NATIONAL TRANSPORTATION SAFETY BOARD

ANALYSIS OF THE SAFETY OF TRANSPORTATION OF HAZARDOUS MATERIALS ON THE NAVIGABLE WATERS OF THE UNITED STATES

NATIONAL TRANSPORTATION SAFETY BOARD
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16. Abstract

The report analyzes the safety of transportation of bulk hazardous materials on the navigable waters of the United States. Typical hazardous materials (H.M.) accidents are analyzed to determine what countermeasures are necessary to prevent recurrence. Risks involved in the transportation of H.M. are analyzed, with priority given to prevention of catastrophic accidents. The ingredients necessary for the occurrence of a catastrophic H.M. incident are discussed, and the risk peaks leading to the casualty are analyzed. Federal regulatory authority over the transportation of H.M. by water is summarized. Projects of the future shipment of H.M., and trends in H.M. accidents are made. The report concludes with a summary of areas of control of H.M. needed to prevent major H.M. accidents, and recommendations made to implement these added controls.

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I. PURPOSE, SCOPE AND PROJECTIONS

A. Purpose:

The purpose of this special study is to analyze data on marine casualties involving the transportation of hazardous materials[1] to determine whether additional safety measures are needed to assure an acceptable level of risk.

The National Transportation Safety Board has noted previously the potential for catastrophes involving hazardous materials transported on the navigable waters of the United States in the following reports: (1) Special Study of Towing Vessel Safety and Accident Preventive Recommendations, released September 12, 1969; (2) Special Study of Collisions Within the Navigable Waters of the United States; (3) Collision Involving the SS ARIZONA STANDARD and SS OREGON STANDARD at the Entrance to San Francisco Bay, released August 11, 1971; and (4) Collision Involving the SS UNION FAITH and M/V WARREN J. DOUCET and Tow in the Mississippi River, released December 22, 1970. The Safety Board's report of a special study of Risk Concepts in Dangerous Goods Transportation Regulations, released on January 27, 1971, also addresses the problem of potential catastrophic hazardous materials accidents.

In addition, Coast Guard accident reports were reviewed and a number of them revealed near-miss catastrophes which would have involved third parties or the general public in the area of the accident. Some of these cases are analyzed in a subsequent section.

The potential for catastrophes, and the threat to the general public prompted this study. The Safety Board considers the investigation and prevention of transportation accidents to be one of its most important missions. Hazardous materials have the potential to cause the largest scale catastrophic transportation accidents.

B. Scope:

The scope of this study has been limited to the navigable waters of the United States for several reasons. First, available casualty data are more complete. Second, the controls needed to minimize risks could be implemented unilaterally on these waters. Third, the potential for massive third party involvement is greatest. Fourth, the greatest incidence of casualties involving hazardous materials occurs on these waters. Fifth, the serious potential ecological losses from casualties involving supertankers.

Emphasis in this study has been limited to the bulk transportation of hazardous materials since it poses the greatest threat of a catastrophic accident affecting the public.

C. Projections:

The transportation of hazardous materials by water increased steadily during the 1960's and that trend is expected to continue during this decade.[2] Petroleum products comprise about 84 percent of the tonnage of hazardous materials

[1] Hazardous materials, for the purposes of this study, are defined as those articles listed in 46 CFR 146.03-8, and in 49 CFR 172.

shipped by water, and chemicals comprise approximately 4 percent. The rate of annual increase in amounts and varieties of commodities transported by water is highest in the chemical and petroleum products categories.

Projections of the U. S. demands for energy consumption indicate an increase in consumption of petroleum from 30 million barrels a day in 1970 to 60 million barrels a day in 1985.[2] Known domestic sources of petroleum, natural gas, and other energy sources can supply only half of this Nation's demands. This will necessitate the importation of half our energy producing commodities, and the development of deepwater petroleum terminals to accommodate the relatively economical supertankers. Barges, tankers, and pipelines will carry a proportionate share of the increase in the distribution of these products. The increase in amounts shipped by water will be at a far greater rate than the development of additional waterways. This will result in higher density of traffic on our inland waterways, and commensurate increase in risks to the general public and the environment.

II. PREVIOUS CASUALTIES

The Texas City disaster on April 16, 1947, and the evacuation of the public in the area of the sunken chlorine barge WYCHEM 112 in the Mississippi River, near Nadres, Louisiana, on March 23, 1961, focused governmental and public attention on the potential for catastrophic accidents in the transportation of hazardous materials. These casualties resulted in the promulgation of regulations and safe operating practices which have prevented catastrophic casualties involving transportation of ammonium nitrate and chlorine.

In addition to the accidents reported in the previously mentioned Safety Board reports, several casualties narrowly missed catastrophic consequencies:

1. *M/V HALIFAX STAR (British) and uninspected M/V JOHN M. WARNER (O.N. 244152) and tow, T/B CHEMICAL 704 (undocumented); collision in Houston Ship Channel, Texas, 6 September 1969.* The inbound M/V HALIFAX STAR (British) collided with the outbound tank barge CHEMICAL 704 in tow of the M/V JOHN M. WARNER in the Houston Ship Channel on September 6, 1969. The CHEMICAL 704 carried about 1900 tons of liquified propylene in two cylindrical cargo tanks at 34 p.s.i. and -14° F. The barge sank and one of the cargo tanks was ruptured; propylene was released which spewed 200 feet above the water, removed the paint from the bows of the HALIFAX STAR, and enveloped both vessels in a dense cloud of gas. The HALIFAX STAR secured her engines and other sources of ignition; the vapors did not ignite and they dissipated. The JOHN M. WARNER parted her tow wires and stood clear of the gas cloud. In view of propylene's low boiling point (-53° F), high vapor pressure (227.2 p.s.i.) and range of flammable limits, it was fortunate that the vapor did not ignite. The cold temperature of the cargo probably reduced the chances of ignition. If this collision had occurred adjacent to one of the numerous industries lining the Houston Ship Channel and if the gas had ignited, a series of explosions could have occurred with large loss of life and property damage. The potential for large loss of life and property damages in the transportation of propylene was demonstrated in the explosions and fire involving railroad tank cars in East St. Louis, Illinois, on January 22, 1972.

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[2] Assistant Secretary of Commerce for Maritime Affairs, Andrew D. Gibson, in his presentation to the 60th Annual Convention of the American Association of Port Authorities in Portland, Oregon.

Valuable data could have been obtained from the CHEMICAL 704 accident which would be useful in analysis of the risks involved in transporting propylene. The collection of such information as the atmospheric conditions, the vapor plume of the escaping gas, the rate for the release, and the size of the orifice in the ruptured tank, would have enabled an analyst to assess the risks involved in accidental releases of propylene. Unfortunately, the report of the investigation did not provide adequate data for such an analysis. The report did develop some of the causal factors involved in the collision, which were: (a) the inadequacy of whistle signals to achieve agreement in passing; (b) the lack of a common mandatory bridge-to-bridge radiotelephone frequency; (c) the failure of both vessels to comply with the Inland Rules of the Road; (d) the towing vessel operator's misinterpretation of the target aspect of the HALIFAX STAR, based on her navigation lights; and (e) the narrow, winding constraints of the channel in the area of the collision. No specific recommendations were made to prevent recurrence of such a casualty.

2. *Fire and Explosions on Tank Barge MOS 106 at La Grange, Missouri; released by the Safety Board on March 9, 1971.* The Safety Board has noted the potential for major losses resulting from casualties during transfer of petroleum products. In the final report of the "Fire and Explosions on Tank Barge MOS 106 at La Grange, Missouri", released on March 9, 1971, the lack of specific maximum loading criteria and the lack of safe transfer procedures were noted. In this case, the MOS 106 caught fire during the discharge of gasoline to the Triangle Oil Refining Company terminal. The burning barge was cut loose; it drifted downstream and damaged a grain elevator and the Chicago, Burlington, and Quincy Railroad bridge. It was fortuitous that the tank barge did not drift down on the waterfront of Quincy, Illinois, as some 270,000 gallons of gasoline were burned or lost.

   The Coast Guard's analysis of reported oil spills in 1970 shows that tank barges were involved in 10.3 percent of the spills, and 10.8 percent of the total volume of products discharged into the navigable waters. Based on 265 reports involving tank barges, 38 incidents were attributed to collisions, groundings, and capsizings; 84 were determined to be caused by personnel error; 67 cases were due to material failure of hoses, valves, pumps, pipes, and hull structures; and four were due to fires and explosions. These data show that a small number of incidents result in fire or explosion, but the damages to the environment are not quantified. Moreover, the potential for a major fire is present in all cases in which combustible liquids or gases are accidentally or deliberately discharged overboard.

3. *Tankship MICHAEL B., (O.N. 231610): fire and explosion aboard at Port Reading, N.J., on 15 March 1969, with loss of life.* Another casualty involving the routine transfer of gasoline to a tankship illustrates this high level of risk. The tankship MICHAEL B. was loading about 215,000 gallons of regular and premium gasoline at the Hess Oil Company Terminal at Port Reading, N. J. on March 15, 1969. A diesel generator was in operation to provide ship's power, and an oil-fired galley range was burning at a low setting. Premium gasoline was being pumped into the port and starboard No. 4 tanks. The deckhand, after lining up the valves, turned in for a nap. Twenty minutes later, a gauger on an adjacent barge heard the sound of valves being operated on the MICHAEL B., and

he noticed another deckhand closing the valves to No. 4 tanks, and gasoline running aft, overflowing from the open tank covers. The gauger heard the sound of flammable vapors igniting, and saw that the No. 4 tanks and the after deckhouse were ablaze. Two explosions occurred in quick sequence a few seconds later, and the whole vessel was engulfed in flames. The Hess assistant gauger notified the Hess fire department which responded within 10 minutes. The flames spread to the pier, the fiber mooring lines of the MICHAEL B. burned through, and the burning vessel swung toward overhead pipelines. The Hess, Port Reading, Annandale, and Woodbridge fire departments fought the blaze on the Hess facility with water, and, assisted by the tugs BRUCE McALLISTER, CATHERINE McALLISTER, and DAZELLEAGLE, used chemical foam on the MICHAEL B. The BRUCE McALLISTER succeeded in towing the burning tank vessel away from the pipelines, and anchored it on the mud flats off Staten Island. The fire on the MICHAEL B. was extinguished several hours later. Two crewmembers were killed and two others were severely burned. The Hess facility was severely damaged. Burning gasoline on the Kill Van Kull channel posed a serious hazard to the densely built-up complex of petrochemical plants, refineries, and oil storage tanks along this waterway. The channel was closed to navigation for a day. The prompt action by the fire departments and the three towing vessels averted a catastrophic conflagration in this populated area.

Several lessons are apparent in this case. The Coast Guard regulations require a certificated tankerman to supervise the transfer of flammable products. The Coast Guard manual for "The Safe Handling of Inflammable and Combustible Liquids" states that "the senior deck officer shall see that an inspection has been made to determine whether boiler fires and galley fires can be maintained with reasonable safety." It is obvious that the transfer operation was not supervised properly as required by regulations. The galley range was the most probable source of ignition, as it was in the case of the MOS 106, yet the operation of the stove is left to the discretion of the senior officer. In its final action on the MOS 106 report, the Safety Board recommended that the Coast Guard evaluate the effectiveness of such recommended safe practices for the purpose of determining whether they should be made mandatory by regulation.

This accident illustrates the need to determine the acceptability of the risks which result from the location of a petroleum transfer terminal in the midst of such a high concentration of petrochemical and oil storage facilities. Many similar colocations of transfer facilities and hazardous materials plants exist in other densely populated areas of the United States. The location of these terminals is influenced by such factors as: the access to the open seas; the economics of distribution; insurance underwriters' requirements; local zoning standards; the availability of property on the navigable waters; and some restrictions exercised by the State and Federal environmental protection agencies. The Coast Guard statistics for reported spills show that 59 percent of the volume of pollution originated from onshore facilities such as refineries, bulk storage facilities, and other waterfront facilities.

4. *SS REGENT LIVERPOOL, (O.N. 304364) (British Tank Vessel); Collision* with Delaware Memorial Bridge, Delaware River, on 9 July 1969, with no injuries or loss of life. The collision of

the British tank vessel SS REGENT LIVERPOOL with the Delaware Memorial Bridge on July 9, 1969, is an example of a reasonably predictable risk which is imposed on the public in the bulk shipping of petroleum. This vessel sustained a casualty to her steering gear, and her port bow struck a glancing blow on the west abutment of the bridge. Fortunately, no oil was lost, and no fire occurred. The REGENT LIVERPOOL was holed longitudinally 100 feet on her port side, and damages amounted to $100,000. The bridge abutment fenders and concrete structures were damaged and repair costs were estimated to be one million dollars. This collision was attributed to a failure of a small part in the port hydraulic pump control motor. The foreign vessel was under the advisory control of a licensed State pilot who had no indication of steering difficulties until just before the collision.

This casualty could have resulted in the closure of this major arterial highway bridge, and the loss of life in the numerous vehicles transitting it, if the vessel had exploded underneath the bridge. There are numerous refineries on both sides of the Delaware River upstream from this bridge, and thousands of transits are made by tank vessels each year. These refineries were built prior to the bridge, and are essential to the highly developed Philadelphia, Camden, and Wilmington area. The demands imposed by the rapid increase in motor vehicles necessitated the construction of another bridge span in 1970. Twenty years ago, ferries carried vehicles across the Delaware River at this point.

5. *T/B NMS No. 41, (O.N. 262900) in tow of M/V DELTA CITIES, (O.N. 262761); collision with West Port Arthur Bridge Fender System at Mile 288.7, WHL, of the Gulf Intracoastal Waterway on 13 September 1970, with loss of life.* An illustration of what could have happened in the REGENT LIVERPOOL case was noted in the collision of the tank barge NMS No. 41 in tow of the M/V DELTA CITIES, with a fender of the West Port Arthur Highway draw bridge, on September 13, 1970. The DELTA CITIES was pushing four tank barges eastbound on the Gulf Intracoastal Waterway and was passing under the bridge at the time of the casualty. The horizontal clearance under this bridge was 100 feet and the barges were 52 feet wide. The bridge supports were fitted with steel fenders to protect the vertical concrete support columns. The leading three barges cleared the bridge with no problem, but the southerly current in the Sabine-Neches and Port Arthur Canals had set the head of the tow towards the south bank, which canted the tow in the channel. The pilot tried to straighten the tow by the use of hard rudder and by increased pitch on the variable pitch propellers, but the starboard side of NMS No. 41 struck against a steel fender of the bridge. The impact fractured the deck of No. 1 port tank of the barge longitudinally for 25 feet. Premium gasoline leaked from the fractured deck and was ignited, presumably by sparks produced from the steel-to-steel contact. Fire immediately engulfed the bow and starboard side of the DELTA CITIES, and the easterly wind blew the flames and smoke over the towing vessel, which precluded access to the towing winches and the release of the burning barge. The master of the DELTA CITIES tried to ground the tow on Pleasure Island to prevent the burning tow from drifting into the Texaco dock and tank farm. The vessel lost power, and the crew jumped overboard. Five of the crew of eight survived, of whom three sustained injuries. Three towing vessels and a Coast Guard patrol

craft responded to emergency whistle signals from the DELTA CITIES, rescued the survivors, and fought the fire. They grounded the burning towing vessel and barge, and assisted by the Port Arthur fire department, extinguished the fires on the vessels, the bridge, and the burning gasoline in the channel. These actions avoided a major fire at the Texaco facility. The highway bridge was damaged severely and has since been replaced by a new bridge. The old bridge had been damaged by vessels six to eight times in recent years. The cause of this casualty was categorized generally as personnel error, and no remedial recommendations were made in the report of investigation.

This case demonstrates the lack of adequate maneuverability of tows to navigate such narrow channels, and the lack of criteria to limit the size and capacity of tows. The operator was not licensed, nor was the towing vessel subject to inspection. Only the tank barges were subject to regulatory control by the Coast Guard.

6. *Uninspected tugboat M/V KATE MALLOY (O.N. 264248) and tow, inspected tank barges LSC-50 (Undocumented) and LSC-52 (O.N. 290961); collision with SS GULF SUPREME (O.N. 287186), at approximately Mile 24.7, Above Head of Passes (AHP), Mississippi River, at Buras, Louisiana, with fire, on 25 December 1967.* The collision of the tank barges in tow of the M/V KATE MALLOY with the anchored tank vessel SS GULF SUPREME, on December 25, 1967, at Buras, Louisiana, is another example of lack of criteria for the capability of towing vessels to control barges. This casualty resulted in serious damage to two tank barges, the GULFSUPREME, and serious injuries to nine of its crewmembers. The KATE MALLOY was maneuvering to take two tank barges loaded with crude oil in tow astern. As the towing vessel backed out into the Mississippi River, it lost control of the barges and they drifted down on the anchored tank vessel. The GULFSUPREME's port anchor chain was parted from the anchor, the chain sheared into the tanks of the tank barge LSC-50, and fire broke out almost at once. The KATE MALLOY cast off the tow and backed clear of the fire. The burning barges and oil on the water alongside ignited fires on board both sides of the GULFSUPREME. Burning oil sprayed on deck and the flames were estimated to have reached a height of 80 feet. The GULFSUPREME had steam on the main throttle, and was able to get underway in a few minutes and to clear the burning barges. The vessel was grounded intentionally after the starboard anchor was also lost. The two burning barges were still connected to the parted port anchor chain of the tank vessel. The KATE MALLOY and several other tugs assisted in removing the injured tankship crewmen and fighting the fires on the barges and the GULFSUPREME. The tank vessel sustained damages in excess of 400,000 dollars. It was fortunate that the fire was brought under control before it spread to shoreside facilities. If this collision had occurred in a more built-up area of the river, such as New Orleans, extensive damage to third party property could have occurred. The operator of the KATE MALLOY was not licensed, nor was the towing vessel subject to inspection. The 900-horsepower engine on the towing vessel was not capable of controlling the loaded barges in the 5-mile-per-hour current. There are no specified criteria for rating the load capability for individual towing vessels.

7. *Fire and explosions of the inspected*

tank barges MOS 101 (O.N. 262739) and MOS 103 (O.N. 262740) in tow of the uninspected towing vessel M/V MARTIN (O.N. 260333) on the Ohio River, under the B&O Railroad Bridge. A most recent casualty occurred on the Ohio River in the vicinity of Parkersburg, West Virginia, on January 7, 1972. The towboat MARTIN was proceeding downriver pushing two empty gasoline barges, the MOS 101 and MOS 103. An explosion occurred on the barges just as they were passing under the B&O Railroad Bridge. Both barges blew up and sank within minutes, the towboat was extensively damaged, the railroad bridge was severely damaged, the highway bridge located a few hundred yards downstream was moderately damaged, and windows were blown out in more than 100 buildings and houses in Parkersburg and Belpre, Ohio. The two crewmembers who were on one of the barges at the time of the explosion are missing and presumed dead. Approximately 12 persons were injured, most of whom were cut by broken glass.

This accident was unique in that it involved three modes of transportation. The main navigation channel was blocked for approximately 2 weeks. The highway bridge was closed for repairs for more than 1 week. The railroad bridge will be closed for several months. The death and injury count could have been much higher if the explosion had occurred moments later when the barges would have been under the highway bridge. There were both cars and pedestrains on the bridge at the time of the accident.

The investigation of this casualty has not been completed, thus, the probable cause of the explosion has not been determined.

8. *SS PRESIDENT HARDING, (O.N. 248275); fire on 8-10 May 1971, in Port Newark, New Jersey, with no loss of life.* Casualties are not limited to tank vessels carrying hazardous materials in bulk. The problems encountered in limiting the adverse results of hazardous materials on cargo vessels are similar to those experienced in incidents involving bulk hazardous material. An example of a cargo vessel casualty is the fire which occurred on board the SS PRESIDENT HARDING in Port Newark, New Jersey, on May 8, 1971. Drums of sodium hydrosulfite were loaded in the upper tween deck of No. 1 hold, on plywood flooring and secured with wood dunnage. A variety of combustible cargo was also stowed in this tween deck, including calcium hypochlorite. The hazards of this commodity were noted in the Safety Board's report of the THORSTREAM casualty. Occasional heavy rain showers had occurred while the cargo was being loaded.

Sodium hydrosulfite becomes chemically unstable upon contact with water or moist air which will cause it to burn slowly at a very high temperature. The chemical reaction with water requires no external source of oxygen to sustain combustion. A heavy shower occurred during the loading of No. 2 hold, and it was covered and battened down. The No. 1 hold had been closed, but the tarpaulins were not battened down. The vents to the holds were open. A few hours later, fire in No. 1 hold was reported. The vents to both holds were closed and 1,500 pounds of CO_2 were discharged in No. 1 hold. Gray and yellow-brown smoke billowed out from under the hatch covers, and the fumes were extremely pungent. Application of another 3,000 pounds of CO_2 was ineffective in controlling the fire. Coast

Guard and fire department officers decided to use water to fight the fire. As soon as water was applied, loud noises and large quantities of smoke emitted from the hold. High expansion foam, water spray, and flooding were applied to try to extinquish the fire for the next 2 days without success. The No. 1 and 2 holds were flooded; the vessel rested on the bottom and listed, and it had to be dewatered. Three days after the casualty, the fire was finally extinquished, with damages estimated in excess of $150,000. Examination of No. 1 hold revealed that the exposed sodium hydrosulfite was no longer capable of self-ignition. The charred interior of No. 1 hold indicated that the extreme temperatures generated by the chemical reaction of the sodium hydrosulfite ignited the other combustibles. The fire did not subside until the chemical reaction was exhausted. The Coast Guard report recommended that firefighting personnel be apprised of the firefighting procedures for sodium hydrosulfite and other hazardous materials. The National Fire Protection Association recommends CO_2, dry foam, sand, and flooding as fire extinquishing agents for sodium hydrosulfite fires. The Coast Guard's recommendation is a valid one, and demonstrates the need for assigning responsibility in shipboard firefighting efforts. The Coast Guard does not have legal responsibility to fight waterfront fires, but frequently assists with the local firefighting authorities with available equipment and personnel. The local Coast Guard Captain of the Port normally responds to such emergencies, and works out contingency plans with other local organizations. These agreements are important in bringing all emergency facilities to bear quickly and in assigning responsibilities.

III. ANALYSIS OF RISKS IN TRANSPORTATION OF HAZARDOUS MATERIALS ON THE NAVIGABLE WATERS OF THE UNITED STATES

A. Ingredients of a Catastrophe:

Before the issue of a catastrophic accident in the marine mode is addressed, it is necessary to discuss the intended meaning of that term. For our purposes, such an accident is considered to involve the risk of large property losses, serious or fatal injury to a large number of persons, or both, in a single accident involving the marine transportation of hazardous materials. A catastrophic accident includes the entire sequence from the occurrence of the first abnormal event to the termination of the final loss-producing event. Thus, the occurrence of the initial abnormal event, the conditions which permit the sequence to continue, and the loss-producing events, are involved.

One way to assess the current approaches and measures applied by the Coast Guard in its efforts to guard against catastrophic accidents is to view them from the perspective of risk level. A possible framework for such a review is suggested in the Safety Board's special study of "Risk Concepts in Dangerous Goods Transportation Regulations." Within such a framework, the potential for catastrophic accidents would reflect the existence of "risk peaks" which occur during the handling and transportation of hazardous materials on the waterways.

One of the ingredients in a "risk peak" is the presence of persons, properties, or systems which may be exposed to severe injury or death in the event of a marine accident involving hazardous materials. Catastrophic accidents involving persons, for example, would require an aggregation in the proximity of the accident. The identification of different elements of the population encountered along the marine pathways falls into essentially three categories, each of which is basically fixed or reasonably predictable. These three categories are bystanders, emergency response personnel, and marine operating personnel. Each segment has a different risk relationship to a potential catastrophe.

Of principal concern are bystanders, who either congregate near the pathway traversed by vessels transporting hazardous materials, or are occupants of the zone which can be affected during a catastrophic accident. The density of the occupancy in the danger zone by such bystanders directly affects the scope of a catastrophic accident.

B. The Approaches to the Avoidance of Catastrophic Consequences:

Concentrations of persons are found in cities along waterways, on bridges or in tunnels over or under waterways, and on passing vessels which are joint occupants of the pathway traveled by vessels transporting hazardous cargoes. The risk level concept involves the documentation of these population concentrations as an essential step in addressing the problem of catastrophic accidents. These concentrations of bystanders may change, as they would on a bridge over a waterway, or on a ferryboat, but the qualitative identification of where these concentrations occur is an essential first step. Subsequent refinements in risk assessment methods can incorporate these changes in the population during the exposure periods.

The second category of persons at risk was illustrated by the losses among emergency response personnel at the Texas City disaster. This category of persons is usually called to the scene of an accident while a threat to personal safety still exists. Such personnel are accustomed to accepting substantial risks, but the Texas City disaster suggests that a greater understanding of their role in accidents is necessary. The third group of persons at risk are the operators of the vessels transporting hazardous materials. Here again, the scope of the catastrophe increases directly with the increase in the number of personnel. Here too, the presence of such personnel lends itself to prediction. Large vessels transporting hazardous cargoes would be expected to contribute to the existence of peak risks.

A second ingredient necessary for catastrophic occurrences is the presence of a hazardous material with the capability of bringing about a large number of loss-producing events. Catastrophic accidents are most likely to occur when materials are present which are capable of a sudden release of large quantities of energy, or which can contaminate life-supporting systems over a large area. The maximum credible catastrophic accident would probably result from the sudden spread of vapor of a toxic or explosive characteristic over a large metropolitan area. Each category of such materials involves a predictable danger zone which moves with the vessel as the vessel proceeds along the marine pathway. When this danger zone overlaps population concentrations, the location of potential catastrophes can be identified. While this approach may be generally understood, coordinated documentation and display of the data do not exist.

A third ingredient essential to a catastrophic accident in marine transportation is the occurrence of a "triggering" mechanism which initiates the sequence of accident events culminating in catastrophic losses. The control of these "triggers" have followed three general approaches:

1. Analysis of historical accident data
2. Expert judgment
3. Transference of technology.

The approach utilizing analysis of accidents which have occurred to determine future corrective measures attempts to benefit from the experience that has been acquired, but it is of little value in assuring the public that the next – and different – catastrophic accident will be avoided. Expert judgment similarly leans heavily on the past experience of the experts, who utilize a type of checklist approach. The development of the present tank vessel regulations is an example of the use of this approach. Frequently, this approach does not include critical testing by logical analysis of the interactions of the items on the checklist. More importantly, it frequently fails to provide a mechanism for the "discovery" of unexpected hazards or relationships which are likely to result in a catastrophic accident of a type not previously experienced. The recent explosions in cargo tanks of foreign flag supertankers is an illustration of an undiscovered hazard.

The transference of existing technology, as refined through accident experience and expert judgment, to new hazardous materials transportation problems, frequently occurs. An example of this approach will be found in the development of transportation systems for liquified natural gas, which utilize technology acquired in the transportation of other liquid combustible materials. This transfer by analogy is not without merit, but it does not provide a mechanism for the "discovery" of risk peaks liable to occur in connection with the operation of hazardous materials transportation systems.

In the absence of analytical techniques designed to facilitate the discovery of hazardous conditions, "triggering" elements, excessive exposure to loss, and the interrelationship of these factors, the identification of risk peaks which might transition into catastrophic accidents involves a substantial degree of chance. Methods for identifying postulated catastrophic accidents, and analyzing these accident mechanisms, appear to be needed to assure that everything possible is done to prevent catastrophic marine accidents involving hazardous materials.

Once the risk peaks have been identified and analyzed, measures for "risk peak shaving" or reducing the risk peaks can be developed and implemented. The application of rigorous logic in the search for these risk peaks, and identification of the factors which contribute to their existence, do not appear to have been incorporated in past efforts. This is not to say that substantive efforts have not been addressed to the problem. For example, the Coast Guard has sponsored research into specific problem areas such as maximum cargo size limitations, cargo mixing, and other cargo-related hazard identification problems in a largely case-by-case approach. Analysis of accident data, cargo vessel inspection programs, and certain emergency planning activities such as the National Oil and Hazardous Substances Pollution Contingency Plan illustrates the Coast Guard's concern for, and efforts to address this problem area. The Coast Guard is also funding efforts to develop better methodologies to diagnose risks associated with hazardous materials transportation. To date, however, the linking together of these efforts into a systematic search for risk peaks, in which the potential for catastrophic accidents exist, has not been accomplished. Instead, risk peaks have been identified by tallying accidents, and attributing the accident to one or more factors described by the accident report. Fortunately, the frequency of catastrophic marine accidents involving hazardous materials has been very low. As a result, statistical analysis of these casualties is of little value. The use of accident experience as a basis for predicting the occurrence of a catastrophic accident is of questionable value. This becomes increasingly apparent when we consider the problems associated with new products which enter the marine transportation system, and the increases in the sizes of shipments, vessels, and tows.

C. Technical Analysis:

Technical methods for an organized search for conditions which can contribute to the occurrence of a catastrophic accident have been developed, based largely on the utilization of "logic trees." The application of logic trees to this problem might proceed from the selection of discrete postulated accidents which could reasonably be anticipated for each class of hazardous commodity which poses a threat to the public when transported by water. The logical construction of the sequence of events which might lead to such accidents, and the delineation of the conditions which must be present for such events to begin and to progress without interruption to catastrophic proportions, would permit analysis of the accident before it occurs. This qualitative analysis could determine the comparative likelihood of hazards which must be removed or controlled by regulatory or private action to minimize the possibility of such an accident. By examining the cost of such control measures, and their resultant impact on the likelihood of the occurrence of a catastrophic accident, a rationale would be available for regulation based on a technical analysis of an accident before it happens.

Refinement of the qualitative analysis, by collecting data on the existence of the anticipated hazard in routine operations, would serve to validate the estimated comparative probabilities, and would provide an indicator of the effectiveness of the regulation. Conditions contributing to the existence of risk peaks can be addressed after review of the entire sequence of events, from the beginning of the accident to the termination of the loss-producing events. The possibility of controlling losses associated with hazardous materials transportation system failures such as groundings, collisions, transfer malfunctions, breakdowns, and fires can be examined.

Evacuation is one method of reducing risks related to possible public exposure. Shielding may offer additional choices. Controls on the quantities of materials which can encroach on concentrated populations may offer another option. Emergency response techniques may offer yet another option. However, for marine casualties, the emergency response structure is not clear, either in terms of statutory authority, or in actual response practices. It is equally unclear what the precise emergency response structure should be. For example, if an accident involving hazardous cargo occurs near the shore of the Ohio River adjacent to Parkersburg, West Virginia, how will this emergency be met? Who has jurisdiction over the incident? Who has the authority, and is equipped to respond to the emergency? Who is accountable for the evacuation of personnel?

The sinking of a chlorine barge in the Mississippi River off Baton Rouge illustrates this difficulty. In that accident, under the right atmospheric conditions, the loss of product from the barge could have resulted in widespread injury. The infrequency of such incidents in any one location, and the resources generally required to be mobilized in response to such emergencies, constitute a significant safety problem area.

D. Example of Risk Analysis:

As an example, the general principles of risk analysis are applied herein to illustrate its application to a planned shipment of liquified natural gas (LNG) by vessel into a densely populated area. The limited amount of natural gas reserves, combined with the projected increase in demand in the United States, will necessitate the importation of large quantities of LNG in the near future. Several U. S. gas companies are building LNG tank vessels in the United States and abroad, in anticipation of this demand for imported gas.

Let us assume that a U. S. company plans to import LNG by tank vessel into the New York City area, via Raritan Bay, and Arthur Kill to a terminal on Staten Island. LNG is classified as a hazardous material, flash point 306° F ambient vapor pressure 2,000 p.s.i.a., flammable limits in air 5 to 15 percent, and vapor density .55. Tests conducted by the Bureau of Mines demonstrated that a flameless explosion phenomena may occur when LNG is spilled in water. Further studies are in progress to determine the causes of this phenomena.

Here are the necessary ingredients for a catastrophic accident: large quantity (120,000 cubic meters) of hazardous material; heavy vessel traffic; railroad and highway bridges; dense population concentrations along the waterway; and a number of "triggers" to ignite LNG vapor should it be released. An interesting article in the September 1971 issue of the Coast Guard "Proceedings of the Marine Safety Council" by Lcdr. H. D. Williams, USCG, shows the possible spread of LNG vapor over Staten Island. A copy of the sketch is attached in the Appendix for reference. It should be noted that the area covered by the explosive vapor propagates from the source of release, and is a function of the time after the accident. Thus, a larger area is actually exposed to the explosive vapors than that shown in the sketch.

Release of the LNG could result from a failure of the tanks of LNG under cryogenic conditions. Another potential risk is release due to a collision with another vessel or a permanent structure such as a bridge. Still another source is the vapor boil-off of the cargo which must be either used on the vessel, or vented to the atmosphere or water. Specific data needed to predict the potential area and time of exposure of the vapor released includes: the amount lost; the pressure; the orifice through which the liquid escapes; the wind direction and velocity; atmospheric conditions; the current; sea condition; water and air temperatures; position of the tank opening relative to the waterline; and other factors which determine the rate of vaporization of the LNG.

Weather conditions are predictable, and follow a cyclic seasonal pattern during the year. It is also possible to predict the area of maximum exposure to cross traffic, and obstructions to navigation of the LNG tank vessel. These data, coupled with known population concentrations along the route, enable an assessment of "peak risks" to be made for this specific commodity, area, and time.

Such an analysis should lead to specific countermeasures. These might include: secondary barriers on the vessel; limit nagivation to daylight hours; escort of the vessel, and control of shipping along its route; elimination of "trigger mechanisms" for released vapor; and preplanned emergency procedures to minimize the results of an explosion of LNG vapors.

This example raises the question of who makes the decision as to what combination of risks exceeds acceptable limits. Is the final decision a matter for the local authorities to make? Should a Federal agency weigh the benefits and risks and have the authority to approve or disapprove the enterprise? It might be in the public interest to transport the hazardous material by pipeline, or in smaller quantities by other modes of transportation. The risks involved must be considered along with the economics of providing necessary commodities for public use. The answers to these probing questions are not currently available. The social, political, and economic factors involved in each such case are complex, and interrelated; yet some responsible institution or group of institutions should protect the public interest. The Office of Emergency Preparedness appears to have responsibility in this area.

The example given is not intended to demonstrate the maximum risk to be encountered in the shipment of hazardous materials. Many other products, such as chlorine and anhydrous ammonia, pose greater risks. A ranking of materials shipped in bulk by water transportation in order of magnitude of risk would serve as a priority guide for analyzing the risks for the various commodities.

IV. PROJECTED TRENDS IN MARINE TRANSPORTATION OF HAZARDOUS MATERIALS

A. Production of Hazardous Materials:

Review of statistical data readily discloses the significant increase during the last decade in production of hazardous materials in the United States. Every year, more than 500 new chemicals are being developed.[1] Production

[1] Control of Hazardous Polluting Substances; Department of Transportation, U. S. Coast Guard, p. 1-0 Executive Summary.

figures for ten classifications of hazardous materials are shown in Table I.[2] Over 2 billion tons of these materials were produced in 1968-69. This figure is expected to increase approximately 73 percent to nearly 4 billion tons by 1979-80. Between 1958 and 1968, yearly percent increase for all classifications except the flammable materials class, has been greater than the annual growth rate of the real Gross National Product (4.4 percent). A 10-year-projected growth rate of hazardous materials production appears to be approximately 1½ times greater than the Gross National Product growth rate.[3]

[2] An Appraisal of the Problem of the Handling, Transportation, and Disposal of Toxic and Other Hazardous Materials; Booz-Allen & Hamilton; hereinafter referred to as Booz-Allen. Exhibit II-1.

[3] Booz-Allen, p. 7

TABLE I

HAZARDOUS MATERIALS PRODUCTION

Classification	Produced & Handled* 1968-69	Produced & Handled* 1979-80	% Increase 1968-69 – 1979-80	% Increase Per Year
Flammable materials	1,620.0	2,420.0	50	3.8
Compressed gases	508.0	1,067.0	110	7.0
Explosives	20.0	40.0	100	6.5
Corrosive materials	45.1	95.9	112	7.1
Oxidizing agents	7.8	19.4	149	8.6
Poisons	1.2	2.6	117	7.3
Etiologic materials	7.8	——	——	——
Cryogenic materials	36.0	92.0	156	8.9
Radioactive materials	17.0**	163.0**	860	22.8
Molten materials	13.0	41.0	215	15.0
Total	2,258.9***	3,778.1***	67***	

*Millions of tons
**Thousands of tons
***Computational errors in the original table have been corrected

Table II[4] provides a comparison of chemical production and population growth between 1958 and 1968. Organic chemical production more than doubled, inorganic chemical production nearly doubled, and petroleum production rose approximately 40 percent. At the same time, the growth in population was only 15 percent.

TABLE II

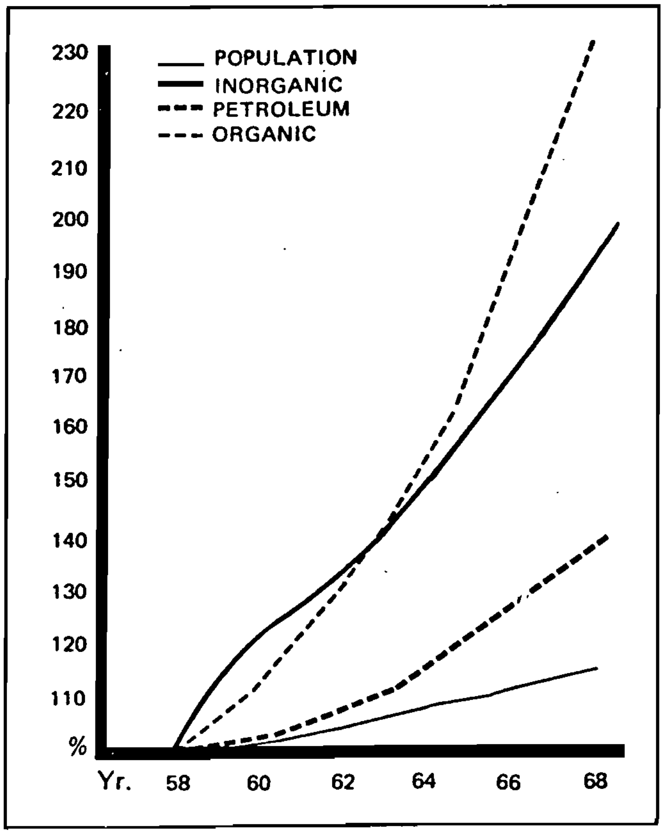

Figure 1. Growth in Population and Chemical Production, 1958–1968 (1958=100%) *

[1] *Chemical Engineering Progress,* February 1970, p. 58, McConnaughey, et. al., and "10 Year Growth Patterns in the Chemical Processing Industries," Chemical Processing PRD No. 263, 1965.

B. Transportation of Hazardous Materials:

As would be expected, the increases in production are directly reflected in the increases in shipments of hazardous materials by all of the primary modes of transportation. In 1967, an estimated 414 million tons of hazardous materials were shipped via water carriers. This constituted approximately 23 percent of the total quantity of hazardous materials shipped in the United States. By 1980, this figure is expected to be approximately 470 million tons, a 13.5 percent increase. Approximately 17 percent of all crude petroleum products is shipped via water carriers. Petroleum and petroleum products constitute approximately 84

[4] Control of Hazardous Polluting, p. 11-27.

percent of all hazardous materials shipped via water carriers.[5]

The increased demand for petroleum products is expected to continue in the future. The Federal Power Commission estimates energy demands in the United States will gradruple by 1990. The Chase Manhattan Bank predicts the energy demand will increase 56 percent between 1970 and 1980. Currently the sources of energy are: oil, 44 percent; natural gas, 32 percent; coal, 20 percent; hydropower, 4 percent; and nuclear power, less than 1 percent.[6]

Today, in the United States, there are 20,000 barges plying 26,000 miles of inland and coastal waterways. In 1970, nearly 200 billion ton-miles of freight was transported along those waterways, an increase of 58 percent over 1960. A 50 percent increase in traffic is anticipated during the next 10 years. Barges carried approximately 10 percent of all intercity freight in 1970, which included 40 percent of all United States petroleum, and 75 percent of all chemicals.[7]

It is anticipated that the total volume of hazardous materials transported will increase at an annual rate of about 3.4 percent, which is faster than the 2.7 percent annual growth rate projected for total intercity freight traffic. These projections indicate that hazardous materials will continue to constitute an increasing proportion of total intercity freight traffic.[8]

C. Marine Accidents:

Table III[9] is a compilation of data that portrays both historical trends and projections of reported accidents involving domestic waterborne carriers. Between 1964 and 1968, both the total number of reported accidents and the number involving hazardous materials have increased. During this 5-year period, total accidents have increased 10.9 percent, or at a 2.2 percent annual growth rate. Meanwhile, accidents to vessels transporting hazardous materials have increased 117 percent, at an annual growth rate of 21.5 percent.

Projections through 1980 are more pessimistic. The predicted percent increase of total accidents from 1968 to 1980 is 57 percent, at an annual growth rate of 4 percent. Accidents involving hazardous materials are expected to increase 330 percent, at a 14 percent annual growth rate. The difference between the 4 percent annual growth rate for all accidents and the 14 percent rate for accidents involving hazardous materials undoubtedly reflects the fact that hazardous materials constitute a larger percentage of total waterborne cargo each year, a trend which will probably continue.

The projections presented in the table are based upon the "best fit" (least squares) extrapolation of the 1964-68 data. They are based upon the conditions which existed during the 1964-68 period. As a result, any significant change in conditions in the future could cause the actual accident occurrences to vary in either direction from the projected trend.

V. FEDERAL AUTHORITY TO CONTROL THE MARINE TRANSPORTATION OF BULK HAZARDOUS MATERIALS

The Coast Guard has the primary responsibility for the safety of the shipment of hazardous materials by water. This agency has general responsibility for protecting life and property on the navigable waters of the United States. Control of shipment of hazardous materials in bulk is exercised by the Coast Guard through the following programs:

1. Approval of design and construction, and inspection of tank vessels, tank barges, and bulk tanks for transporting hazardous materials: This authority does not include control over inland motor propelled towing vessels which handle

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[5] Booz-Allen, p. Exhibit II-2, Appendix B(12), B-11(1), and B-11(2)

[6] "The Coming Energy Crunch," Our Sun, Spring 1971, p. 23.

[7] "Now Traffic Jams on U.S. Rivers," U.S. News and World Report, September 20, 1971.

[8] Booz-Allen, pp. 9&10.

[9] Booz-Allen, Exhibit C-4.

TABLE III

DOMESTIC WATER CARRIER ACCIDENT EXPERIENCE 1957-1968 AND PROJECTIONS TO 1980

	Domestic Waterborne Traffic (Ton-miles in billions)	Number of Accidents Reported: Total(1)	Number of Accidents Reported: Involving Vessels(2) Transporting Hazardous Materials	Accident Frequency (Number of accidents per billion ton-miles): Total	Accident Frequency (Number of accidents per billion ton-miles): Involving Transport of Hazardous Materials	
1957	480	NA	NA	NA	NA	
1958	429	NA	NA	NA	NA	
1959	461	NA	NA	NA	NA	
1960	476	NA	NA	NA	NA	
1961	463	NA	NA	NA	NA	
1962	474	NA	NA	NA	NA	
1963	478	NA	NA	NA	NA	
1964	487	1,625	237	3.3	0.5	
1965	489	1,685	384	3.5	0.8	
1966	505	1,569	387	3.1	0.8	
1967	505	1,783	433	3.5	0.9	
1968	506	1,803	515	3.6	1.0	
Annual Growth Rate - 1957-59/68	1.0%	2.7%	21.5%	1.6%	20.5%	
1970	506	1,880	627	3.7	1.2	Data based on "best fit" (least squares) curves as shown in Exhibits II-3 and II-4
1975	506	2,146	1,174	4.2	2.3	
1979	506	–	–	–	4.3	
1980	506	2,840	2,200	5.6		
Percent Increase - 1968/80	–	57%	330%	57%	330%	
Annual Growth Rate - 1968/80	–	4%	14%	4%	14%	

(1) Calendar Year.
(2) Fiscal Year beginning July 1.

Sources: U.S. Coast Guard; U.S. Army Corps of Engineers, Waterborne Commerce of the United States (selected years).

Note: Projections by Booz, Allen & Hamilton.

barges. The Coast Guard has attached great importance to this authority, and has required protection for tanks carrying chlorine, anhydrous ammonia, and other hazardous materials. Warning signs, chemical data cards, and emergency equipment are required. Pressure relief valves, vents, screened openings, explosion proof lights and wiring are mandatory in certain installations. This authority can be used to limit the quantities of hazardous materials permitted on a vessel or barge, as is done in the design of chlorine barge tanks.

2. Licensing of tank vessel personnel, and issuance of tankerman certificates: This program addresses the problem of personnel error, which the Coast Guard determines to be a frequent factor in hazardous materials incidents. The Coast Guard requires a certificated tankerman or licensed officer to supervise transfer of bulk combustible materials. A chemical data card must be made available to the supervisory person for the commodity involved. The rapid proliferation of new hazardous chemicals shipped in bulk has reduced the effectiveness of the existing tankerman certification system. The Coast Guard is currently considering special examinations and endorsements for handling certain dangerous cargoes. The safe handling procedures and emergency measures vary widely for these products, and it is practically impossible for one individual to be competent to handle all of them.

   The training of tankermen is accomplished by the operators and the unions. The National River Academy, with the support of a number of inland towing companies, has organized training courses for tankermen, as well as for pilots and engineers.

3. Requiring specified safe operating procedures: Regulations prescribe such safe operating requirements as: grounding transfer hoses; prohibiting welding, smoking, open flames and spark producing devices during transfer; gas-free certification prior to repairs; closing cargo tank hatches; keeping flame screens in place; supervision of the transfer operation by qualified personnel; and inspection of the vessel prior to transfer of cargo. Procedures to be followed in emergencies are also specified. These operational procedures are supplemented by the Coast Guard "Manual for the Safe Handling of Inflammable and Combustible Liquids." This manual provides recommendations only, and adherence to them is not mandatory.

   The Coast Guard has proposed rules to govern transfer of oil between vessels and shore terminals (33 CFR 154, 155, 156). These proposed regulations provide for inspection of oil terminals and shore facilities, issuance of permits, and emergency procedures and equipment. They also require certification of personnel supervising the transfer of oil products. Tank barges built after December 31, 1972 would be required to be constructed with double walls on each side and end. Some tank vessels and tank barges are currently built with double bottoms which afford protection against loss of cargo in groundings.

4. Promulgating regulations which are intended to prevent collisions:
   These regulations stem from the applicable Rules of the Road, and the Bridge-to-Bridge Radiotelephone Act of 1971. The Rules of the Road prescribe passing rules, whistle signals, navigation lights, and other operational rules which assist the persons in charge of navigating vessels to achieve a safe passing of other vessels. The bridge-to-bridge radiotelephone regulations have been recently proposed, and will supplement the other

collision avoidance systems required by the Rules of the Road.

This voice communications system could be used by the operator of a vessel or tow to alert other vessels in his vicinity of the hazardous nature of his cargo. The proposed regulations do not require such a broadcast, but would not prohibit the transmittal of such information.

In addition, Coast Guard aids to navigation serve as a collision and grounding avoidance system. These aids include buoys, fixed structures on shore, radio direction finding stations, LORAN, and recommended traffic separation lanes.

5. Reporting and analyzing of hazardous materials incidents: The Department of Transportation (DOT) and the Coast Guard require the carrier who transports hazardous materials to give the Department immediate notice of hazardous materials incidents in which there is a fatality, a person is hospitalized for an injury, damages exceed $50,000, or when a situation exists where a continuing danger to life exists at the scene of the incident. The master of an ocean-going vessel carrying hazardous materials is required to report fires, or any other hazardous condition, to the nearest Coast Guard District Office. Damaged containers or packages of hazardous materials are required to be reported to the nearest Coast Guard office.

   These reports serve a twofold safety purpose. Prompt notification of major incidents involving hazardous materials with properties that are not commonly known enables the DOT Chemical Data Center to advise on-scene personnel of the best procedures to limit the harmful effects of the incident. The Coast Guard Office of Hazardous Materials maintains a 24 hour telephone standby service, and has responded to a number of calls involving fires and other casualties. The previously mentioned PRESIDENT HARDING case is an example of the need for such an advisory system. The Manufacturing Chemists Association also maintains a continuous emergency advisory service, at its Chemical Transportation Emergency Center (CHEMTREC). This Center advises personnel involved in a hazardous materials incident of the safest method of controlling spills, leaks, fire and exposure.

   A second benefit is derived from an analysis of the reports. Many of the existing hazardous materials regulations resulted from the analysis of causal factors found in accidents. Defective container designs, the exposure of incompatible commodities, and sources of ignition of flammable vapors are a few examples of data available from these reports. The centralized and standardized reporting to DOT enables all the modes of transportation to benefit from lessons learned in the individual modes. This requirement has been in effect for a year, but the responses in the maritime mode have been few. As a result, data concerning hazardous materials incidents in this mode are inadequate for meaningful analysis at the present time.

6. Prescribing regulations for specific labeling, stowage, and handling requirements for the nine classes of dangerous articles set forth in the 1960 International Convention for Safety of Life at Sea: These regulations place the responsibility for stowage and handling of listed explosives, other dangerous articles, and combustible liquids. Certain dangerous articles are prohibited from shipment in railroad tank cars or trucks on board passenger or ferry vessels. These classes of hazardous materials include explosives, compressed gases,

inflammable liquids and solids, oxidizing substances and organic peroxides, poisonous and infectious substances, radioactive materials, corrosives, and other miscellaneous dangerous substances. The properties of these substances, cautions on stowage, and prohibitions against stowing adjacent to incompatible materials are specified. These commodities are listed by their chemical derivatives, rather than the manufacturer's trade name. The regulations governing noncompatibility of commodities do not apply to commodities carried in separate barges in a tow.

These regulations are supplemented by those promulgated under the Tank Vessel Act for carriage of combustible liquid cargo in bulk.

7. Port security regulations enforced by the Captain of the Port (COTP): The Coast Guard Captain of the Port is responsible for the security of vessels, harbors, and waterfront facilities of the United States. This responsibility is derived from the Magnuson Act, which amended the Espionage Act; and Executive Orders Nos. 10173, 10277, and 10352. This authority was based on the need for anti-subversive protection of our ports. The regulations govern the handling, loading, and stowage of explosives and ammonium nitrate, both on board ship and at waterfront facilities. The regulations prescribe minimum conditions for facilities which are authorized to handle these cargoes. Explosive anchorages are also designated. Coast Guard port security personnel inspect the shoreside and shipboard facilities for unsafe conditions. Foreign vessels carrying hazardous materials are required to give advance notice of arrival to the COTP, and are boarded, and in some cases, escorted to anchorages or berths. Detailed requirements for the handling and transportation of radioactive materials are specified.

   The Department of Transportation and the Coast Guard have sought legislation which would give the Coast Guard permanent authority to control the movement of vessels transporting certain hazardous materials, including combustible liquids. The House of Representatives passed such a bill entitled "The Port and Waterways Safety Act of 1971," and the Senate has recently passed a similar bill.

   The Captain of the Port prepares and implements contingency plans for his port area, which utilizes all available emergency facilities. The Coast Guard contingency plan for Houston has been a model for other port areas.

8. Surveillance of vessels carrying hazardous materials:

   Coast Guard Captain of the Port units board and escort vessels carrying certain categories of hazardous materials in the harbors of the United States. An example of this is the monitoring of LNG tank vessels. Most are foreign flag vessels, and the Coast Guard has actually exercised control of the movements of these vessels entering U. S. ports. In addition, the Coast Guard has required design plans for foreign vessels to be submitted for approval for the transportation of 39 specified bulk liquid hazardous materials in U. S. waters. These vessels are boarded and inspected to make sure they meet the safety requirements the Coast Guard considers necessary to protect U. S. ports. These inspections are more comprehensive than those made on foreign flag passenger vessels which carry U. S. citizens from our ports.

9. Emergency operations to minimize the damage and loss of life after casualties: The Coast Guard frequently exercises

operational control at the scene of hazardous materials accidents. These controls include: the control of shipping in the area; assistance in firefighting efforts; movement of the vessels from berths in the vicinity of the casualty; the marking of sunken vessels in the harbors, channels, or rivers; broadcast of emergency notices to mariners advising of restricted navigation; and on-scene coordination of rescue and firefighting forces.

The Coast Guard disclaims any legal obligation for firefighting efforts, but, under their responsibility to protect life and property, they often utilize their units to assist local firefighting forces. As previously mentioned, contingency planning is the responsibility of the local Captain of the Port. There are hundreds of miles of rivers and inland waterways along which there are no Coast Guard or local firefighting facilities. Municipal fireboats are very scarce and located only in major ports, such as New York, New Orleans, Houston, San Francisco, among others.

The Coast Guard also serves as the on-scene-coordinator (OSC) for the National Oil and Hazardous Substances Pollution Contingency Plan. This plan was developed under the provisions of the Federal Water Pollution Control Act. The President delegated authority for the development of this plan to the Council on Environmental Quality. Generally, the Coast Guard serves as OSC on coastal waters, and the Environmental Protection Agency (EPA) for inland rivers, where EPA has regional personnel available. The plan delineates areas of responsibility among the Federal agencies, and encourages state and local governments, as well as private organizations to commit resources in cases of hazardous materials accidents. In major disasters, provisions are made for the President to designate them as national emergencies, and for the Office of Emergency Preparedness to mobilize all available forces.

Other Federal agencies such as the Army Corps of Engineers, the Atomic Energy Commission, the Federal Power Commission, Department of Defense, the Maritime Administration, and EPA exercise limited authority over transportation of hazardous materials. However, the primary responsibility for safe transportation of these materials rests with the Department of Transportation and the Coast Guard.

VI. CONCLUSIONS

A. Marine Casualties Involving Hazardous Materials:

1. Data on marine accidents involving hazardous materials are incomplete, due to lack of compliance with reporting requirements in the marine mode, and inadequate development of data during investigations. Valuable data can be derived from reports of hazardous materials incidents in all modes of transportation.
2. Reported accidents involving bulk hazardous materials have been infrequent, and no catastrophic casualty has occurred since the Texas City disaster in 1947. This fact indicates that Federal regulatory measures, industry practices, and a certain element of luck, have been effective in preventing catastrophic accidents involving hazardous materials.
3. Analysis of hazardous materials casualties shows that there have been a number of near misses in which major losses were narrowly averted.
4. Emergency contingency planning, such as that in effect in the Houston Ship Channel, is necessary to minimize the

harmful results of hazardous materials accidents.

5. There should be a specific assignment of responsibility for firefighting or other countermeasures needed to handle hazardous materials accidents on all United States navigable waters.
6. There is a need for specific criteria for the operating capability of towing vessels handling tows of hazardous materials.
7. Hazardous materials facilities are frequently located in proximity to petrochemical facilities and densely populated areas, thus posing a serious risk to third parties, in event of an accident. There should be a prescribed risk analysis system for determining the location of these facilities.

B. Analysis of Risks in Transportation of Hazardous Materials on Navigable Waters:

1. Ingredients for a catastrophic hazardous materials accident include: presence of large quantities of hazardous materials; transportation in densely populated areas; and a triggering mechanism which initiates the chain of events resulting in serious losses.
2. Traditionally, hazardous materials regulations have been developed on the basis of analysis of previous accidents, expert judgment, and transference of technology. This basis for developing regulations does not assure the discovery of undetected risks.
3. Risk analysis, utilizing such techniques as logic trees, can postulate accidents which can be reasonably anticipated for a given hazardous material and waterway route. This analytical approach can be used as the basis for making decisions to promulgate regulations to prevent these predicted accidents from occurring. The analysis should include: potential danger area; population density along waterways; exposure factor; risk peaks; among others.
4. Analysis of the risks involved in transporting a specific hazardous material can provide the criteria for limiting the quantity transported, providing a shielding barrier, limiting operations, escort, among others.
5. The Coast Guard is now attempting to develop methodologies to determine quantitative rankings of risks for materials possessing severe hazardous properties.

C. Projections of Marine Transportation of Hazardous Materials:

1. Projections indicate that within the next 10 years:
   a. Production of chemicals will increase at a rate 1½ times greater than the gross national product growth rate.
   b. There will be a 50 percent increase in water carrier traffic on the inland and coastal waterways of the United States.
   c. Accidents involving the marine transportation of hazardous materials are expected to increase 14 percent per year.
   d. Supertankers and LNG tank vessels will import half of the United States requirements for oil and natural gas.
   e. The energy demands in the United States will increase 56 percent.
2. Aproximately 20 percent of the total quantity of hazardous materials shipped in the United States is transported via water carriers.
3. Practically all estimates and projections indicate that hazardous materials will continue to constitute an increasing proportion of waterborne freight transported on the inland waterways of the United States.

D. Federal Authority to Control Marine Transportation of Hazardous Materials Is Inadequate in the Following Areas:

1. Inspection of inland motor towing vessels and licensing of their operators.
2. Movements of vessels transporting hazardous materials in congested waters.
3. Tracking or monitoring movements of vessels carrying hazardous materials.
4. Carriage of incompatible commodities on adjacent barges.

E. Other Inadequacies in the Protection of the General Public Against Hazardous Materials Are Created by a Lack of:

1. Emergency contingency plans for all United States waters.
2. Delineation of responsibility for combating fires, or controlling damages resulting from hazardous materials accidents occurring on the navigable waters of the United States.
3. Formalized risk analysis procedures to protect the public from harm resulting from location of hazardous materials facilities.
4. Special qualifications for shipboard and terminal personnel handling particularly hazardous materials.
5. Federal, State, or local emergency personnel or equipment along hundreds of miles of navigable inland waters, which can be used to minimize the losses resulting from a hazardous materials casualty.

VII. RECOMMENDATIONS

The Safety Board has recommended previously that the Congress enact legislation such as H.R. 6479 which would require the licensing of operators of certain towing vessels, and the Ports and Waterways Act such as H.R. 8140. Based on our analysis of casualties involving hazardous materials, and the potential for a catastrophic accident resulting from the transportation of these materials by water, such legislation is urgently needed.

In addition, the Safety Board recommends that:

1. When statutory authority is obtained to control the movement of vessels carrying hazardous materials, the Coast Guard consider the need for monitoring the movements of certain materials which pose a risk of catastrophic accidents, or requiring emergency-position-indicating equipment to be carried on vessels transporting those commodities.
2. Persons who ship hazardous materials by water, comply with the Federal reporting requirements for hazardous materials incidents.
3. The Coast Guard, in its investigations of hazardous materials casualties, identify all the technical factors involved, particularly those which significantly affect the risk levels of the incident, and be alert to factors which might have application in similar accidents in other modes of transportation.
4. Designers and builders of towing vessels develop operating performance criteria such as the capacity limits for tows, which would serve as a guide to the operator of the vessel.
5. The Department of Transportation accord high priority to the Coast Guard research and development program to develop methodologies for determining quantitative risk rankings for those hazardous materials which are transported in large quantitites on the navigable waters of the United States.
6. The Department of Transportation and the Coast Guard, in development of hazardous materials regulations, utilize the "Risk Concept" technique in addition to their analyses of hazardous materials accidents.

7. The Office of Emergency Preparedness, the Coast Guard, and the U. S. Army Corps of Engineers prepare emergency contingency plans, similar to the Houston Ship Channel plan, to respond to catastrophic accidents involving hazardous materials for those waterways which carry large quantities of these materials. These plans should include an inventory of firefighting and emergency equipment and response personnel available by regions. They should include the stockpiling of firefighting and other emergency equipment at strategic locations from which they can be dispatched to the scene of the casualty by air or other expeditious means.
8. The Coast Guard, within its Captain of the Port areas of jurisdiction, designate specific functions of firefighting and emergency operations in those areas in which risk of hazardous materials incidents are greatest.
9. The Department of Transportation establish a National Hazardous Materials Response Center which would advise onscene personnel how best to control hazardous materials accidents, and which would be capable of dispatching the nearest qualified personnel and necessary equipment to render assistance.
10. The Coast Guard revise the regulations concerning the qualifications of tankermen and licensed officers who handle extremely hazardous materials to require special qualifications and endorsements for these specific materials.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

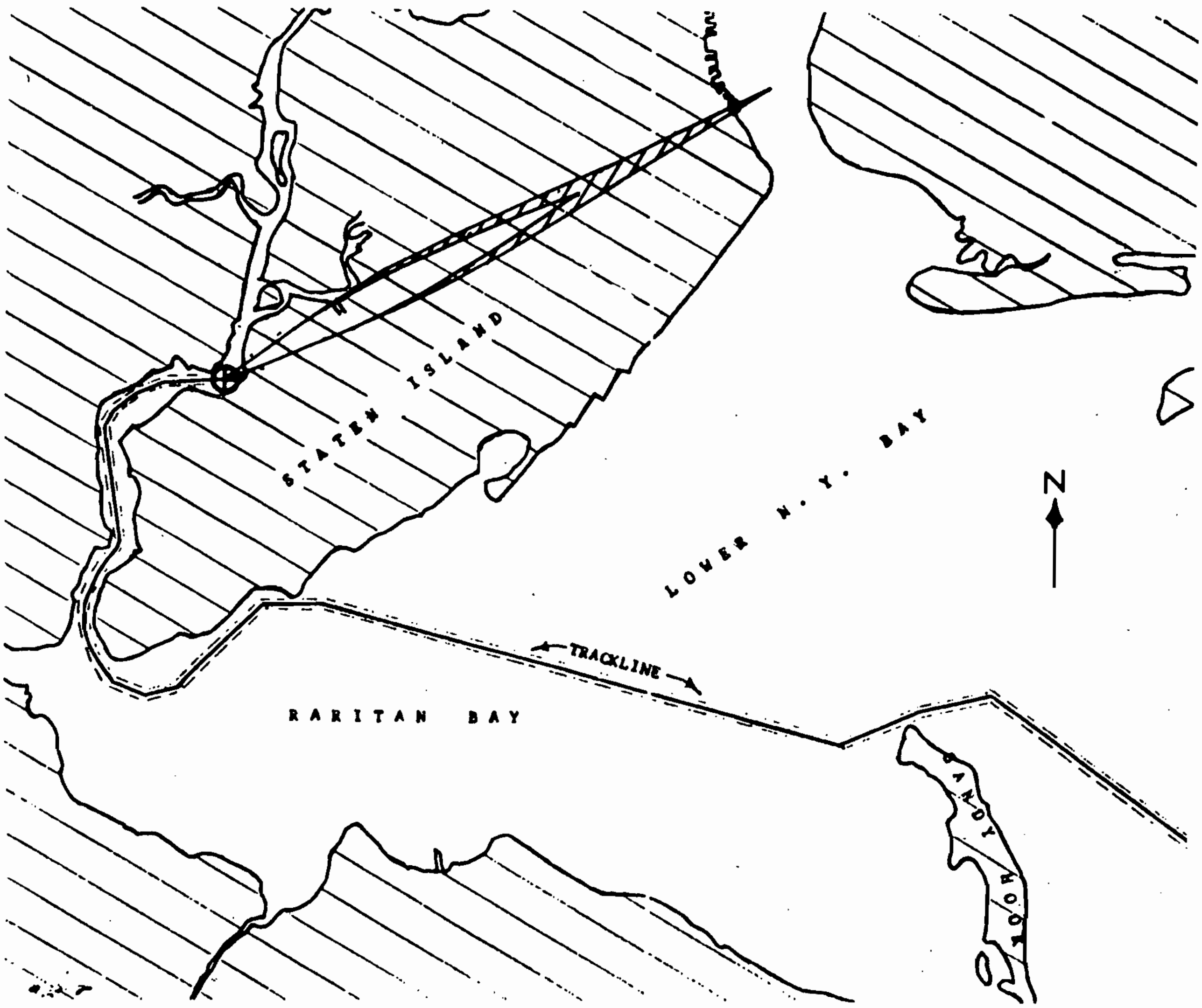
/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

March 15, 1972



Hypothetical maximum plume resulting from the instantaneous vaporization of 24,000 cubic meters of LNG. Surface wind 260° T at 8 knots. Cross hatched area indicates vapor in the explosive range.

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