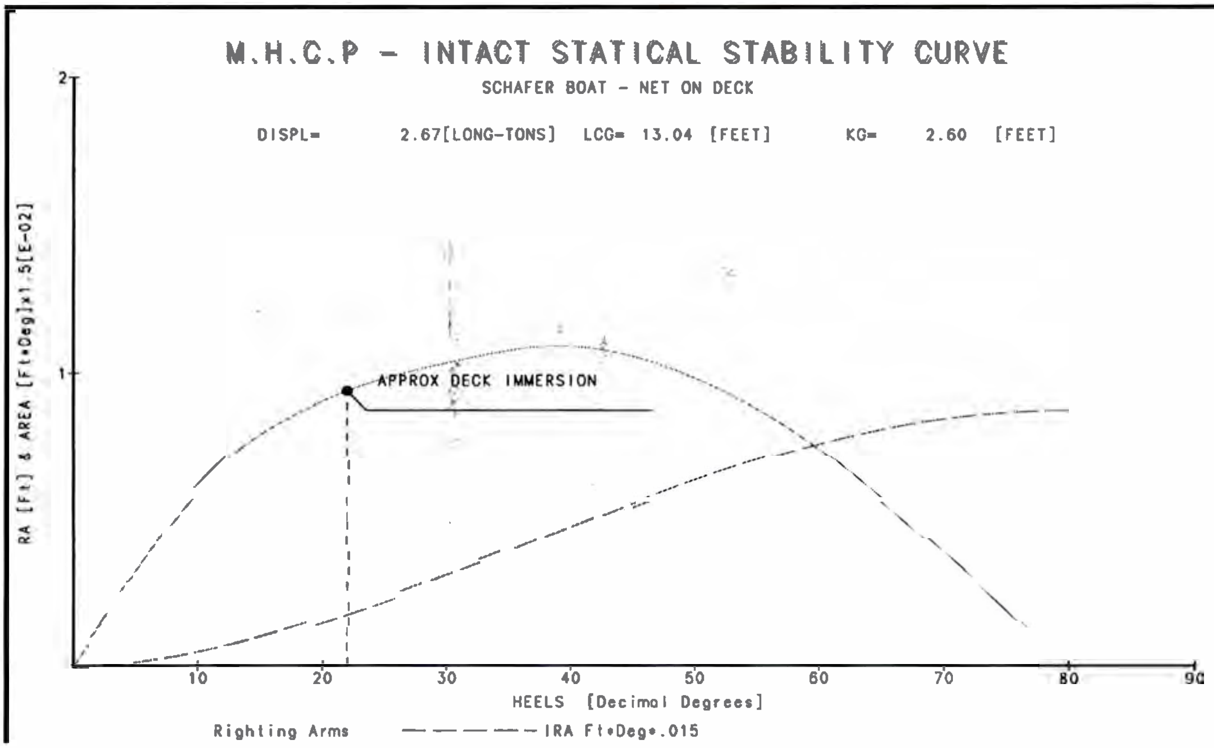

Figure 17. Righting arm curve for SCHAFER

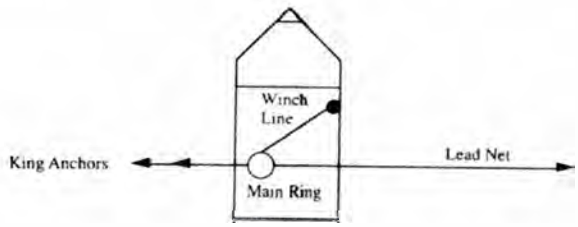

Figure 18. Schematic of tensioning operation

caused dynamic heel angles which oscillated between 4 and 10 degrees, but the static load caused no more than an average of 7 degrees. For the rest of the sequence, the net was drawn to the side of the boat for emptying. Heel angles of 2-3 degrees were observed with all crew members to the side of the boat with the net in the water.

The pulling operation was not directly observed, but has been estimated to produce large angles of heel and a rise in the vertical center of gravity. As seen in Figure 15), a deck reel is utilized to haul and store the net. The maximum size of the deck reel for these size boats is approximately 6 feet, which could have a significant impact on the vertical center of gravity toward the end of the haul when most of the net is on board. This operation reportedly takes approximately 30 minutes with a maximum heel range of 10 to 12 degrees.

GRAND TRAVERSE BAY WEATHER ESTIMATES

Of primary concern in our analysis are the wave heights that the fishing vessels will be experiencing. For the two boats evaluated in this report, the operations area is limited to Grand Traverse Bay in northwest Michigan. Presently, as part of a tribal experiment in comparing gill net and trap netfishing, trap net vessels are limited to fishing on the east side of the bay while gill-netting is restricted to the west side Wave information for upper Grand Tranverse Bay was obtained from the Army Corps of Engineers hindcast wave information for Lake Michigan (Hubertz et al, 1991). The publication is a summary of wave data taken over a 32 year period for different locations on the lake. The closest station to Grand Transverse Bay is approximately 5 miles (1.6 km) due north of the mouth of the bay and generally representative of conditions in the trap net area.

Due to the north and south alignment of Grand Traverse Bay, the only waves that can have any fetch at all are those due to northerly and southerly winds. North winds could build wave with significant fetch from the northern Lake Michigan and south winds could produce waves with 10-15 miles (16-24 km) of fetch up the bay. The narrow bay restricts any wave development from the east or west. When extracting data from the hindcast information only north and south azimuths were considered for the station due north of the mouth of the bay. Since the wave station is in line with the bay north and south, the wave conditions due to north or south winds at the station can be assumed to be the same as inside the bay.

Table 2 contains the pertinent wave information. Of main interest is the probability table for waves of varying heights and the distribution of wave periods. This data will be useful in a final risk assessment of the vessel stability. As expected, waves and wind out of the north tend to be much larger and more frequent than those from the south.

CAPSIZE RISK ANALYSIS

Given the trap net boat hull characteristics including hydrodynamic data (e.g., length, beam, GZ curve, roll damping, etc.), the various operational scenarios (e.g., induced mean heel angles, positioning of vessel), and environment (e.g., incident wave height, wind velocity, and wave period) a first principles risk analysis would explore the influence of the various parameters on the risk of capsize. For example, the increased probability of capsize relative to an upright vessel could be determined for a hull heeled 8 degrees and exposed to beam seas for 30 minutes. With this information available, a rational evaluation could then be made as to whether similar operational conditions constituted an acceptable or unacceptable level of risk. Unfortunately, as demonstrated in the next section, this type of analysis is beyond the capabilities of currently used stability calculations.

"Existing general stability criterion based solely on ship statics is no applicable to small boats which are the most likely to be lost in storms" (Hutchison, 1990). Large amplitude rolling motion is not static but rather a highly nonlinear dynamical process. Understanding this nonlinear dynamic phenomenon on a fundamental level is the only way to improve stability standards. In the past fifteen years, several methods dealing with nonlinear rolling have been proposed. Many are perturbation related, based upon the assumption that the restoring force is weakly nonlinear. Examples of this for periodic forcing are given by Nayfeh and Khdeir (1986, a, b). This assumption of weakly nonlinear motions may be true when the ship rolls in the range far from capsizing but is certainly untrue when ship motion becomes dangerous. Simulation, which is not restricted to certain forms of the restoring force, has been used and combined with the concepts of safe basin and basin erosion for deterministic and stochastic forcing, e.g., Thompson (1990) or Thompson, et al (1992). However, simulations, which are time consuming, are generally inconclusive unless exhaustive studies of the parameter

Continued

Probability Tables—This is a representation of probability of experiencing waves of given height from the specific sector of wave directions		
Height, m	**349°–010° T**	**168°–192° T**
0.00–0.23	0.01733	0.02375
0.24–0.49	0.01437	0.01800
0.50–0.74	0.02583	0.01123
0.75–0.99	0.00980	0.00130
1.00–1.24	0.00883	0.00014
1.25–1.49	0.00252	0.00004
1.50–1.74	0.00139	0.00001
1.75–1.99	0.00025	0.00000
2.00–2.24	0.00018	0.00000
2.25–2.49	0.00013	0.00000
2.50–2.75	0.00003	0.00000

Central Wave Information—Expressed as a percentage

Height, m	349°–010° T	168°–192° T
% of total	13%	11%
0.0–0.4	40%	75%
0.5–0.9	41%	24%
1.0–1.4	16%	1%
1.5–1.9	2%	0%
over 1.9	1%	0%

Station M34 45.35N 85.53W Azimuth (deg) = 0.0 Percent Occurrence (×1000) of Height and Period by Direction

Height, m	Peak period (sec)										Total
	3.0	3.0–3.9	4.0–4.9	5.0–5.9	6.0–6.9	7.0–7.9	8.0–8.9	9.0–9.9	1.0–10.9	11.0–longer	
0.00–0.24	1499	222	11	1							1733
0.25–0.49	188	1214	34	1							1437
0.50–0.74		1685	874	24							2583
0.75–0.99		2	904	74							980
1.00–1.24			818	64	1						883
1.25–1.49			152	98	2						252
1.50–1.74			3	118	18						139
2.75–1.99				19	6						25
2.00–2.24				10	8						18
2.25–2.49				1	12						13
2.50–2.74					3						3
2.75–2.99											0
3.00–3.24											0
3.25–3.49											0
3.50 –											0
TOTAL	1687	3123	2796	410	50	0	0	0	0	0	

Mean HS = 0.6 Largest HS(M) = 2.7 Mean TP (sec) = 3.3 No. of Cases = 7554

Station M34 45.35N 85.53W Azimuth (deg) = 180.0 Percent Occurrence (×1000) of Height and Period by Direction

Height, m	Peak Period (sec)										Total
	3.0	3.0–3.9	4.0–4.9	5.0–5.9	6.0–6.9	7.0–7.9	8.0–8.9	9.0–9.9	1.0–10.9	11.0–longer	
0.00–0.24	2056	300	19								2375
0.25–0.49	534	1258	8								1800
0.50–0.74		1117	6								1123
0.75–0.99		75	55								130
1.00–1.24			14								14
1.25–1.49			4								4
1.50–1.74			1								1
2.75–1.99											0
2.00–2.24											0
2.25–2.49											0
2.50–2.74											0
2.75–2.99											0
3.00–3.24											0
3.25–3.49											0
3.50 –											0
TOTAL	2590	2750	107	0	0	0	0	0	0	0	

Mean HS = 0.3 Largest HS(M) = 1.5 Mean TP (sec) = 2.5 No. of Cases = 5100

Table 2. Environmental wave data for Upper Grand Traverse Bay (Hubertz et al, 1991) Army Corps of Engineers data. Station No.: 34. Lat 45.35 N, Lon 85.53 W. Location is approximately 5 miles due north of mouth of Grand Traverse Bay. Depth at station is 85 m

space are performed and thus not suitable for establishing stability standards. If the excitation is random, the method proposed by Roberts (1982, 1985) can handle highly nonlinear restoring forces, but still fails to give a realistic prediction for extreme motion." (Jiang et al, 1994)

In a recent series of papers, the global geometric method employing Melnikov analysis has been used to study ship stability. Falzarano et al (1992) applied the method to study capsizing in regular sinusoidal waves. Global analysis techniques have also been applied to periodic and parametric forcing, with and without bias (Esparza and Falzarano (1993) and Bikdash et al, 1994). Hsieh et al (1994) have successfully applied the Melnikov function method to an unbiased vessel in random beam waves. Jiang et al (1994 a, b) extended it to a biased vessel with arbitrary restoring force and random excitation.

The examples described here are applications of the global analysis technique given by Jiang et al (1994 a, b) Details of the theory can be found in those publications. We will state here simply that the random nature of the seaway and its impact on vessel stability are included in a nonlinear, biased, single degree-of-freedom model. Appendix 1 gives a short summary of the method.

Briefly, traditional stability analysis is based upon the righting arm curve, e.g., Figures 16 and 17. By expanding the roll analysis to include the vessel's distribution of mass (i.e., roll mass moment of inertia), the stability characteristics can be expressed in the roll angle-roll velocity phase plane This phase plane representation, unlike the more commonly used but relatively restrictive GZ curve characteristics of GM, area under the GZ curve, and angle of vanishing stability, now includes the nonlinear roll natural frequency and preliminary estimates of safe basin boundaries. (The "safe basin" refers to those initial conditions in the phase space which can be safely integrated forward in time without leading to capsize. The basin boundaries are the lines separating safe area from unsafe area, or in other words, separating initial conditions into sets which will or will not lead to capsize.) By next including the vessel's roll damping characteristics and the spectral density shape of the incident waves, a probabilistic estimate of capsize can be made.

Based upon phase flux concepts (*e.g.*, for general theory see Wiggins, 1990, 1992 and for applications related to ships see Falzarano *et al.*, 1992, Hsieh *et al.*, 1994, or Jiang *et al.*, 1994 a) the wave height at which phase flux becomes "significant" (H^*s) can be estimated from equation 1, below:

$$H^*s = \frac{\sqrt{2\Pi}M_\delta}{2\sigma_1}$$

M_δ is the mean part of the Melnikov function, directly related to the system nonlinear stiffness, inertia, and linear and quadratic roll damping; and σ_1 is the rms value of the time-dependent part of the Melnikov function, directly related to the roll exciting moment, the incident wave spectra, and the solution of the nonlinear undamped, unforced roll equation of motion.

The quantities, M_δ and σ can be calculated in a straight forward manner on typical engineering desktop workstation. See Appendix 1.

Increased transport of phase space from safe areas to unsafe areas in the phase plane physically implies increased likelihood of capsize. While there currently does not exist an explicit relationship between phase flux and capsize probability, comparisons between theoretical predictions and numerical simulation have established a direct, albeit empirical, correlation (Hsieh et al. 1994 and Jiang el al, 1994 a). Based upon these studies, the wave height where the vessel has a probability level of capsized 1/n, H , can be expressed as

$$H = \beta(n;T)H \qquad \textit{Equation 2}$$

where b*(n;T)* is constant for a given ship dependent upon the time of exposure T and the probability risk level. *1/n.* The function, b*(n;T)* is determined through comparison of H with a limited set of simulations. Typically, the value of β is based upon phase flux simulation comparisons where the mean period of the incident waves matches the vessel's natural frequency in roll. This approach is conservative since studies have shown that by selecting a certain probability level of capsize at roll resonance, the risk of capsize at non-resonant encounter frequencies is over estimated. (See Figures 11-13 in Jiang et al, 1994 a.) An example calculation of b*(n:T)* for the Harry Robert is given in Appendix W.

Before equation (2) is applied to the two vessels considered here, the GZ curves for *HARRY ROBERT* and *SCHAFER*, Figures 16 and 17 have to be modified. The flat deck vessels with nets on deck, *HARRY ROBERT* and *SCHAFER*, have angles of vanishing stability, ϕvanish, or that the water trapped on deck and capture in the lower holding tanks will not adversely affect the vessels' stability. For these reasons, the two vessels GZ curves have been adjusted to reflect shifting cargo that is nearly fluid in behavior for large heel

Continued

angles and lost righting arm area due to trapped water. It is assumed that the curves remain approximately unaltered up to the angle of deck immersion. The following Sarchin and Goldberg (1962), the heeling arm correction follows a cosine curve resulting in a reduced

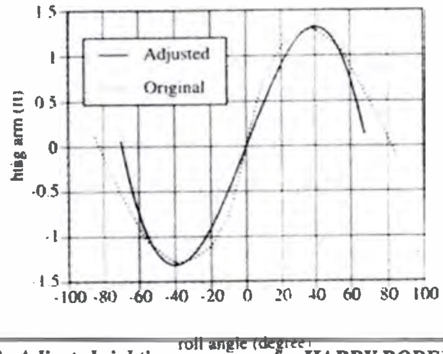

Figure 19. Adjusted righting arm curve for HARRY ROBERT including effects of cargo shifting

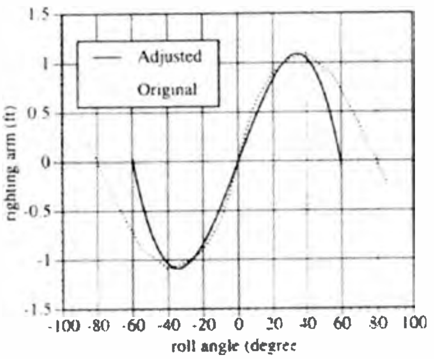

Figure 20. Adjusted righting arm curve for SCHAFER including effects of cargo shifting

area (approximately half of the original area beyond the angle of vanishing stability) and lower values for ϕvanish. To simplify the calculations of the examples used in this paper, the resulting curves were fit to a cubic polynomial. A higher-order polynomial can be used for the general case. The final results are shown in Figures 19 and 20 where the original and modified GZ curves are given. The authors recognize that the effects of trapped water and shifting fish and ice are only modeled approximately and may require further refinement if additional accuracy is warranted.

Based upon the modified GZ curves, the critical wave height, H^* in Equation 1, was calculated for a variety of wave periods and heel angels. The spectral density function of the lake waves was based upon a calibrated ISSC two-parameter spectrum. The assumed vessel operating conditions were for fish on deck and in the holding tanks; a worst case scenario. For a risk level of $1/n = 0.1$, the value of β becomes approximately 0.17

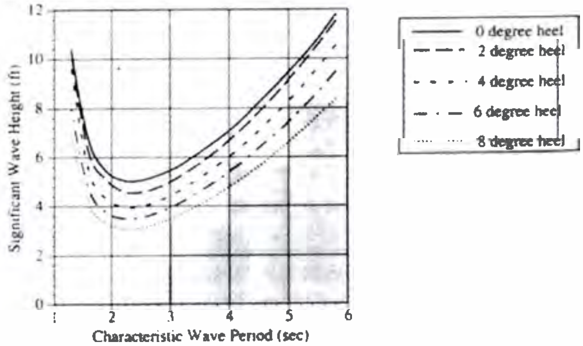

Figure 21. Significant wave height vs wave period for HARRY ROBERT corresponding to a capsize probability of less than 10% when exposed to beam seas for 34.2 min. Shaded areas are extent of observed wave conditions in Upper Grand Traverse Bay as given in Table 2.

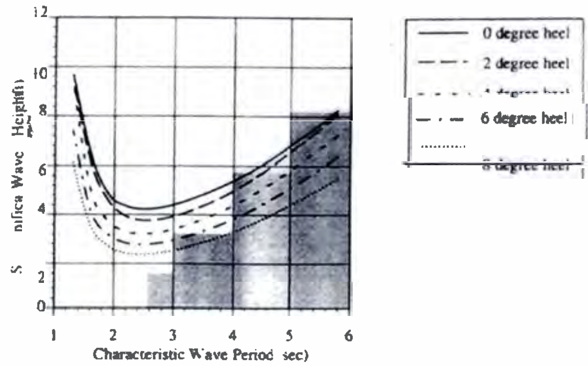

Figure 22. Significant wave height vs wave period for SCHAFER corresponding to a capsize probability of less than 10% when exposed to beam seas for 34.2 min. Shaded areas are extent of observed wave conditions in Upper Grand Traverse Bay as given in Table 2.

for the Harry Robert and 0.21 for the *SCHAFER*. (See Appendix 2). Curves showing the significant wave height and mean period where capsize has a 1/10 probability of occurring in thirty-four minutes [i.e., H 1/10, equation with a dynamic analysis the highest risk of capsize, whether the boats are in the heeled or unheeled condition, occurs when the mean period of the incident waves approximately matches the roll natural period. Also shown in Figures 21 and 22 as shaded areas is the extent of the recorded significant wave heights and wave periods in the Grand Traverse Bay area. Note that the largest significant wave heights at any wave period have the smallest probability of occurring.

Risk levels for different angles of heel can be determined from the plots. What is significant, is that the value of $H1/n$ for $n = 10$ in a lake storm with a wave period of 4 secends suggests the unbiased vessels can operate safely for an exposure time of 34.1 minutes in seas up to 7.1 feet (2.2 m) and 5.5 feet (16 m); *HARRY*

ROBERT and *SCHAFER*, respectively. However, when heeled over with a mean angle of 8 degrees, the safe wave heights with the same risk level as for unheeled vessels have been reduced to 4.8 feet (1.5 m) and 3.4 feet (1.0 m) Table 2 indicates that waves with significant wave heights of 3.28-4.07 feet (1.0-1.24 m) and wave periods between 4.0 and 4.9 seconds occur less than 0.8% of time. If is assumed that the Great Lakes storms are uniformly distributed throughout the calendar year (a conservative assumption since the more severe storms are likely to occur in November or December, months when there are no fishing operations), the probability of a heeled *SCHAFER* capsizing in any 34-minute operational window is of the order of 10 -4. For the *SCHAFER* in the upright condition, the value of H1/n for n = 10 increases to 5.5 feet (1.6 m), a much less likely wave height. Using again the information of Table 2, a similar analysis shows that the probability of an unheeled *SCHAFER* capsizing in any 34-minute operational window is now reduced to the order of 10-7. The actual significance of the probability levels is subjective; however, the analysis suggests that practical limiting sea states for the *SCHAFER* and *HARRY ROBERT* in the heeled conditions are 3 feet (0.9 m) and 4.5 feet (1.4 m), respectively. If the vessels are upright with zero heel, the practical limiting sea states increase by approximately 2 feet (0.61 m)

The heel angle of 8 degrees requires different line tensions for the two boats, but is consistent with the differences in fishing gear and net size. While these calculations are highly dependent upon the individual vessels loading condition, they clearly demonstrate and quantify the increased risk of heeled vessels over unheeled vessels.

DISCUSSION OF REGULATIONS

The intent of this section is to explain the application of U.S. Coast Guard regulations with respect to stability evaluation of vessels in the Native American fishing fleet. It is worth noting that stability regulation for small commercial fishing vessels is presently a major concern of the Coast Guard and several proposed rules in this category are still pending (DOT/USCG 1991 and 1992). Currently there exists no rule governing this size of vessel.

Recent changes in fishing vessel regulations date tack to 1988 when the Commercial Fishing Industry Vessel Safety Act was passed. The rule directed the Secretary of Transportation and the U.S. Coast Guard to prescribe regulations for operational safety of fishing industry vessels which were previously unregulated as a specific category. The driving force behind the regulation was a large number of accidents and high fatality rates among the fishing fleet. Stability regulation was major concern as it was found that 70% of deaths involving commercial fishing industry vessels were related to poor or inadequate stability.

In August, 1991 a final rule was published in 46 CFR (Code of Federal Regulations) Part 28 (DOT/USC, 1991.) This rule had many new requirements for all fishing vessels ad well as regulations for vessels of specific uses and lengths. A major portion of this rule was concerned with new stability rule that were categorized by vessel length. However, during the proposed rule making stage, there was too much controversy for smaller fishing vessels to finalize rules concerning them. Consequently, stability ruling for vessels less than 79 feet in length was not addressed allowing industry and the Coast Guard more time for input and discussion.

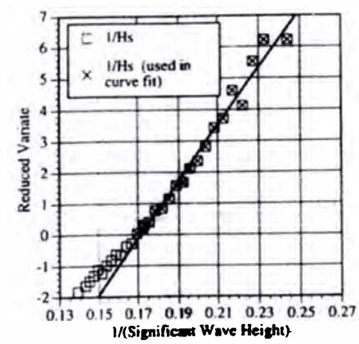

Figure 23. Reduced variate for HARRY ROBERT in 34.2 min. exposure

On October 27, 1992 a proposed rule was published with addressed stability for fishing vessels less than 79 feet in length and which is still pending (DOT/USCG, 1992). The rule proposes more stringent regulation for the vessels but focuses primarily on the human side of the issue rather than vessel specifics. It had previously been discovered that human error was especially responsible for losses of stability in the smaller fishing vessels, particularly those less than 50 feet in length. The Coast Guard has proposed to separate the class into vessels less than 50 feet in length, and those 50 to 79 feet in length. For the vessels 50 feet and less, the Coast Guard has proposed that (1) There are stability instructions on the vessel that have been developed by a qualified individual: (2) A letter of attestation is signed by the owner and master stating knowledge and understanding of the stability instructions: and (3) The vessel meets the alternate subdivision requirement of Part 28.505.

Continued

Criteria	Harry Robert	Schafer Boat	Required
GM (ft)	7.7 ft	3.9 ft	1.15 ft
GZ @ 30° (ft)	1.25 ft	1.0 ft	0.66 ft
Max RA @ (°)	40°	40°	>25°
RE @ 40° (ft°)	38.0 ft°	29.3 ft°	16.9 ft°
RE @ 30° (ft°)	25.33 ft°	19.2 ft°	10.3 ft°
RE@40°-30°	12.67 ft°	10.1 ft°	5.6 ft°
Pos. RA to (°)	82°	77°	>60°

Comparison with current stability regulations for larger vessels S 28.275 (Intact Righting Energy (no heel), Result: all conditions met for both vessels.

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Pos. RA to (°)	82°	77°	>60°

Comparison with current stability regulations for larger vessels S 28.275 (Intact Righting Energy (no heel), Result: all conditions met for both vessel

Table 3. Stability analysis for HARRY ROBERT and SCHAFER using 48 Code of Federal Regulations Part 28 (DOT/USCG, 1991)

A question that has been raised is whether or not the Native American fishing vessels have to comply with 46 CFR Part 28. The answer is yes. These vessels must comply to all applicable sections of the rule which presently include rules on equipment (fire extinguishers, life jackets,, EPIRBS, etc. but does not presently include any stability guidance until the proposed rule is finalized.

STABILITY CRITERIA

To illustrate the application of the rule, the intact righting energy criteria from 46 CFR Part 28, required of the larger (e.g., length greater than 79 feet) fishing vessels, has been applied to the Harry Robert and Schafer. While not being entirely conclusive, this criteria provides good insight into initial measures of stability for the two vessels. Calculations were performed for the zero heel condition and a working heel condition estimated to be 6.5 degrees. A summary of the results is shown in Table 3.

As we can see in the above summaries, both vessels passed the regulation criteria in their unheeled conditions which are good first indications that the boats have adequate stability. However, the Schafer boat fails some of the current regulations for larger vessels in the heeled condition. This is not to say that the Schafer is unsafe. Since these regulations were not developed for vessels of this size, this analysis can only be used as a way of gaining a feel for the relative stability of the Harry Robert and the Schafer boat.

An additional set of regulations were examined under section 28.545 (Intact Stability When Using Lifting Gear. These rules only apply when the maximum heeling moment exceeds 2.27 feet-LT (Schafer), and 6.4 feet-LT (Harry Robert). Since the maximum heeling moment for both boats is only 1.39 feet-LT, neither of the boats fell under the requirements for this section, i.e., S 28.545.

While not directly applicable, the regulation criteria for the unheeled conditions are good first indications that the boats have adequate stability. However, the criteria only concern heel due to static loading and do not account for dynamic loading conditions of the vessel in a seaway as does the analysis of the previous section of this paper.

CONCLUSIONS

This paper does not give an absolute stability judgment on the Native American trap net fishing boats. The unheeled boats pass the CFR static intact righting energy test for larger vessels. However, this static approach used in isolation, does not give any risk assessments or place any limits on the operating conditions with respect to dynamic capsize. Of more practical use is the dynamic analysis which suggests constraints on operations in different sea states, in unheeled and heeled conditions. Specifically, for the vessels Harry Robert and Schafer, conducting trap net operations in the upper Grand Traverse Bay in waves with heights greater than 3.0 ft to 4.5 ft may pose unacceptable risks.

In summary, as an alternative method to the static stability an alternative method to the static stability analysis when assessing risk of capsize, the global geometric method employing Melnikov analysis provides significantly more information. While the numerical results presented here are specific to the small trap net hulls, the method is valid for any hull form where rolling is the dominate capsize mechanism.

RELIABILITY DATABASE OF SHIP OPERATIONS COOPERATIVE PROGRAM FOR SAFER AND MORE EFFICIENT SHIPS

By Dr. Bahadir Inozu, University of New Orleans,
Zbigniew J. Karaszewski, U.S. Coast Guard, National Maritime Center,
Peter G. Schaedel, Corporate Quality, Energy Transportation Group, Inc.

Ship operators are constantly looking for ways of improving ship safety, reliability and life-cycle cost effectiveness to face the ever increasing competition of the global shipping industry. Vessel operators worldwide are implementing reliability centered maintenance programs to maintain and improve vessel reliability with less resources. In the mean time, regulatory agencies are embracing risk based technologies to improve ship safety with reduced regulatory burden.

In order to develop reliability characteristics of marine machinery and to apply risk based technologies for regulatory reform, a cooperative structure is desirable, where the failure data is obtained from many sources operating similar equipment. This allows statistically relevant data to be analyzed and conclusions drawn on the reliability of equipment much sooner than would normally be possible.

The concerns of ship operators are the same, regardless of the cargo being carried or the market being served. Every ship operator wants to provide high quality service to their customers, while minimizing operating costs and maximizing ship safety and reliability. A cost-sharing cooperative research program is a proven method of providing for industry-wide research and development (R&D) to improve quality and efficiency in this time of limited resources. With the above in mind a cost-sharing cooperative research program called the Ship Operations Cooperative Program (SOCP) was formed in the US in late 1992. One of the SOCP's first projects was to form an integrated Reliability, Availability and Maintainability (RAM) database/SHIPNET. The RAM project will supply quantitative data to support the processes of several decision analysis tools.

SHIP OPERATIONS COOPERATIVE PROGRAM

The Ship Operations Cooperative Program was formed as an industry/government cooperative effort to improve the competitiveness of US owned shipping companies and the US maritime industry. The five charter members of the program were Sea-Land Service Inc., ARCO Marine Inc., Energy Transportation Group, Inc., National Oceanic and Atmospheric Administration (NOAA) and the US Maritime Administration (MARAD). Membership of the SOCP continuously grows. As of August 1, 1996, the SOCP membership also includes the American Bureau of Shipping, ARCO Marine, Inc., Bay Ship Management, Inc., BP Oil Transportation Corporation, Calhoon MEBA School, the Gulf Coast Region Maritime Technology Center (GCRMTC) at the University of New Orleans, -Univ. of New Orleans, Houston Marine, Interocean Ugland Management, Kirby the Maritime Institute of Technology and Graduate Studies (MITAGS), The Nautical Institute, The United States Coast Guard, and Marine Management, Inc.

The purpose of the SOCP is to address and promote commercially beneficial innovations in ship operations through the identification, development, and application of new methods, procedures, and technologies. The overall objective of the SOCP is to improve the competitiveness, productivity, efficiency, safety and environmental responsiveness of US vessel operations. All US vessel operators are eligible to participate in the program. With the support of MARAD, industry and government will work together to address common challenges and identify new solutions for improvements in ship operations. The SOCP is tasked with making efficient use of the energy and resources expended on ship operations technology and procedures. This cooperative program allows members to participate in research which would not be economically feasible on an individual basis, or possibly even in a small segment of the industry through trade associations. Some of the projects will result in systems to be implemented throughout the industry, while others will produce results from which management decisions can be made. In either case, information about new technologies, systems, or procedures that would otherwise not exist will be made available to all cooperative members. The vision of the SOCP is to be the preeminent research forum for ship operations and ship management in the United States.

INTEGRATED RAM DATABASE PROJECT OF SOCP

One of the SOCP's first initiatives was to form a RAM database. Based on the consensus of the SOCP members, this has become the flagship project of the cooperative. This project will develop and implement a system to collect ship's equipment failure/corrective maintenance data and store it at the Reliability, Operation and Maintenance Division of the Gulf Coast Region Maritime Technology Center (GCRMTC) located at the University of New Orleans. The project is developing the tools necessary for SOCP members to access and analyze the stored data to allow better management decisions to be made, which will reduce the life-cycle cost of vessel equipment. SOCP members will have access to their own vessel's data as well as the data of comparable equipment onboard vessels of other members. This central repository of shipboard equipment reliability information is currently not available in the US for the commercial maritime industry.

The project is currently in its third phase where data collection, processing and analysis software are being tested and implemented. To accelerate database population growth, entries are being made for selected target equipment from ship log books and machinery repair history records. Pilot data analysis studies are now underway. For acquiring, using and storing the data, four computer programs are currently being developed and tested:

- A shipboard equipment Data Entry Program called DATE for use by vessel Chief Engineers to collect machinery history data
- A shipboard Equipment Performance Program called SHIPPER for use by vessel Chief Engineers to track and evaluate ship equipment performance
- A Fleet Performance Indicator Program called SPIN for use by shoreside managers to compare key equipment performance parameters at the vessel, class or fleet levels
- A Ships' Equipment RAM program to manage the master database at the University of New Orleans.
- The current version 2.0 of the data entry program, DATE, has four main entry options:
  1. Initial Setup - Ship Information and Equipment Operating Parameters
  2. Voyage Information
  3. Preventive Maintenance
  4. Corrective Maintenance

Voyage information data entry captures Voyage Number and Vessel Operating Hours Underway, in Port, at Anchor and in Shipyard/Lay-by modes. The Preventive Maintenance data entry module records any machinery history information not associated with a corrective maintenance action. The fourth main entry module captures corrective maintenance actions. This module captures equipment failure information essential to evaluate equipment reliability.

For the coordinated review of equipment failure data, vessel personnel and management will use the programs SHIPPER and SPIN. The Ship Performance Review Program, SHIPPER, will enable the Chief Engineer to sort and view the following performance indicators/RAM indices in three major categories as "the entire ship", "equipment class" i.e. all pumps, all compressors etc. and "individual equipment" for three failure criticality classes namely critical, major and minor:

- Number of Failures
- Failure Rates for Different Failure Modes
- Number of Preventive Maintenance Actions
- Vessel Mission Delays Caused by Failures
- MTBF (Mean Time Between Failures)
- MTBCF (Mean Time Between Critical Failures)
- MTTR (Mean Time to Repair) in Man-Hours
- Max TTR (Max Time to repair) in Man-Hours
- MLDT (Mean Logistics Delay Time)
- Cumulative Repair Man-Hours
- Operational Availabilities based on Repair Man-Hours and Lapsed Time to Repair
- Mean Lapsed Time to Repair
- Average Spare Parts Cost

SHIPPER will also serve as a comprehensive vessel machinery history data display tool. The program will allow the vessel chief engineer to view the complete history of a piece of equipment including date placed in service, dates of major overhauls, failure history and equipment replacement history.

The RAM data collected from ships will be first sent to the headquarters of the shipping companies. Shipping companies will be able to analyze their own

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data using SPIN which is an expanded version of SHIPPER. SPIN will enable ship operators to merge data from various ships of their fleet and to examine various combinations of performance indicators for problem detection and optimization of operating reliability. Shipping companies will forward their RAM data regularly to the master database at the University of New Orleans using SHIPNET and other channels. SHIPNET is a network to facilitate consensus building and electronic data exchanges using the internet and other means.

An expanded version of the SPIN Program, Ships' RAM, is currently being developed to merge, process, analyze and disseminate ships' RAM data provided by various SOCP member companies. SOCP members will share this data for making decisions to improve the reliability and safety of their vessel's equipment and to reduce total life-cycle costs.

The SOCP has also initiated the formation of an International "Ship Network" to exchange RAM information for the improvement of the safety and quality of ship operations worldwide. Via the International Cooperation on Marine Engineering Systems Organization (ICMES) and through direct contacts, other organizations have been invited to participate in the establishment of the Ship Network. The SOCP is willing to share their equipment performance information, specifically performance indicators and RAM indices, with other ship operators and RAM databases around the globe in exchange for reciprocal access.

In the proposed system, the SOCP envisions an open network where complete identification of the equipment such as its manufacturer, model number, capability, and its global RAM history are shareable similar to the international networks of the airline and nuclear industries. The name of the ship where the equipment is installed and the name of its operator would be kept confidential. The SOCP recognizes the importance of the legal issues that could arise from the ownership of shared data. The technical problems of compatible equipment identification terminology and database structures also need to be overcome to implement the network. These are similar obstacles that the nuclear industry overcame in the formation of the international "Nuclear Network" and the electrical industry in Canada overcame in the formation of Equipment Reliability Information System of the Canadian Electrical Association. The legal ramifications could affect owners/operators, flag-states, shipyards and classification societies. The SOCP believes that the demand for higher safety, productivity and better quality will eventually overcome these legal, cultural, and technical obstacles.

AN EXAMPLE OF THE USE OF RAM DATABASE

During the second phase of the RAM database project, each participant selected target equipment for RAM data collection by considering both safety and total life cycle cost. For safety related equipment, both ABS and USCG provided guidance for the determination of critical systems. For target equipment, RAM Data entry from vessel machinery history records started in September 1995. Pilot analysis of data commenced in November 1995. An example of a pilot study is given below.

A participant identified a specific pump type as a potential target for reliability and life cycle cost improvement. Pumps from two different manufacturers were installed in identical service applications on board a participant's fleet of vessels. RAM data for this type of pump was collected from vessel machinery history records for the 1985-1995 period. The data was entered using the SOCP's DATE program and forwarded to the RAM database via SHIPNET. At the RAM database of GCRMTC, a detailed data analysis was conducted. Failure time probability density functions have been developed using censored data analysis methods. Reliability and failure rate functions have been derived for the pumps of both manufacturers using parametric distributions such as Weibull as well as non-parametric ones. Estimations of MTTF and reliability functions have been developed both at the equipment and system level, since two of these pumps are installed on each vessel. During normal vessel operating conditions, one pump is operating and one is on standby. After the development of failure characteristics, a cost-benefit analysis study has been conducted to examine various overhaul, upgrade and replacement options. The results of the study will be used to fully understand which option will be the most cost efficient over the projected remaining vessel service life.

REGULATORY REFORM AND PARTNERSHIP WITH REGULATORY AGENCIES

Revolutionary changes are currently taking place in the US Maritime Regulations as a result of Regulatory Reform. It has been well documented that current U.S. Maritime regulations inhibit competitiveness in the open market by being overly restrictive, thus inadvertently providing an unfair advantage to foreign ship builders and owners/operators. In response to industry concerns regarding competitiveness, the United States Coast Guard (USCG) developed a comprehensive program to

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achieve reform and meet its common goal of safe shipping in a commercially viable and active maritime market place. This program has three main initiatives: leveling the playing field, changing Coast Guard roles, and setting up partnerships in safety.

As part of its initiative in "Changing Roles", USCG is becoming more flexible and conducting some of its business in new, more efficient ways. As a result, it is moving from an inspection role to an auditing role. A pilot program is currently underway which allows ABS to perform vessel inspections as an agent of the USCG. Under this program, the USCG would assume and audit role verifying the work performed by ABS on their behalf.

MARINE SAFETY EVALUATION PROGRAM (MSTEP)

In the current environment of dwindling resources, the USCG is becoming more efficient by implementing a systems engineering approach to marine safety determinations. Through regulatory reform, the USCG is embracing Risk Based Technology (RBT) and the IMO's Formal Safety Assessment (FSA) initiative. In 1993, the USCG established the Marine Safety Evaluation Program (MSTEP) based on the use of RBT, which enables the USCG to make better decisions with less resources.

The primary objective of MSTEP is to improve the current process of assessing the safety of marine systems, subsystems, and components that fall within the USCG's regulatory domain. Improving this process will provide a basis for identifying reductions in the regulatory burden and improving the competitive position of the U.S. maritime industry.

A major part of the overall MSTEP program is the Marine Safety Assessment System (MSAS). MSAS is a methodology that adopts state-of the art technology for performing system safety assessments and provides a logical basis on which to develop safety criteria. MSAS employs proven risk-based technologies and assessment methodologies used in the nuclear, chemical, and other industries operating complex engineered systems, and adapts them to the maritime environment.

BUILDING THE BRIDGE BETWEEN RAM DATABASE AND MSTEP

One of the main goals of the SOCP's RAM Database/SHIPNET is to provide qualitative and quantitative equipment and system performance data to regulatory agencies to improve ship safety and reliability with reduced regulatory burden. The RAM Database is designed to be a foundation for efficient utilization of complex decision analysis tools, such as risk based technology, using industry accepted RAM parameters. As a member of SOCP, the USCG is developing an approach to incorporate the SOCP's RAM database / SHIPNET in its Marine Safety Evaluation Program (MSTEP). The RAM Database / MSTEP interface plan is currently under development. The immediate link is via the Preliminary Hazard Analysis (PrHA) of MSAS.

The MSTEP core team recognizes the importance of using both qualitative and quantitative analysis for the accomplishment of its goals. In its pilot studies, investigations started with qualitative analysis which usually is the standard procedure in other industries as well. Further refinement of the results requires additional quantitative analysis. The role of SOCP's RAM Database / SHIPNET in MSTEP is expected to be the prime provider of references in ship reliability, availability, maintainability and operability. This information is needed to perform both qualitative and quantitative analysis and to facilitate constructive communication between the MSTEP team and all stake holders using electronic questionnaires via internet and other channels.

The amount of information needed to support MSTEP is enormous. Since much of the information needed is not currently available in digital form, expertise is needed to efficiently and effectively collect this information from documents and directly from end users. Various analytical, groupware and software tools for consensus building such as Lotus Notes and INFORUM are currently being examined and tested for this purpose.

CONCLUSIONS

The RAM database / SHIPNET project is now moving forward into its third phase. We already have some demonstrated successes where RAM database / SHIPNET is used to improve the total life cycle cost efficiency of ships. SOCP has already developed and is currently testing new decision support tools to help ship owners/operators to make sound vessel management decisions consistent with safety and required reliability. These tools have been developed by the SOCP team by pooling expertise, where it is appropriate, and sharing R&D costs in a cooperative effort to gain a competitive advantage.

Risk Based Technology is a practical, structured assessment approach which is being used to pursue several maritime regulatory reform initiatives in the U.S. This technology has been successfully applied to complex engineered systems such as marine terminals and transport systems, nuclear power plants, weapons

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production facilities, and space and defense systems. Based on RBT, use of the MSTEP methodology illustrated that when a system is analyzed in the context of its total operational and design environment, alternatives to strict adherence to the regulations may be achieved with the potential for significant cost savings without sacrificing personnel safety or property damage goals. Several pilot studies completed to date by the USCG have demonstrated that RBT is viable, efficient and safe for use in the maritime industry.

MSTEP recognizes that much of the specific information needed to support the activities that are being planned does not exist in an easily accessible form, and therefore must be collected directly from the industry. SOCP's RAM Database has been created to collect equipment reliability data which directly affects vessel life cycle cost and safety performance. SOCP's SHIPNET has been designed to exchange vessel operational information to facilitate improvements in life-cycle cost and safety performance through consensus building. Experience indicates that technology programs succeed through active end user involvement. Hence, the direct involvement of end users is critical to establishing successful implementation of any technology oriented program. It is imperative that the industry take an early interest in MSTEP and SOCP's RAM Database / SHIPNET, participate in the formulation of requirements, review the specifications, comment on the design, and participate in testing the prototype to achieve increased safety with reduced regulatory burden. The RAM database is essential to support MSTEP and the use of RBT.

With the current structure, the immediate beneficiaries of the Ships' RAM database / SHIPNET will be ship operators and regulatory agencies. Participation by ship designers, shipyards, and marine equipment manufacturers is needed and is being solicited in order to close the operational experience feedback loop. Significant improvements of new designs, installation parameters, equipment maintenance practices, instruction manuals, personnel training, onboard parts stocking and test equipment will then result from the Ships' RAM database. Trends can be established and analyzed to improve corrective maintenance actions, preventive maintenance schedules and spare parts optimization. Reliability and equipment failure data in the RAM database can be evaluated:

- To make meaningful comparisons of the reliability and maintainability of similar equipment to determine the cost-benefit of equipment renewal or replacement with a model of greater reliability.
- To rank in terms of criticality and to prioritize the causes of equipment failures that can be repaired onboard in order to optimize the inventory of spare parts carried onboard and resources spent on training vessel personnel in equipment maintenance and repair.
- To improve the efficient use of maintenance resources onboard through the practical migration from a time based planned maintenance to a reliability based planned maintenance system.

The reliability feedback loop will be closed by the marine equipment manufacturers improving their designs and the shipyards reducing the life-cycle cost of the vessels they construct by using equipment of greater and greater reliability.

Cultural and legal barriers for data sharing seem to be crumbling. If the will of the shipping and shipbuilding communities persists, networking for Ships' RAM information sharing will soon become a reality both domestically and globally. SOCP continues its efforts to accelerate the establishment of an International Ship Network for RAM information exchange. Development of STEP Life Cycle Change Process Standards for Ships is the first step for meaningful data exchange. The benefits of sharing ships' RAM data are already evident: safer and more reliable ships, higher productivity, greater life-cycle cost effectiveness, and emulation of industry's best practices.

THE MARINE SAFETY EVALUATION PROGRAM

MSTEP Government/Academia Group: (left to right) Dr. Bahadir Inozu, Zbigniew Karaszewski, Norman Lemley, RADM James Card, Dr. John Crisp, and Dr. William Vorus.

The Coast Guard is developing an improved approach to address safety of marine systems, in which risk-based technology (RBT) will play a significant role. We call this new safety assessment effort the Marine Safety Evaluation Program (MSTEP). Fully developed, MSTEP will provide the maritime industry with methodologies and clear guidance on how to address system safety criteria and alternative strategies for regulatory compliance.

The MSTEP effort is being supported by a coalition of marine industry, academia, engineering consultants, and government. This wide spectrum of expertise was chosen to assure the utility of MSTEP to the maritime industry.

MSTEP TEST CASE

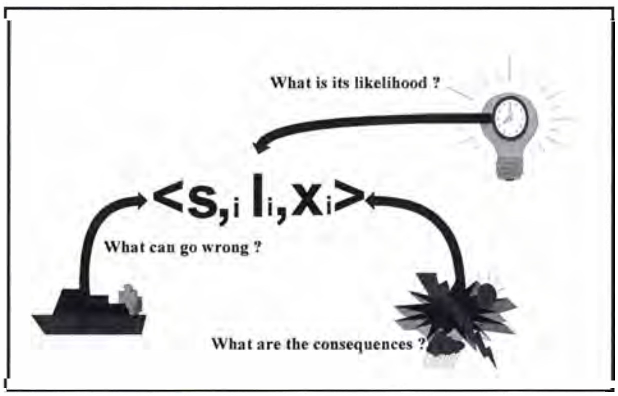
To demonstrate the utility of the MSTEP risk-based approach as a methodology for determining alternative regulatory compliance, various candidate systems were considered for a proof-of concept. The basic selection criteria for a candidate system was that the system must have a high cost-to-safety ratio, and the system must be a good representative of all other applicable systems.

The MSTEP team chose the cargo hold lighting system installed aboard the U.S. Maritime Administration (MARAD) reflagged *Cape H Class* and *Cape W class* RO/RO vessels. This system was chosen because of the high cost of upgrading the lighting fixtures in order to comply with Federal regulations and class society rules.

The analysis of the cargo hold lighting system set out to answer two essential questions: (1) Is the current hazardous location classification of the cargo spaces consistent with the true safety risks and (2) Are the currently installed lighting fixtures adequate if the cargo space were to be reclassified?

RISK-BASED TECHNOLOGY (RBT)

MSTEP proposes to use RBT to evaluate the safety risks of complex ship systems. RBT uses a top-down approach to define hazards and accident scenarios. RBT is based on answering three fundamental questions namely: (1) What can go wrong?(2) What is the likelihood of that situation? and (3) What are the consequences of that happening?



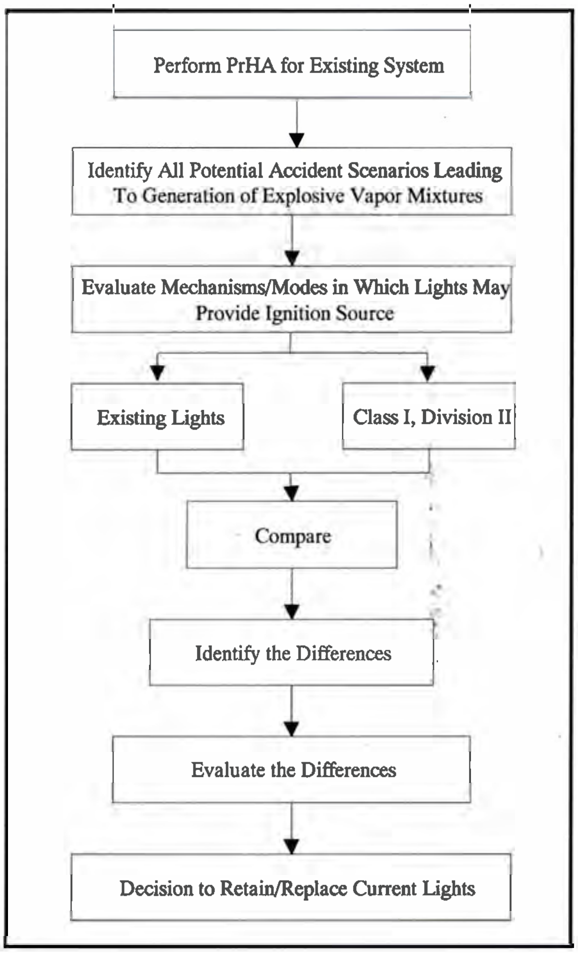
A rank-ordered list of major risk contributors is developed, and thereafter, efforts and resources are

Continued

concentrated on systems with the highest consequences and frequency of failure. Thus, RBT provides a logical basis for balancing risk and economic impact in the development of regulations or the evaluation of alternative compliance strategies.

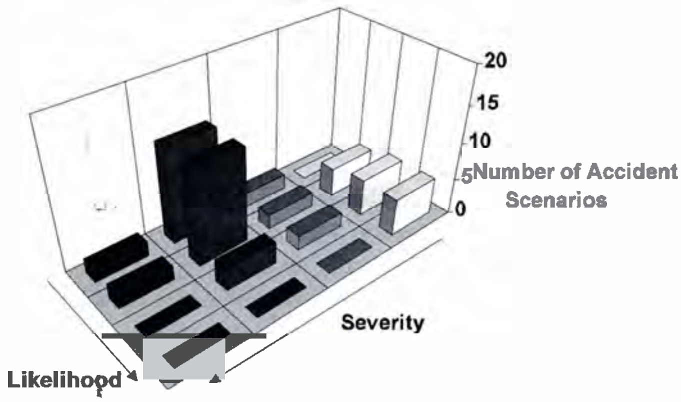
PROOF OF CONCEPT

In the present proof-of-concept, a team of safety analysts and ship systems experts performed a Preliminary Hazards Analysis (PrHA) to demonstrate the RBT application. The following figure presents the logical decision-making process used in deciding whether to retain or replace the normal lights currently installed on the AFP RO/RO ships.



PrHA RESULTS

Over the course of the evaluation, the team documented more than 50 potential accident scenarios that had unfavorable consequences. A summary graph presenting the results of the study is depicted below.



CONCLUSIONS

The evaluation concluded the following: (1) There is a risk of personal injury due to inadequate emergency lighting for safety inspection; and (2) The likelihood of an explosion being ignited by existing lights is low. This conclusion is based on the amount of fuel that is required to be spilled and its ability to reach lower explosive limits at the location of the current lights. Thus, reclassification of the compartments in order to retain the current lights is appropriate.

ANALYSIS RESULTS

The MARAD lighting system analysis resulted in a savings of over $7,000,000 for five ships. Operational, intrinsic design, and other risk mitigating features were given "credit" and provided the basis for the decision to retain the existing lights.

Use of the MSTEP methodology illustrated that when a system is analyzed in the context of its total operational and design environment, alternatives to strict adherence to the regulations may be achieved with the potential for significant cost savings without sacrificing personnel safety or property damage goals.

MITIGATING THE FINANCIAL RISKS OF AN OIL SPILL: CERTIFICATES OF FINANCIAL RESPONSIBILITY

LCDR Steve Carpenter, USCG, National Pollution Funds Center (NPFC),
with technical assistance from Mr. Robert Skall,
LTJG Kevin Ivey, USCGR, Marine Safety Office, Houston, Texas (formerly with the NPFC)

Although the final figure has not been determined, the Exxon Corporation paid several billion dollars for clean up efforts, fines, penalties and as compensation for those damaged by the discharge of 11 million gallons of oil spilled from the *EXXON VALDEZ*. The tanker grounded in Prince William Sound, Alaska in 1989. That's a lot more money than most people ever imagined would be spent on an oil spill, but, the Exxon Corporation has deep pockets. Most other transporters of oil do not.

Before 1970, the federal government, or private parties, were more often than not left absorbing this risk. Back then, the government's best chance for diminishing the cost of an oil pollution incident was the hope that the responsible party was concerned with preserving its public image and would, therefore, assume full responsibility for the costs and damages. This, fortunately, was the case with the *EXXON VALDEZ*.

The *EXXON VALDEZ* spill was a legal and technical turning point in the history of merchant shipping. In this catastrophic spill, all damages were paid by Exxon, but the incident raised awareness of the potentially astronomical financial impact on public and private parties. The risks were far too great to rely on the good graces and public concern of the petroleum industry. In fact, the spill's reverberations provided much of the impetus which sent lawmakers into action. As a result, long pending legislation was enacted in the form of the *Oil Pollution Act of 1990* (OPA 90). The philosophy behind this legislation is that the spiller—not U.S. consumers and taxpayers—should bear the lion's share of costs and damages; the "polluter pays." In Title I of OPA 90, Congress included provisions which ensured that vessel and offshore facility operators would have specific amounts of money available to pay for the clean up and damages resulting from an oil spill.

National Pollution Funds Center staff members explain their unit's vital mission at an Oil Spill Conference

A NEW RISK MANAGEMENT APPROACH: THE NATIONAL POLLUTION FUNDS CENTER.

The United States Coast Guard's National Pollution Funds Center (NPFC) has been tasked with implementing much of Title I of OPA 90. Title I is the heart of the comprehensive federal oil pollution liability and compensation regime for marine-related oil discharges. The Coast Guard's Certificate of Financial Responsibility (COFR) program is designed to make sure that vessel owners and operator, also known as the responsible party (RP), have the financial ability to pay, up to certain limits, for removal costs and damages. Operators of vessels generally must provide the NPFC with assurance, in accordance with 33 CFR 138 and predominantly by means of a guaranty from an insurer, of their ability to meet OPA 90 limits of liability. As a backup to that assurance of payment, OPA 90 triggered into effect a billion dollar Oil Spill Liability Trust Fund (OSLTF) for oil pollution cleanup and damage compensation. Title I also increased the limits of liability for oil spills, with commensurate changes to financial responsibility requirements, and reduced the defenses of a guarantor. In addition, Title I significantly broadened the scope of damages for which a polluter and its guarantor are liable. It also made it easier to "break," or do away with, a polluter's (but not a guarantor's) limit of liability if fault was a factor, *e.g.*, gross negligence.

Continued

An oil spill threatens our valuable water supply. Both animal and vegetational elements of the ecosystem are highly susceptible to destruction and our fragile environment is put at risk

NEW COFR REGULATIONS

As part of the Coast Guard's mandate to implement Title I, NPFC developed new COFR regulations for vessels which reflect the changes made by OPA 90. An Interim Rule, published on 1 July, 1994, implements the vessel financial responsibility portion of OPA 90. A final rule, which clarifies the regulation, incorporates several minor technical changes, and reflects recent amendments to OPA 90, was published early in March 1996. The COFR rule also implements the less well known vessel financial responsibility provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (known as CERCLA or Superfund), which deals with the discharge of hazardous substances other than oil. The COFR program, however, is not a new one. It has been in existence for about 25 years as a federal program. It was administered by the independent Federal Maritime Commission until 1984 when responsibility was shifted to the Coast Guard. In 1991 NPFC was formed to implement the financial and liability aspects of OPA 90 contained in Title I, and certain similar provisions of Superfund. Administration of the COFR program than fell to the NPFC. There are 15 individuals presently involved in the administration of the COFR program which generates approximately one million dollars in user fees annually. Compliance with COFR regulations has been excellent. Eighteen vessels were detained for COFR violations in 1994; only 10 were detained in 1995. Since the interim rule was published, NPFC has issued more than 12,000 new COFRs, including 1,856 for tank vessels, more than 3,400 for dry cargo vessels, and nearly 4,200 for tank barges and Mobile Offshore Drilling Units. There are still approximately 9,000 old (Clean Water Act) COFRs in use, for non-tank vessels, which will be replaced by OPA 90 COFRs before December, 1997.

WHAT IS A CERTIFICATE OF FINANCIAL RESPONSIBILITY?

A COFR is a necessity for most vessels, of all types and flags, to operate in U.S. waters. It demonstrates that the owner and operator of a vessel are financially able to fund the clean up of an oil spill, and pay for certain types of damages, up to their limit of liability. Types of damages include: damage to real or personal property, damage to natural resources, subsistence loss, loss of government revenue, loss of profits and earning capacity, and increased cost of government services.

Prior to OPA 90, various Federal statutes dealt with oil spills. However, each was narrow in scope and far from adequate. In essence, OPA 90 replaced the liability provisions and financial responsibility requirements of the Federal Water Pollution Control Act, the Outer Continental Shelf Lands Act Amendments, the Trans Alaska Pipeline Authorization Act, and the Deepwater Port Act. OPA 90's comprehensive requirements for financial responsibility replaced these earlier requirements, and established higher and broader limits of liability which more closely reflect the actual costs and damages of an oil spill. This also allowed a single COFR to serve a vessel, where previously several COFRs might have been required. OPA 90's liability provisions are somewhat similar to those of the International Convention on Civil Liability for Oil Pollution Damage of 1969 (CLC). However, OPA 90's limits of liability are higher and easier to break. Another significant difference between OPA 90 and the CLC is that OPA does not preempt state liability legislation regarding oil spills.

OPA 90 LIMITS OF LIABILITY

The amount of liability for all vessels are calculated according to a vessel's type and size as follows:

Vessel Type	Vessel Size (Gross Tons)	Liability Limit
Tank vessel	≤ 3,000	The greater of $2,000,000 or $1,200 per gross ton.
Tank vessel	> 3,000	The greater of $10,000,000 or $1,200 per gross ton.
Non-tank vessel	all	The greater of $500,000 or $600 per gross ton.

Under pre-OPA 90 law, liability limits could be broken. However it was difficult to do so. OPA 90 expanded both liability limits and the basis for breaking these limits. The responsible party, but not its guarantor, may be held liable for the total cost associated with cleanup and damages resulting from an actual or threatened oil spill, even if that amount exceeds the responsible party's limits of liability. This may occur if the proximate cause of an incident was: gross negligence; willful misconduct; a violation of an applicable federal safety; construction, or operating regulation; failure to resort an incident; failure to provide reasonable cooperation with government officials; and failure (without sufficient cause) to comply with certain orders issued by the Federal On-Scene Coordinator.

COFR'S IMPORTANCE TO OIL SPILL CLEAN UP

Under OPA 90, liability limits and the scope of compensable damages are more attuned to the real life consequences of oil spills. The new OPA 90 COFRs serve not only to ensure that responsible parties are able to pay for oil spill cleanup and damages, but that they in fact do pay. Each certificate is backed by a guaranty of payment from a stable and reliable guarantor (e.g., the Water Quality Insurance Syndicate), or in some cases by a type of self-insurance.

In the event of pollution incident, a vessel's type and tonnage determine its limit of liability and thus its guarantied financial responsibility. In many cases, obtaining jurisdiction over a vessel's owner and operator is hindered by a maze of holding companies and corporate shell entities scattered across the globe. A COFR, however, makes these traditional hindrances irrelevant. If the responsible party does not pay, its guarantor will. In essence, a COFR is an assurance of payment up to the limits of the law. During the last twenty-five years, a COFR guarantor has never refused to meet a valid liability backed by a USCG guaranty.

The Coast Guard's Maine Safety Information System database (MSIS) contains information concerning a vessel's inspections, the last known status of its certificates and their expiration dates, as well as any previous violations of maritime regulations. The COFR information contained in MSIS is not "real time" but it is often updated daily by the NPFC. Any vessel operating in U.S. waters which has not demonstrated evidence of financial responsibility under OPA 90 and Superfund, is subject to detainment and, among other sanctions, a civil penalty of not more than $25,000 per day of the violation. As the ultimate testament of OPA 90's resolve to ensure that vessels are in compliance with its financial responsibility provisions, the law states that, "Any vessel subject to the COFR provisions of OPA 90, found in the navigable waters of the United States without the necessary evidence of financial responsibility is subject to seizure by and forfeiture to the United States."

COFR REQUIREMENTS AND COMPLIANCE SCHEDULES

According to OPA 90, any owner and operator is subject to liability for oil they spill unless a specific defense, such as an Act of God, is available. However, statutorily, not all vessels are required to have a COFR. Again, the amount of financial responsibility required to be demonstrated is set in accordance with the type of vessel (tank vessel or non-tank vessel) and its gross tonnage. OPA 90 further specifies that any size vessel which lighters petroleum products in the Exclusive Economic Zone of the United States must also carry a COFR, if its oil is destined for a port or place subject to the jurisdiction of the U.S.

Tank vessels are subject to higher liability limits because they have a greater likelihood of incurring substantially larger costs in the case of an actual or threatened oil spill.

OPA 90 basically requires that all vessels of 300 gross tons or more, operating in U.S. waters, must have a valid COFR. There are exceptions: government-owned ships on government business and non-self-propelled barges which do not carry oil or hazardous substances, are not required to have a COFR.

There is a specific schedule for compliance with the COFR requirement, depending on vessel type. Compliance schedules for self-propelled tank vessels, non-self-propelled tank vessels, and all other vessels, are delineated below.

SELF-PROPELLED TANK VESSELS

Tank vessels were required to demonstrate financial responsibility under the new rule as of 28 December 1994.

Continued

A variety of high-tech oil response equipment and methods are used during an oil-spill cleanup. Mark Ploen, Quali Tech Environmental, played a key role in the Kolva River Basin Oil Spill Containment and Recovery Project in the Komi Republic of Russia

NON-SELF-PROPELLED TANK VESSELS (BARGES)

Barges were required to demonstrate financial responsibility, and obtain a new COFR as of 1 July 1995.

ALL OTHER VESSELS

Operators of all other vessels are required to file new COFR applications and evidence of financial responsibility, and obtain new COFRs, before the preexisting COFR for a particular vessel expires. Thus, some non-tank vessel operators were required to apply for new COFRs as early as 28 December 1994. Others will be permitted to operate with pre-OPA 90 COFRs until 28 December 1997.

GETTING A COFR

In all cases where a COFR is required, the vessel operator must submit the application for a COFR, along with the guaranty and processing fees, to the NPFC (see 33 CFR 138). Generally, only vessels over 300 gross tons require a COFR. The appropriate forms and request for assistance may be obtained from the NPFC by calling (703) 235-4813. The fees, evidence of financial responsibility, and applications must be provided to NPFC 21 days before the vessel intends to operate in U.S. waters. Exceptions are made in cases of true emergency. The applications are processed in the order in which they are received. All documentation must be presented in English and all monetary information provided in U.S. currency. The application for a COFR identifies the vessel, its owner and operator, and may be signed only by an authorized official of the vessel operator. Should any of the information contained within the application change, the applicant must notify the NPFC within 5 working days. The key submission, in the COFR application process, is the evidence of financial responsibility.

Many familiar with the COFR program look upon it as a model for other government programs. It pays for itself in user fees and relies on the private insurance industry to enable compliance with the law. Most importantly, it works! Historically, COFR guarantors paid approximately $66 million annually in cleanup costs and damages. Moreover, because Superfund and OPA 90 give U.S. claimants the legal right of direct action against guarantors, a significant potential burden on courts and litigants has been precluded.

RISK-BASED REGULATION—WHERE DO WE STAND?

B. John Garrick, Ph.D.

In March 1994, I chaired an American Nuclear Society Executive Conference on Policy Implications of Risk-Based Regulation that attempted to develop a perspective of where we were in this field. At the end of the conference, it was concluded that we were not very far along and that there were serious differences within both industry and government about not only how to achieve risk-based regulation but whether we should even try. After 3 days, we finally developed a consensus that risk-based regulation was a good idea but we very much needed a plan-both industry and the US Nuclear Regulatory Commission (NCR). We also needed something to happen that indicated confidence on the part of either industry or the NCR in the value of the greater use of probabilistic risk assessment (PRA) in the regulatory process. We still do not have a definitive plan for risk-based regulation although the NCR is finally developing one for the use of PRA, an important first step. And, we now have something else that may be a break-through: the NCR has issued a Policy Statement on probabilistic risk assessment.

There are now three important observations that we can make, of which the latter two were made at the conclusion of our conference in 1994. They are (1) a Policy Statement on PRA is up for approval before the NCR: (2) the evidence is very strong that the transition to risk-based regulation will be in small increments (i.e., very evolutionary); and (3) the principal mechanism of making progress will be pilot applications of license amendments and responses based on risk assessments.

THE POLICY STATEMENT

Of those events that have transpired in the risk field, none is more significant that the NCR's long-awaited announcement of a Policy Statement on PRA. As of this writing, the statement had gone through public comment and the final statement was before the NCR for approval. The Policy Statement has as an objective to improve regulatory decision making, more efficiently use staff resources, and reduce industry burden. The key commitment of the NRC in the statement is that, "The use of PRA technology should be increased in all regulatory matters...." The stage would appear to be set for stepped-up activity in the use of risk-based assessments to support licensing actions and, thereby, a quickening of the pace towards riskbased regulation. The latter may be too much to expect.

The NRC Policy Statement is accompanied by an implementation plan that is intended to cover all NRC activities including nuclear reactors, nuclear materials, and nuclear waste. The encouraging aspect of the implementation plan is that it is nonprescriptive. Thus, the opportunity remains for creative analysis in support of licensing actions. There is come concern that the plan does not have mile-stones that are more forceful in making greater use of risk analysis with visibly less dependence on traditional design basis methods. In its implementation plan, the NRC has been methods. In its implementation plan, the NRC has been very careful to protect those regulatory practices that it believes have been very effective in the past including the concept of "defense-in depth."

During the comment period for the Policy Statement, the NRC received 17 letters with comments: six utilities, three state regulatory agencies, two industrial groups, tow engineering firms, the U.S. Department of Energy, a major university, a law firm, and a citizens group. In general, there was strong support for the "basic tenet of the Policy Statement." There were the expected concerns from the citizens group of using risk analysis to get around rigid rules and the worry by industry that greater use of PRA would add to the regulatory burden of the utilities.

TRANSITION TO RISK-BASED REGULATION

It is clear from the implementation plan that the transition to risk-based regulation will take place very gradually. In fact, indications are strong that the burden to industry, at least in the short term, may be greater, not less, out of the desire of applying both current practices and increased use of risk assessment techniques. The important point of the PRA Policy Statement is that there is a commitment to change and that change is in the direction of risk-based regulation. What we now need to do is provide some basis for measuring progress to make both the regulator and industry accountable to the stated goals of the Policy Statement.

Considering that there is now a PRA Policy Statement with its implied commitment to risk-based regulation, it is interesting to speculated on the key issues standing in the way of significant change in the use of risk assessment in regulatory decision making. Some of the issue considered important are discussed below.

Decision Criteria

There lacks a consistent decision criteria for accepting PRA results as part of a justification for a licensing decision. For example, the application will require agreement "regarding what constitutes adequate" "defense-in-depth" from a risk point of view.

At this point, the position of the NRC is that "appropriate decision criteria will be developed and documented as part of the PRA implementation plan." The most direct action taken by the NRC that might lead to a basis for decision criteria is the formation of the Regulatory Review Group (RRG) to conduct a review of power reactor regulations with an eye towards reducing unnecessary regulatory burdens. The RRG recommendations have been published (SECY-94-003) and include the recommendation to use more risk-based approaches. They specifically identified quality assurance, in-service inspection and testing, and the concept of a PRA plan. Other NRC groups have also been involved in providing source material and recommendations on the use of PRA and other matters relating to risk-based regulation. They include the PRA Working Group and the Regulatory Analysis Steering Group.

The Merit of Risk-Based Regulation

A clear consensus needs to be developed and exposed by both industry and the NRC on the merit of a risk-based regulatory process; as it is now, both government and industry have voices for and against risk-based regulation.

While the advantages of PRA have been articulated by both government and industry, there lacks a strong expression of confidence in risk-based regulation from both segments-the kind of expression that provides a clear direction to applicants and licensees. At present, the emphasis seems to be on risk-based applications, or risk-based regulations, but not on the real objective of risk-based regulation-a big difference. The absence of a clear objective leaves open the speculation that NRC is just experimenting and is not really committed to risk-based regulation, which may, in fact, be the case.

Cultural Inertia

The institutional structure in which regulations are made and enforced has cultural inertia to change, and especially change that has the appearance of including uncertainty as a part of the process. Regulatory lawyers often refer to the chaos they can create when uncertainty is involved and, thus, they appropriately warn the innovators of risk-based regulation of its possible implications. To be sure, we do not need more chaos, but if the tradeoff for telling the truth is choas or continued bliss through partial ignorance then chaos has to be the choice. The better view is that we can lean how to deal with decision making under uncertainty in a rational and reasonably efficient manner.

Industry Concerns with the Cost of Keeping PRAs Current

Industry has a dilemma. On the one hand, they want regulatory reform in the form of risk-based regulation, at least most seem to, while on the other hand, they do not want the added burden of having to do more risk assessment.. Meanwhile, the NRC has made it quite clear that the current industry individual plant examination results do not provide a complete basis for supporting risk-based regulatory decision making. The NRC thinks that the way out of this dilemma is for industry, in coordination with the NRC staff, to initiate the actions necessary to develop PRA's that are acceptable for risk-based regulation. Issues of acceptability have to do with standardized methods, assumptions, level of detail, etc. It seems clear that risk-based regulation with not happen without some agreement between NRC and industry

Continued

on what constitutes an acceptable PRA. Unless industry on what constitutes an acceptable PRA. Unless industry sees a long range advantage of having risk-based regulation and, therefore, the need for reasonably current PRA's, then the chances of any expeditious movement towards risk-based regulation appears slim.

The solution to the industry dilemma would appear to be for both NRC and industry to develop a risk-based regulation plan that defines the steps involved while, hopefully, displaying the advantages of moving in such a direction to industry, NRC, and the public. So far, the only mention of a plan is from the NRC, and there they seem to be only talking about a "PRA plan" (SECY-95-126).

Consistency of Application of Risk-Based Regulations

Regulators and licensees have concerns that the lack of consistency in different risk models precludes meaningful comparisons between plants and could lead to inconsistencies in regulatory enforcement.

This would appear to be all the more reason for a risk-based regulation plan that provides some of the principles that have to be the bases for consistency in application of risk-based regulations. Most practitioners of PRA believe that such consistency can be achieved with a good set of guidelines that clearly specifies the scope of the analysis. Experience has indicated that the differences are more attributable to differences in scope than other differences, such as, for example, the methodology. Scope questions have to do with uncertainty analysis, plant-specific data updates, the treatment of external events, human response analysis, breadth of the analysis (Level 1,2, or 3), etc.

Risk Results Interpretation and Communication

Considering that many of the people involve in the regulatory process are not risk assessment experts, it is critically important that the risk-based regulation plan include training not only to the engineers and analysts directly involved in the process but also to those who will have to concur and act on the findings and results such as lawyers, NRC Commissioners, management personnel, and the public. The NRC has already committed to an expansion of their in-house training as part of the PRA implementation plan. Industry probably needs to be more aggressive in this regard especially as it relates to the management and decision makers. It is clear that there is only a very limited understanding among many of these groups of just what the results from a PRA are really saying. This especially true in the area of uncertainty analysis, perhaps the most critical part of the story. There is little evidence that either the NRC or industry fully appreciates the extent of the cultural change required in order for risk-based regulation to be successful. finally, there is the overwhelming task of building public confidence in rsk-based regulation. Here, the most challenging issue might be to convince the public that a risk-based approach can be sensitive and responsive to the so-called "soft science" issues such as human factors and human values.

Quality Control

Perhaps the key issue for making risk-based regulation really work is the system for controlling the quality of the supporting analyses. The right quality control system, more that anything else, can provide the assurance necessary to deal with many of the issues already discussed. Scope control and quality control are the keys to being able to make comparisons between facilities and to achieve consistency of application. With tight control of those two attributes, issues having to do with differences in methodology and input data can most likely be easily resolved. A convincing quality control process is believed to be the means by which risk-based regulation can be made to work smoothly and effectively.

Of course, the above issues are not all of the concerns that stand in the way of an expeditious movement toward risk-based regulation. The will to want to make it happen is what will lead to success of failure. In this regard, it is up to industry more than anyone else. Industry must take the lead with creative and confidence building applications that provide the necessary experience for systematic and deliberate movement toward such dramatic regulatory reform. An important element of this challenge is the pilot applications to get the process really started.

PILOT APPLICATIONS

The NRC has made it clear that transitioning into risk-base regulation with be best accomplished through carefully selected pilot applications of PRA to implement and support licensing activities. The NRC has identified a number of candidate pilot applications. They include motor-operated valve testing requirements (GL-89), configuration risk management, in-service inspection and testing requirements, fire protection, and the implementation of the Maintenance Rule. One of the most promising near-term pilot applications for industry would appear to be in the preparation of technical specification submissions that utilize PRA models to justify enhanced flexibility for on-line testing and maintenance. Some actual success stories have already bee reported. It is clear that, initially at least, the deterministic criteria will also have to be met and that considerable care will have to be given to identifying the specific points of the submittal that are being made using probabilistic methods.

The good news is that in addition to a limited number of pilot applications that have been submitted and that are underway, the NRC has had discussions with volunteer licensees regarding pilot applications of risk-based regulatory initiatives. The concern, as indicated earlier, is whether industry will seize the initiative and push for action in an aggressive and effective way.

CONCLUSION

It is believed that the best path to achieving any kind of goal connected with risk-based regulation and the implementation of the NRC PRA Policy Statement is a path involving phases. That is, we need to move in the direction of risk-based regulation in manageable increments that allow for changes in direction and even reverses in direction, if necessary. We also need some effective check points to see if either the industry or the regulators are making any real progress against the goals of the PRA Policy Statement. It is believed by many that the most likely eventual outcome is a regulatory practice that involves both deterministic and probabilistic methods. Interpreted in the conjunctive sense I would certainly agree with this outcome. That is from the perspective of this author, probabilistic analysis is just an added dimension to deterministic analysis. The two types of analysis are not competitive and they certainly are not thereby permit the importance ranking of issues-clearly an improved state over not doing so and certainly a logical direction for the regulatory process to take.

It is up to industry to make risk-based regulation work by taking the initiative to make license requests and amendments based on risk assessments that will assist the NRC to recognize and eliminate outdated and ineffective regulations.

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AN APPLICATION OF RISK BASED TECHNOLOGY FOR REGULATORY COMPLIANCE

Robert A. Dykes, PLG
Subodh R. Medhekar, PLG
Robert A. Landman, USCG

ABSTRACT

The purpose of this paper is to describe a risk-based technology (RBT) methodology, utilizing a preliminary hazards analysis (PrHA) format, that can be used to justify compliance alternatives to the Code of Federal Regulations (Title 46) requirements currently in force and being complied with by U.S. flagged vessels, and to a great extent, the U.S. shipbuilding industry.

The U.S. Maritime Administration (MARAD) Cape W and Cape H classes of Afloat Preposition Fleet (APF) ships were originally constructed as commercial roll-on/roll-off (RO/RO) ships for non-U.S. flag operators. With the change in service brought about by the MARAD acquisition of these vessels, several of the systems, safe for the originally intended mission, do not fully meet the requirements as stipulated by the U.S. Coast Guard regulations or major ship classification societies. One of the systems, the normal lighting system in the cargo holds, is the subject of this analysis.

The results of this analysis enabled authorities to determine the safety significance of the installed Cape W and H cargo hold lights in comparison with compliant fixtures.

BACKGROUND

Changes in the U.S. Department of Defense force structure and the need to maintain the capability to rapidly respond to threats in a worldwide environment has increased the need for the additional prepositioned shipboard capacity to forward-deploy the heavy equipment of ground forces. To assist in providing a logistical solution, MARAD purchased several commercial ships, not originally built in U.S. shipyards to U.S. standards, for conversion to Military Sealift Command ships and subsequent assignment to the APF. These ships are designated as the Cape H and Cape W class ships.

The Cape H and Cape W class ships were originally constructed as commercial RO/RO ships for foreign flag operators. Several of the systems, safe for the originally-intended mission, did fully meet U.S. Coast Guard requirements for U.S. flag vessels. One of the systems, the normal (vice emergency) lighting system in the cargo holds, is the subject of this analysis.

The original commercial mission of these ships was the transport of automobiles and diesel trucks between ports. The vehicles had sufficient fuel in their tanks to drive them on and off the ship, normally less than 3 gallons of gasoline per gas tank. Furthermore, bulk fuel could be transported in tank trucks. The lights in the cargo compartments were required to be enclosed and protected against the escape of sparks and there had to be an operating ventilation system that provided at least 10 air changes per hour whenever vehicles were on board. The spaces were classified by authorities as a Zone 2 hazardous location, the equivalent of a Class 1, Division 2 hazardous location. As such, electrical installations in this space must meet the requirements of the International Electrotechnical Commission (IEC) Publication 79 for Zone 2 hazardous locations.

The new mission has U.S. Army vehicles and equipment being stored on board for months at a time with up to 110 gallons of JP-8 in a vehicle's fuel tank. To prevent material degradation due to high temperature and humidity, the cargo holds are sealed and an air conditioning/dehumidifying (AC/DH) system has been installed to keep the cargo holds at a temperature not to exceed 100°F and approximately 40% humidity. Under these conditions, there was concern by the U.S. Coast Guard (USCG) that explosive vapors would build up and present a potential safety hazard. Based on this, the USCG initially determined that the cargo holds should be reclassified as a Class 1, Division I (Zone 1) hazardous location. This reclassification would force the removal of the installed lighting system due to the stricter Class I, Division I electrical requirements.

ISSUES

Previously, MARAD had replaced the existing emergency lights with explosion-proof fixtures (Class 1, Division 1), meeting the requirements of UL Std. 844. To comply with the USCG's and major ship classification societies' requirement that all of the lighting fixtures should be explosion proof, MARAD and the U.S. Army have implemented procedures to ensure that the currently installed normal lights are not activated unless adequate ventilation is available in the cargo holds. However, actual operations under these conditions proved to be impractical. Specifically, the spaces were very dark when solely illuminated by emergency lighting and presented a safety hazard to the personnel performing the biweekly visual cargo hold inspections. Therefore, activation of the normal lighting was necessary more than initially anticipated. Additionally, the normal circulation from the ventilation system was not available since it is secured and the AC/DH system is activated.

There were two regulatory issues that needed to be resolved:

Are the current hazardous location classification(s) of the APF RO/RO cargo compartments consistent with the true safety risk?

Are the currently installed normal lighting fixtures adequate for the resulting classification(s) of the compartment?

Based on the above, there were two major safety questions to be resolved:

- What is the risk of an explosion/fire with the currently installed lighting?
- What is the risk of personnel injury due to inadequate lighting in the cargo holds?

In evaluating the CFRs and other regulations, the following underlying safety criteria for an APF RO/RO ship cargo hold with fueled vehicles were determined as valid:

• **Lights.** The lights should not present a potential ignition source (i.e., sparking, heat, etc.) that could cause an explosion given an accumulation of explosive vapors in the expected operational environments. There should be adequate lighting for maintenance personnel to inspect the cargo hold for safety hazards.

• **Ventilation.** The ventilation should be sufficient to prevent the accumulation of explosive vapors, air stratification, or the accumulation of air pockets.

• **Detection.** When the ventilation system is not operational, the detection system should be capable of detecting and alarming the crew of the accumulation of explosive vapors well before the lower explosive level (LEL) is reached. The USCG requires that the alarms be set at 25% of LEL.

These safety criteria were used in the preliminary hazards analysis to determine the overall risk in the cargo compartment from the existing installed lights.

SYSTEM DESCRIPTION

The Cape H and Cape W class ships have been purchased and mollified for assignment to the APF. In completing their assigned mission, the ships operating cycle will include several major modes of operations. A summary of the operations and systems required is presented in Table 1.

The cargo holds on the RO/RO ships run the length and breath of the ship. On the lower two decks, there is a watertight door that subdivides the hold into two compartments. The movable decks are in the up position, providing maximum height for cargo storage.

The cargo currently loaded aboard these ships is military vehicles and other related equipment required for rapidly deploying forces. The hazards aboard these vehicles include fuel (JP-8 and diesel), ammunition, oil, and hydraulic fluid. The fuel tanks on the vehicles are filled to either 3/4 tank or 110 gallons, whichever is the less. Ammunition is in sealed containers (and is not viewed as a vapor threat in creating an explosive atmosphere). In some cargo holds, there is a possibility of ship's fuel lines passing through the compartment and in the lower compartments, ship's fuel tanks sounding tubes.

In the original configuration, the RO/RO ships had adequate ventilation that met USCG and Class Society Requirements. As Cape H and W class ships, the ventilation systems to the cargo holds are secured and the holds sealed. There is an AC/DH system that provides conditioned and dehumidified air at a circulation rate of about one complete air cycle per hour. This is a closed loop system, so should fuel leaks or spills occur in either the vehicle's or ship's fuel lines, this AC/DH system has the potential for accumulating vapors and possibly creating an explosive atmosphere.

To mitigate the potential for the development of an explosive atmosphere, safety systems have been installed and selected ship procedures have been implemented to protect the crew from this hazard. This includes an LEL detection and alarm system in each of the AC/DH systems. Unnecessary electrical systems are secured and tagged out, and there are biweekly visual inspections and checks with hand-held LEL detectors.

The cargo holds were originally installed with normal lighting fixtures that meet IEC Publication 79 for Zone 2 hazardous location applications. For the original mission, this was adequate since the cargo holds were

Continued

Table 1: Summary of Major Cargo Hold Systems

Cargo Hold System	Ventilation	LEL System		Lights	
		Ship	AC/DH	Normal	Emergency
Loading or Unloading Operations	On	On	Off	On	On
Transient	On	On	Off	On	On
Anchorage	Off[1]	Off[1]	On	Off[2]	On

Notes: 1. Will be on during periods when heavy maintenance is being performed.
2. Will be on during periods of heavy maintenance.

not sealed nor environmentally controlled, and the air turnover rate met the required standard of at least six complete air exchanges per hour. At USCG insistence, MARAD installed emergency lights that meet the UL 844 Class 1, Division I standards when vessel operations changed.

There are two fixed LEL systems installed on the Cape H and Cape W class ships: the fixed ship system and one within the AC/DH system. In addition, each ship carries several portable LEL detectors. The fixed LEL detectors should be set to alarm at the lowest point where the possibility of a false alarm is low. MARAD procedures currently call for the alarm point to be set at 10% LEL, which is below the USCG setpoint of 25%.

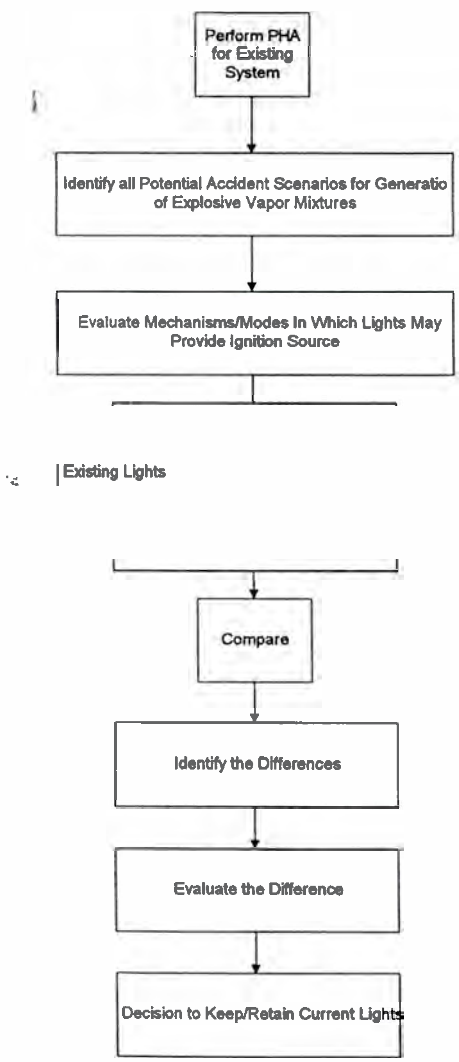
Whenever a high LEL reading is detected, the appropriate cargo hold(s) will be inspected to determine the cause of the reading.

METHODOLOGY

The primary reason a PrHA is performed is to identify the dominate risk contributors to the system and facilitate management decision-making. A PrHA, whether a detailed quantitative analysis or a qualitative expert judgment evaluation, has the purpose of identifying the actions necessary to reduce the overall risk of the system to acceptable levels.

The PrHA is a top-down approach that defines the hazards, accident scenarios, and risks of a particular process or system. Its purpose is to develop a rank-ordered list of major risk contributors to the system being studied. The results from the PrHA allow management to concentrate efforts and resources on those areas that have the highest consequence and frequency of failure. It provides management with a logical basis for balancing the risk and economic impact of regulations.

Figure 1. The Decision-Making Process



The methodology presented in this section details the process involved in a PrHA and its subsequent analysis. Figure 1 presents the logical decision-making process used in deciding whether to retain or replace the normal lights currently installed on the APF RO/RO ships.

TECHNICAL DATA

The current regulations for RO/RO ships are based on automobiles and diesel trucks carrying sufficient fuel for driving on and off the ship or transportation of fueling bulk (tank trucks). The current regulation is based on the use of unleaded gasoline, 89 octane. However, the fuel used by the U.S. Army in the vehicles stored on the MARAD RO/RO ships is JP-8. Table 2 presents a comparison of physical properties. There is a significant difference between gasoline and JP-8.

Table 2. Fuel Physical Properties (temps in °F)

Fuel	LEL%	Flash Point	Boiling Point	Vapor Density (air = 1)
Gasoline	1.3	-45	10-338	>1
JP-5	0.6	145	370-530	>1
JP-8	0.7	100	320-525	>1

JP-8 is a fuel that is much less volatile than gasoline. It has a flash point of 100°. Spilled JP-8 will evaporate slowly. Moreover, the vapors being much denser than air will stay near the deck.

The LEL level for JP-8 is 0.7%. Thus, the 0.7% LEL concentration would have to exist for the possible fire/explosion to take place.

On the lowest deck, the lights are located approximately 10 feet above the deck. The analysis of the AC/DH ventilation system and general cargo hold environment determined that since the JP-8 fuel vapors are heavier and tend to stay at the deck, the whole cargo space would have to be well mixed in order to elevate the JP-8 vapors to the overhead of the cargo hold.

A minimum volume of 28 gallons of JP-8 has to be spilled and well mixed within the smallest cargo deck volume to reach LEL levels near the lights. It must be noted that local LEL levels may be exceeded for smaller spills (as JP-8 is heavier than air), but the vapors from these spills should not reach the cargo lights.

Additionally, several deck are interconnected through the AC/DH system. For example, the air from deck 1 goes through the AC/DH unit and is sent to deck 8. Thus, if all of the decks are assumed to be well mixed, a spill of over 900 gallons would be required to reach LEL levels in all cargo holds.

However, from a conservative point, it was assumed for this study that a spill of about 28 gallons was adequate to cause a presence of potentially explosive mixtures in a small cargo hold.

LIGHTS

The lights that were the subject of this study are made by Wiska, Type II 44/142, Enclosure IP 56. They are the original lights installed aboard the ships when under foreign flag and meet IEC Publications 79 and 529, Zone 2 requirements. They have complete protection against contact with live or moving parts inside the enclosure and against harmful deposits of dust.

Zone 2 is essentially equivalent to the U.S. NEC of Division 2. In the U.S., Division 2 lights must comply with UL Std 844, in that the electrical components must be totally enclosed to prevent the escape of sparks or other hot materials.

Tests, completed by an independent laboratory commissioned by the USCG, indicate that for the expected operating environment, the currently installed Zone 2 lights are very close to the Class 1, Division 2 requirements. The only significant difference is that the external ballast temperature in the Zone 2 light reaches 100°C, where the requirement for a Class 1, Division 2 light is 90°C.

The installed lighting is a minimum of approximately 10 feet above the deck. This is for the lower deck only. For all other decks, the lights are approximately 20 feet above the deck.

LIGHT FAILURE MODES

Potential lighting failure mechanisms were examined. Table 3 presents a list of failure modes that could present an ignition source.

Of the failure modes presented in Table 3 only three apply to Class 1, Division 2 lights. These are numbers 1, 3, and 4.

One of the primary objectives of this study is to determine the possibility of a fire or explosion resulting from damaged or defective lights. To examine this, an event sequence diagram was developed. This diagram

Continued

depicts the sequence of events that need to develop for a fire or explosion to occur. Figure 2 presents the event sequence diagram.

According to the sequence diagram, a fire or explosion could occur as a result of the lights if the following sequence of scenarios occur:

1. There is a fuel leak greater than 28 gallons and/or the vapors are localized and exceed LEL.

2a. The fixed LEL indicators fail to operate or detect the rise in LEL, or

2b. A localized accumulation of vapors occurs, and the crew fails to detect these pockets of accumulated vapors when making their biweekly inspections.

3. An undetected, damaged, or improperly repaired light exists and provides an ignition source to the accumulated vapors.

All scenarios developed during the PrHA were reviewed for situations where more that 28 gallons of fuel could be spilled at one time.

These scenarios were designated as initiating events that could be propagated through event sequence diagrams. The initiating event scenarios identified in the PrHA were assigned a frequency based on the experience and knowledge of the team. Based on this analysis, it was concluded that the likelihood of eventually resulting in a fire or an explosion as a result of a light fixture is very small.

CONCLUSIONS

Risk of Personnel Injury

The emergency lighting in the cargo holds is not sufficient for personnel to perform a thorough safety inspection. Crew members need to use non-sparking (hazardous location) flashlights in an area that has extensive physical obstacles to stumble over or oily residues to slip on. These are difficult to see with only a flashlight, and the potential for minor physical injuries is high.

Reclassification of Compartments

Classification of the compartments into two divisions was judged appropriate based on the amount of fuel spilled or leaked and the ability to reach LEL levels at the height of the lights. The PrHA revealed that most scenarios could not spill/leak sufficient

Figure 2. Process Flow to have a Fire/Explosion with the Lights as an Ignition Source

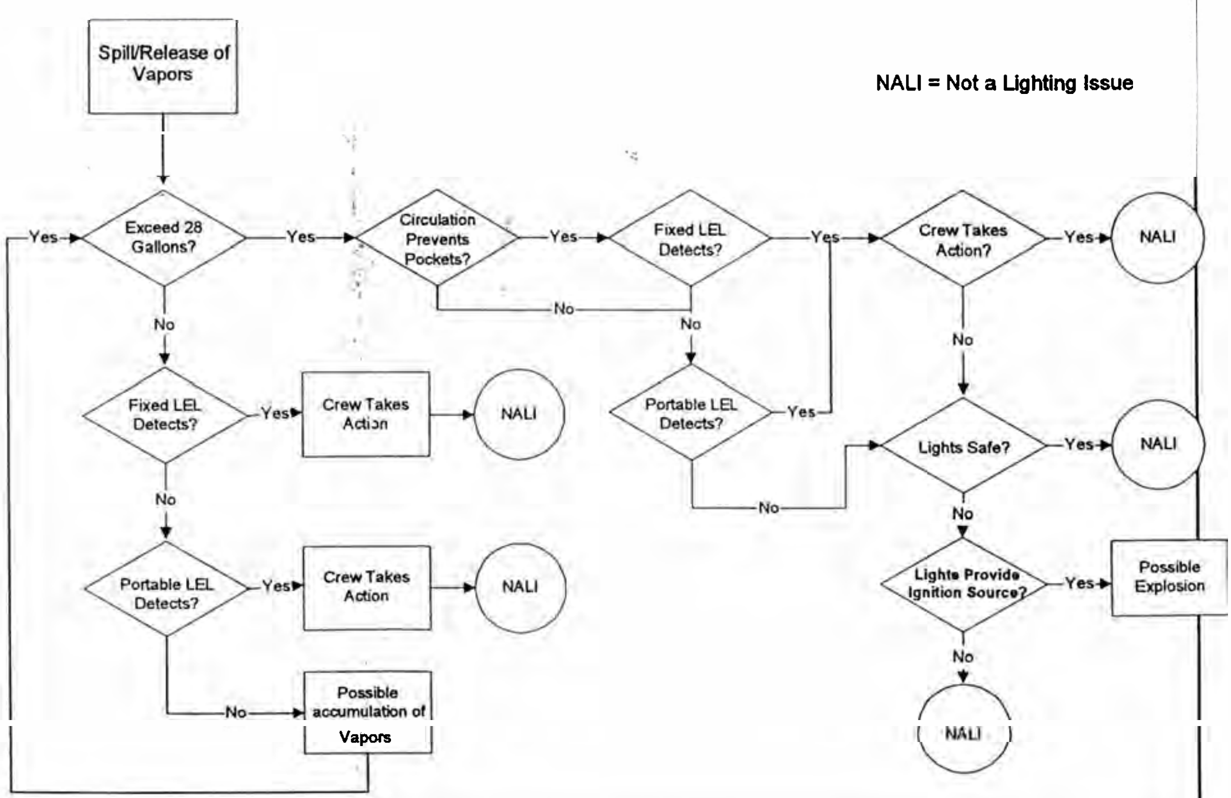


Table 3. Lighting Failure Modes*

Number	Failure Modes
1	Broken Tube
2	Ballast/Capacitor above Auto-Ignition Temperature
3	Ballast/Capacitor Failure (Sparking)
4	Loose Connections
5	Lack of Conduit/Gland Protection
6	Arcing/Sparking of Components
7	Power Cable

** Not in order of likelihood*

quantities (greater than 28 gallons) of fuel to cause high LEL levels. In addition, sufficient protection measures, like fixed and portable LEL detectors, are in place for early detection (greater than 10% LEL) in the event of such spills.

The use of the AC/DH system, with its subsequent lack of ventilation, requires the compartments to use Class I, Division 1 electrical equipment. Previously, the ships used Zone 2 equipment, based on the ship class society requirements dividing the cargo holds into two zones, Zone I for the first 45 cm and Zone 2 above 45 cm.

For the APF RO/RO ships there are several safety features that mitigate the hazards brought about by the lack of ventilation. These include the following:

- The use of JP-8 versus gasoline in the vehicles fuel tanks. JP-8 and gasoline vapors are both heavier than air, but JP-8 has a slower rate of evaporation than gasoline.
- The ship has one LEL detector installed in each AC/DH unit that provides an indication of fuel leaks in unmanned cargo holds. The air circulates among all of the cargo holds, so if one LEL detector fails, a rise in LEL level would be indicated on another detector.
- The detectors are set to alarm at 25% LEL.
- The ventilation system of the ship is available as a backup should fuel vapors be detected with the LEL system.
- The cargo holds are inspected at least biweekly with portable LEL detectors for safety hazards.

In light of these considerations and the fact that JP-8 is much denser than air, has a high flash point, and auto ignition temperature, most of the cargo holds could be classified as Division 2. Only 45 cm (18 inches) above the deck should retain Division I classification when the AC/DH system is in operation.

Existing Lights

Existing normal lights are appropriate in their current usage. The PrHA, supported by laboratory testing, revealed that the existing lights could provide sparks and be a potential ignition source only if the lights were damaged, had incorrect parts, or improper connections.

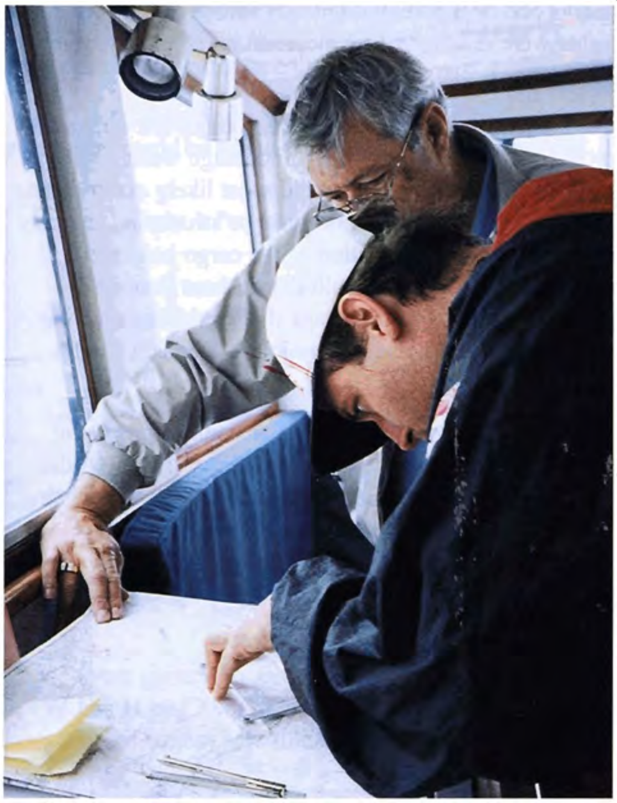
Damaged lights, when turned on or left on, could provide an ignition source if the damage went undetected. This damage could most likely occur during vehicle onload, when lights could be struck and severely damaged. Visual inspection of the cargo hold and circuit ground checks should detect these damaged lights. However, such damage that could cause arcing or sparking would also be possible if Division I lights were installed.

Incorrect parts and improper connections were also possible for Division I lights. Thus, the PrHA did not reveal any additional scenarios in which the existing lights could pose an additional risk compared to the Division I lights. The only difference between the installed lights and Class 1, Division 2 lights is the ballast temperature.

Based on the above, the risk of leaving the currently installed normal lights in the Class H and W APF vessels RO/RO cargo holds was judged as appropriate.

APPROVED COURSES PROGRAM DEVELOPMENTS

Reports from studies prompted by recent marine casualties as well as the pending implementation of new international standards for commercial vessel personnel are generating significant interest in the Coast Guard's approved courses program.



hoto courtesy of DG Training System's OUPV Cou

A student determines the correct course to a chartered destination from a fixed course.

As noted in the last issue's Mariner's Seabag, students may attend Coast Guard approved courses for any one of the following reasons:

a. To satisfy training requirements for licenses or endorsements on merchant mariner's documents (MMDs);

b. To present the course completion certificates in lieu of completing Coast Guard examinations; or,

c. To substitute training time for required service time toward licenses or MMD endorsements.

To improve marine safety , the Coast Guard facilitates the development and approval of effective training courses for seafarers. Courses may be offered by employers, maritime labor organizations, and other public or private training facilities. As we develop/incorporate changes driven by the aforementioned reports and international standards, we are also reviewing approved courses program policies, as documented in Navigation and Vessel Inspection Circulars (NVICs) and other specific course guides listed below. Your suggestions and comments on any of these documents are encouraged; revisions to the policies will consider all input received. Letters may be sent anytime to:

Director, National Maritime Center (NMC-4B)
4200 Wilson Blvd., Suite 510
Arlington, VA 22203-1804;

or by July 24, 1996, to:

Executive Secretary, Marine Safety Council (G-LRA)
U.S. Coast Guard Headquarters
2100 Second Street SW
Washington, D.C. 20593-0001

Letters sent to Headquarters should note the Coast Guard Docket Number 96-021.

HOW TO APPLY FOR APPROVAL

The course approval process is explained in 46 CFR 10.301-307. Basically, a school wishing to have a course approved by the Coast Guard must submit a written request to the Director, National Maritime Center.(NMC-4B) via the Officer in Charge, Marine Inspection, of the nearest Regional Examination Center. A step-by-step guide to course approval, NVIC 5-95, is available from the National Maritime Center. The following specific course guidelines are also available:

1. Able seaman - practical (Regulations excerpts)
2. Automatic Radar Plotting Aids (IMO Model Course 1.08)
3. Basic and Advanced Firefighting (USCG-MARAD,IMO)
4. Basic Stability (IMO Model Course 1.17)
5. Boating Safety (USCG-NASBLA)
6. Crude Oil Washing (IMO)
7. First Aid/CRP
8. Fishing Vessel Safety Instructors/Conductors (NVIC 7-93)
9. Flashing Light/Signaling Examination (USCG)
10. GMDSS (IMO)
11. Lifeboatman (Regulations excerpts)
12. Master 100/200 Gross Tons License (USCG)
13. MODU Stability (USCG)
14. Operator of Uninspected Passenger Vessels License (USCG)
15. Radar Observer (NVIC 9-94)
16. Refresher Courses for Renewal of Licenses/ MMDs (USCG)
17. Shiphandling (CAORF Report CG-D-7-83)
18. Ship Simulator and Bridge Teamwork (IMO Model Course 1.22)
19. Survival, for MODU personnel & others (IMO-USCG)
20. Tankerman - Firefighting (Regulations excerpts)
21. Tankerman - PIC DL/LG (Regulations excerpts)

Again, any thoughts you have that may improve our guidelines are welcome.

Photo courtesy of DG Training System's OUPV Course.

[redacted] instructor, Rich Koch, setting the anchor. The student in the [redacted] is indicating the direction of strain on the anchor line to the vessel operator.

Engineering

1. Which of the journal bearings listed most easily accommodates the minor turbine shaft misalignment?

A. Ball bearings
B. Roller bearings
C. Spring bearings
D. Spherically seated bearings

2. Fuel injectors used in heavy fuel oil systems are usually provided with cooling to reduce

____

A. cold corrosion of the nozzles
B. fuel viscosity for better atomization
C. carbon accumulation on the nozzles
D. fuel detonation in the cylinders

3. An eight cylinder, four stroke/cycle, single acting diesel engine has a 650 mm bore and a 1400 mm stroke. What will be the developed indicated metric horsepower if the average mean effective pressure is 30 kg/cm2 at a speed of 100 RPM?

A. 1689 kw
B. 9,111 kw
C. 12,388 kw
D. 24,776 kw

4. If ignited, which of the listed materials would be a class "B" fire?

A. Magnesium
B. Paper
C. Wood
D. Diesel Oil

5. Fire main outlet valves, or hydrants shall be installed __________.

A. in screened enclosures in all passageways
B. where they are protected from the weather
C. in a protected location to prevent cargo damage
D. pointing downward or horizontal to prevent kinking of the fire hose

6. Which of the bearings listed is most widely used for main and connecting rod bearings of modern diesel engines?

A. Steel-lined
B. Poured babbitt, self-aligning
C. Split roller
D. Precision insert

7. The greatest danger in cold temperatures, when at sea in an inflatable liferaft is __________.

A. asphyxiation due to keeping the canopy closed
B. hypothermia caused by the cold temperature
C. collapsing of the raft due to the cold temperature
D. starvation

8. Low velocity water fog is used in firefighting as a __________.

A. cooling agent
B. smothering agent
C. barrier against radiant heat
D. all of the above

9. The procedures recommended for auxiliary boilers having high salinity include __________.

A. treating with oxygen scavengers
B. securing the boiler and giving it a bottom blow
C. increasing the pH
D. reducing the phosphate level

10. While on watch aborad a 900 psi steam vessel, you suddenly hear loud piercing, high pitched noise. Which of the following actions should you take?

A. Vacate everyone from the engine room immediately, as this is the preliminary signal that C02 is about to be released.
B. Rapidly move towards the direction of the noise to investigate the probable source.
C. Cautiously move towards the source of the noise, sweeping the beam of your flashlight ahead of you.
D. Move away from the noise to find a broom, then, cautiously advance, sweeping the handle ahead of you to locate the source.

ENGINEERING ANSWERS

1-D, 2-C, 3-B, 4-D, 5-D, 6-D, 7-B, 8-D, 9-B, 10-D

Deck

1. On a cargo vessel, fire and boat drills must be held within 24 hours of leaving port if the percentage of the crew replaced was more than ________.

A. 5%
B. 10%
C. 25%
D. 40%

2. All of the following can be determined by use of a stabilogauge EXCEPT ________.

A. metacentric height
B. mean draft
C. moment to trim one inch
D. deadweight

A vessel's "quarter" is that section which is ________.

A. abeam
B. dead astern
C. just forward of the beam
D. on either side of the stern

What is the length of a nautical mile?

A. 1,850 meters
B. 6,076 feet
C. 5,280 feet
D. 2,000 yards

5. Which statement is TRUE concerning lifeboat gripes?

A. They must be released by freeing a safety shackle.
B. They should not be released until the boat is in lowering position.
C. They may be adjusted by a turnbuckle.
D. They are normally used only with radial davits.

An azimuth angle for a body is measured from the ________.

A. observer's meridian
B. Greenwich meridian
C. body's meridian
D. zenith distance

7. Which statement is TRUE concerning life preservers?

A. Buoyant vests may be substituted for life preservers.
B. Life preservers are designed to turn an unconscious person's face clear of the water.
C. Life preservers must always be worn with the same side facing outwards to float properly.
D. Lightly stained or faded life preservers will fail in the water and should not be used.

8. What shallow water effect will increase dramatically as you increase your ship's speed past the "critical speed"?

A. Squatting
B. Smelling the bottom
C. Parallel sinkage
D. Bank cushion

9. Retrograde motion is the ________

A. movement of the points of intersection of the planes of the ecliptic and the equator
B. apparent westerly motion of a planet with respect to stars
C. movement of a superior planet in its orbit about the Sun
D. movement of the celestial north pole in an elliptical pattern in space

10. What would give the best radar echo?

A. The beam of a three masted sailing vessel with all sails set.
B. A 110-foot fishing vessel with a radar reflector in its rigging.
C. A 300-foot tanker, bow on.
D. A 600-foot freighter, beam on.

DECK ANSWERS

1-C, 2-C, 3-D, 4-B, 5-C, 6-A, 7-B, 8-A, 9-B, 10-D

If you have any questions concerning this quiz, please contact the National Maritime Center at (703) 235-1368.

PREVENTION THROUGH PEOPLE AND RISK MANAGEMENT

The Coast Guard's Prevention Through People (PTP) initiative is rooted in the principles of risk management. PTP has a primary focus of identifying root causes of casualties by analyzing human factors, particularly human and organizational elements.

On February 10, 1995, the U.S. flag tankship MORMACSTAR was steered had aground in the East Section of Sandy Hook Channel, off Sandy Hook, New Jersey. The grounding resulted in a two inch diameter breach of a center cargo tank with the loss of over 17,000 gallons of fuel.

At the time the MORMACSTAR (22,354 GT, 175 M) was inbound in the Sandy Hook Channel, the Chinese flag tankship DA QING 88 (51,565 GT, 243 M) was outbound. Communication between the pilots on board both vessels led to preparations for a port to port passing. Weather during this period was calm with SW winds at 10 to 15 knots and visibility at 10 nautical miles. The project width of the channel is 800 feet and at the time of passing the vessels were within 300 feet of each other. Shortly after the passing the MORMACSTAR grounded.

The events that led to this grounding may be used to illustrate the relationship of PTP with the basics of risk management.

Commandant G-M labels the identification of risks and the management of those risks as one of its primary "Business" Coast Guard attain the goals needed for the preservation of life, property, and the environment.

PTP may be thought of as a tool to fine tune the focus of risk management. This focus targets the identification of root causes, specifically human error, which in conjunction with faults in organizational elements (such as deficiencies in safety, training, and other management systems), have sparked many marine casualties.

The principles that form the foundation of PTP include: management, behavior, work environment, and technology. The five root cause categories of human error the Coast Guard has identified include: management, operator status, working environment, knowledge, and decision making. The grounding of the Mormacstar can be used to highlight the behavior component of PTP, specifically the root cause category of decision making.

The Pilot on board the MORMACSTAR had over twenty years of experience with the Sandy Hooks Pilots Association, however, he relied solely on this visual observations of the aids to navigation in positioning the MORMACSTAR within the channel. The use of electronic means to ascertain position was not initiated by the pilot or master before or after the grounding. Differential Global Positioning System (DGPS) points, plotted by the Coast Guard, found the MORMACSTAR to be just outside the right had side the channel.

The sole reliance on visual observation of the aids to navigation, the failure to accurately fix or know the position of the MORMACSTAR, and the decision to meet near and area of known shoaling fit within the behavior and decision making elements of PTP.

Discovering what has happened and tracing back to a core problem to discover what individuals and organizations should focus upon to prevent future casualties is one part of PTP at work. PTP will require a working relationship between industry and government identifying root causes and developing systematic risk based methods to reduce the occurrence of these casualties.

Once implemented, PTP will work to complement existing regulations and risk management tools to support safe and profitable operations. Critical to accomplishing this goal will be the placement of risk management as a top priority by both industry and government.

"YOU CAN'T SAY THE GOVERNMENT ISN'T TRYING."

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U.S. Department
of Transportation

**United States
Coast Guard**

National Maritime Center
4200 Wilson Blvd., Suite 510
Arlington, VA 22203-1804