DEPARTMENT OF TRANSPORTATION

COAST GUARD

MARINE CASUALTY REPORT

WILLIAM

SS WILLIAM T. STEELE; DEATH OF THREE SHIPS OFFICERS AT GUAYANILLA, PUERTO RICO ON 18 NOVEMBER 1972

U.S. COAST GUARD
MARINE BOARD OF INVESTIGATION REPORT
AND COMMANDANT'S ACTION

ACTION BY
NATIONAL TRANSPORTATION SAFETY BOARD

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16. Abstract

On November 17, 1972, preparations were being made to receive a cargo of benzene aboard the tankship WILLIAM T. STEELE. Because of an oversight in lining up the cargo-tank valves, benzene was inadvertently loaded into the No. 9 center tank, which was reserved for xylene. The benzene was transferred to a forward tank, and the No. 9 center tank was washed and ventilated. Two crewmembers entered the forward section of the tank to insert a blank between the flanges in the cargo pipeline, while the chief mate entered the aft section of the tank to educt water. When the flanges were opened, benzene began to leak and the benzene fumes forced the two crewmembers to leave the tank without inserting the blank. The chief mate remained in the tank and was overcome by the fumes. In attempting to rescue the chief mate, the master and the second mate perished, as did the chief mate. This report contains the action taken by the National Transportation Safety Board, the Marine Board of Investigation report, and the action taken by the Commandant, U.S. Coast Guard.

The National Transportation Safety Board determines that the probable cause of the death of the chief mate was the prolonged inhalation of a highly concentrated mixture of benzene vapor and air within the tank in which he was working, and that the death of the two other senior ship's officers resulted from the same cause while they were attempting to rescue the chief mate.

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NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON, D.C. 20591

SS WILLIAM T. STEELE
Guayanilla, Puerto Rico
18 November 1972

ACTION BY THE NATIONAL TRANSPORTATION SAFETY BOARD

This casualty was investigated by a U. S. Coast Guard Marine Board of Investigation which convened at Houston, Texas, on December 1, 1972. The National Transportation Safety Board has considered only those facts in the investigative record which are pertinent to the Safety Board's statutory responsibility to determine cause or probable cause of the casualty and to make recommendations.

SYNOPSIS

The SS WILLIAM T. STEELE is operated by Texas City Tankers to transport petroleum products between the Texas gulf coast, the east coast, and Puerto Rico. On November 17, 1972, preparations were being made to receive a cargo of benzene. Because of an oversight in lining up the cargo-tank valves, benzene was inadvertently loaded into the No. 9 center tank, which was reserved for a cargo of xylene. The benzene was transferred to a forward tank, and the No. 9 center tank was washed and ventilated. Two crewmembers entered the forward section of the tank to insert a blank between the flanges in the cargo pipeline for positive isolation of cargoes, while the chief mate entered the aft section of the tank to educt water. The two crewmembers installing the blank were unaware of the chief mate's presence. When the flanges were opened, benzene began to leak and the benzene fumes forced the two crewmembers to leave the tank without inserting the blank. Shortly after they emerged from the tank, the two crewmen saw that the chief mate had passed out in the tank. Several crewmen, including the second mate, entered the tank without a breathing apparatus to rescue the chief mate. The master, using a breathing apparatus, entered the tank to assist, but when he attempted to pass his mask to the second mate, both men fell from a pipeline and were incapacitated. The master, the chief mate, and the second mate perished before further assistance was available.

The National Transportation Safety Board determines that the probable cause of the death of the chief mate was respiratory failure due to the prolonged inhalation of a highly concentrated mixture of benzene vapor and air within the tank in which he was working, and that the death of two other senior ship's officers resulted from the same cause while they were attempting to rescue the chief mate.

Factors which contributed to the entry into and prolonged stay within the tank were: (1) their lack of knowledge regarding safety precautions for working in tank spaces where the possibility of benzene spillage existed; (2) the failure to provide the supervision necessary for coordinating work within the tank; (3) the lack of proper personnel training and drills in the use of equipment for rescuing personnel incapacitated in a tank; (4) the lack of adequate emergency equipment to facilitate rescue of incapacitated personnel from tank spaces; and (5) the inadequate maintenance and inspection of emergency equipment to assure its availability.

Contributing to the presence of benzene vapors within the tank were: (1) the intentional separation of a flange joint to blank off a section of the cargo pipeline, which allowed benzene to spill; (2) the non-tight valves, which permitted benzene to continue to flow through the opened flange joint and which precluded stopping the flow quickly and safely; and (3) reliance upon an ineffective manner of ventilating cargo tanks.

The design of the STEELE's cargo-handling system contributed to the necessity for men to enter tanks to use portable eductors, to reverse line blind valves, and to separate pipeline flange joints for insertion or removal of blanking plates.

ANALYSIS

Work Practices Aboard the SS WILLIAM T. STEELE

Desirable operations and safety. The coastwise trade of the STEELE required the crew frequently to prepare tanks for new cargoes. The crew cleaned, ventilated, and dried the tanks and reset the valves to assure that tank cargoes did not contaminate one another during shipment. Tank drying and reconfiguration of line blind valves required crewmen to enter tanks routinely.

The internal structures of most tanks present numerous obstacles to personal mobility within the tank and therefore increase the risk of personal injury. Whenever cargoes which emit toxic vapors are carried, vapor concentrations within the tank may exceed the levels safe for human exposure. The probability that excessive concentrations of toxic vapors will occur is increased when men are required to work on pipeline fittings, which can result in cargo spillage. Effective dispersion of such vapors requires an adequate ventilation arrangement, which depends on the physical properties of the vapor (e.g., whether the vapor is heavier or lighter than air) and the configuration of structures within the tank.

Precautions which can be taken to reduce the risk of death or injury to a crewmember who is working in a tank which may contain toxic vapors are described in numerous publications concerned with work in enclosed spaces. Safety guides have been specifically established for application to marine tankers by the International Chamber of Shipping 1/ and the International Oil Tanker Terminal Safety Group 2/. Recommended practices developed by the American Petroleum Institute 3/ are widely publicized but have been limited to pipeline and tank facilities ashore. Also, the Manufacturing Chemists' Association has published chemical safety data sheets for the safe handling of many chemicals.

Precautions which apply to work in enclosed spaces whether aboard ship or ashore, and which have appeared in one or more of the above publications include:

* Determining that the space is not deficient in oxygen and does not contain toxic vapor concentrations in excess of the Threshold Limit Value (TLV) while men are working within the tank;

* Closing off sources of toxic products from tanks and periodically monitoring tank atmoshpere to detect any toxic vapor concentration or oxygen deficiency;

1/ International Chamber of Shipping, Tanker Safety Guide (Petroleum), London, 1970

2/ International Oil Tanker Terminal Safety Group, International Oil Tanker and Terminal Safety Guide.

3/ American Petroleum Institute, Guide for Inspection of Refinery Equipment, 1st ed., Chapter V, 1961.

* Requiring personnel working in enclosed spaces to use a fresh-air breathing apparatus, lifelines, safety harnesses, and protective clothing if necessitated by the possibility of toxic vapor concentrations and oxygen deficiencies; and

* Providing a topside watch to observe workers in enclosed spaces and making adequate rescue equipment readily available for such personnel.

These general safety guidelines, however, can be effective only when those responsible for a vessel's operation make the necessary adaptations so that the guidelines might be carried out by the vessel's officers and crew. Procedures must be written; checklists and equipment must be provided which account for the vessel's construction and cargoes; and the crew must be instructed on these procedures and drilled in the use of emergency and safety equipment.

Except for the requirements to carry certain emergency equipment (46 CFR 35.30-20) and a combustible gas indicator (46 CFR 35.30-15), there are no Federal regulations which specify precautions to be taken when a ship's officers and crew enter cargo tanks or other enclosed spaces. Thus, the scope of any safety program for entering cargo tanks by a ship's officers and crew is solely at the discretion of those responsible for management of the ship's operations. In contrast, there are Federal regulations (29 CFR 1915) which mandate safety precautions aboard ship for those other than the vessel's officers and crewmembers (harbor workers, longshoremen, etc.); specific precautions which encompass those outlined above, are set forth in the regulations.

Crew training and experience. Texas City Tankers had no formal program to indoctrinate crewmembers in tank cleaning, safety practices, and emergency procedures other than the required boat drill. The company depended on contacts between shore personnel and the master and chief mate to assure that cargo was handled safely and expeditiously. Indoctrination of the other crewmembers was left to the discretion of the master.

Except for the senior officers, the crew of the STEELE are rotated through the union hall. Many crewmembers joined the vessel after recent shipyard work and the biennial inspection was completed, just 35 days before the accident. The company had also assigned a new master at that time.

The rotation led to a low retention rate for most of the crew, which reduced the crew's collective familiarity with the vessel and cargo characteristics. For example, the pumpman was not sure of the nature of the cargo (but thought it was benzene) and had virtually no awareness of its toxic effects. Many crewmembers were not familiar with the safety equipment approved for use in cargo tanks. The crewmembers thought that a combustible gas indicator measured toxicity, even though it is not sensitive enough for determining the toxicity of benzene.

Since coming aboard, none of the new crewmembers was instructed regarding the hazards of benzene, the use of the combustible gas indicator, the shipboard piping arrangement, or safety precautions for entering cargo tanks. During cargo handling, the crew normally worked considerable overtime and performed their tasks in the most expedient manner. Consequently, the officers and crew often performed their tasks while fatigued and without sufficient guidance to assess the risks in selecting a given method of operation. Such guidance and assurance of a crew's capability to perform assigned tasks safely are normally the responsibility of management, and would be expected to be executed by Texas City Tankers.

The Accident Events

Improper loading of cargo. Instead of distributing a cargo-loading plan to the crew or providing a checklist to assure that all valves and blinds were configured as planned, the chief mate issued verbal orders to the pumpman which specified only the setting of certain conventional and line blind valves. Because of his limited experience on the STEELE, the heavy workload, and the insufficient information regarding the desired lineup of cargo tanks to receive benzene, it is unlikely that the pumpman would have realized any omission in the chief mate's orders. The chief mate, on the other hand, without a checklist and probably fatigued from working more than 24 hours immediately before his death and from supervision of numerous tasks, was not prepared to supervise cargo loading adequately. These problems led to the oversight in not closing the line blind valve in the No. 8 center tank. (A diagram of the pertinent section of the cargo piping system, with shaded areas indicating the tanks originally intended to receive benzene is shown in Figure 1.)

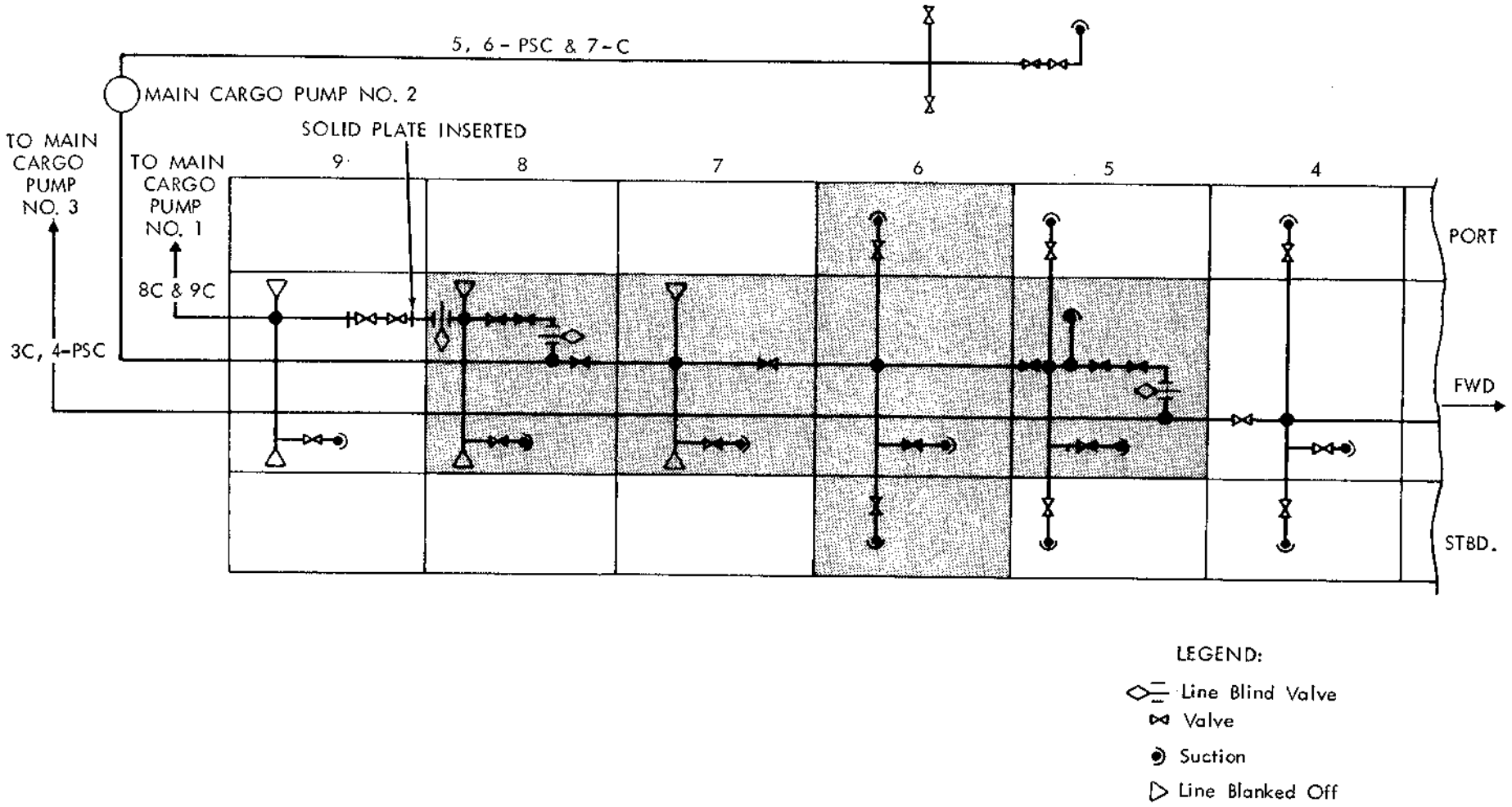

Figure 1. DIAGRAM OF CARGO PIPING SYSTEM FOR TANKS 4-PSC, 5-PSC, 6-PSC, 7-C, 8-C & 9-C

Blanking off the cargo pipeline. After benzene flowed through the open line blind valve and the conventional valves into the No. 9 center tank, the chief mate decided to empty, wash, and ventilate the No. 9 center tank and then blind the cargo pipeline in the tank at the flange nearest to the bulkhead with the No. 8 center tank. Thus, crewmembers entered the No. 9 center tank to blind the cargo line and educt residual tank washings. The uncoordinated manner in which these tasks were carried out, as well as the absence of other safety practices, led ultimately to the loss of life.

Blinding the cargo line involved opening a flange to insert a plate in the pipeline carrying benzene. (An arrow points to this flange in Figure 1.) The two block valves in the No. 8 center tank, just forward of this flange, were closed. The Marine Board did not determine what precautions were taken to purge benzene from that section of pipeline. There could have been a considerable amount of benzene in the 12-inch-diameter pipe which would have leaked out once the flange was separated. Further, the two block valves were relied on to sustain without leakage the pressure head of benzene in the No. 8 center tank, which was partially loaded.

The chief mate decided to insert a plate between the flanges forward of the double block valves in the No. 9 center tank. In part, this decision was probably based on his prior success in similar blanking operations; insertion of plates between flanges was standard practice on the STEELE before the line blind valves were installed. In fact, the third mate testified that an experienced crewman using the proper shaped wedges could split the flanges, insert a blank, and secure the line without leaking more than 2 or 3 gallons of benzene. Thus, it appeared to be an accepted practice to allow benzene to leak into enclosed spaces where men were working.

Unaware of the hazards involved, the pumpman entered the tank, began to separate the flanges, and was joined by the second mate. After the pumpman loosened the flange bolts, benzene began to leak and flow aft. The two men continued their efforts to insert the blank for almost 10 minutes, at which time they decided to leave because the pumpman began to feel dizzy and experienced loss of coordination.

Although benzene was leaking from the opened flanges, there were other possible sources of benzene vapor. The residual tank washings in the aft end of the tank may have contained benzene. The two block valves in the No. 8 center tank were not sufficiently tight to

prevent benzene from leaking through to the flanges. If the condition of these valves is indicative of the condition of remaining valves between the bulkhead and the suction opening in the No. 9 center tank, or if the remaining valves were left open, benzene could have been leaking through the cargo suction for more than an hour before the pumpman's entry into the tank. Since the cargo suction is in the aft section, where the residual tank washings are collected, the chief mate would have been exposed to benzene vapors from the time he entered the tank.

Monitoring and dispersing toxic vapors. The chief mate determined that the tank was gas free before he directed the pumpman to insert the blank in the 12-inch cargo line. The combustible gas indicator which he used to make this determination is intended to measure the flammability of vapor-air mixtures. The indicator was not sensitive enough to determine whether the concentration of benzene in air was lower than the TLV of benzene, which is a very low 25 parts per million (ppm). 4/ As a consequence, there was no assurance that crewmembers entering tanks would not be exposed to benzene vapor concentrations in excess of the TLV.

Benzene vapor concentrations immediately dangerous to life could have been determined by the combustible gas indicator. However, since benzene vapors are heavier than air, they would be more concentrated toward the tank bottom. Thus, sampling the atmosphere at the top of the tank would not truly measure conditions near the bottom where the men were working. Specific information regarding the use of the combustible gas indicator in this case was not developed by the Marine Board. However, it is possible that because of his limited knowledge of benzene, the chief mate did not understand the necessity of determining whether the atmosphere near the tank bottom was safe.

The initial sampling of the tank atmosphere, even if performed properly, would not have been effective because of the possibility that benzene might be spilled within the tank when the cargo line flanges were separated and the possibility that deteriorated conventional block valves might leak benzene into the tank. Under these circumstances, it would have been necessary to determine periodically or continuously whether dangerous concentrations of vapors were forming. The means of ventilating the tank did not effectively disperse the toxic vapor concentrations. Air was being blown into the

4/ TLV refers to the toxicity of a vapor concentration and is further described in the Findings of Fact section of the Marine Board of Investigation report.

tank from the Butterworth openings at the top through a sock which directed the air to a point near the bottom. Although this diluted and mixed the vapors near the tank bottom, only the least concentrated and lighter mixture near the top of the tank was being exhausted. Further, movement of air over the surface of the benzene liquid increased the rate of vaporization.

Educting the heavier-than-air benzene vapors from the bottom of the tank would have provided more effective ventilation than blowing air into the tank. The more concentrated vapor mixtures would have been drawn off, and the eduction process would not have promoted mixing of benzene vapors throughout the tank compartment.

Benzene poisoning. On the STEELE, many crewmembers evidently were regularly exposed to benzene vapors when benzene was carried. Aside from the benzene vapors in the tanks, the crew noticed slight odors of benzene in their living quarters. This indicates that the crew was being exposed to values in excess of the TLV for benzene, since the TLV is 25 ppm and the odor threshold is 100 ppm. Vapor concentrations of more than 140,000 ppm form when liquid benzene accumulates in confined spaces at temperatures exceeding 85 degress F., which were reported to exist in the STEELE's tanks. Thus, the crew of the STEELE risked either chronic or acute poisoning when benzene cargoes were carried.

The toxic effects of benzene vapors have been described in available professional literature:

> "Poisoning occurs most commonly through inhalation of the vapor, though benzene can penetrate the skin, and thus contribute to the poisoning.
>
> "In chronic poisoning, the onset is slow, with symptoms vague; fatigue, headache, dizziness, nausea and loss of appetite, loss of weight, and weakness are common complaints in early cases.
>
> "In acute poisoning, the worker becomes confused and dizzy, complains of tightening of the leg muscles and of pressure over the forehead, then passes into a stage of excitement. If allowed to remain in exposure, he quickly becomes stupefied and lapses into coma.

"Exposure to high concentrations of the vapor (3,000 ppm or higher) results from accidents such as failure of equipment or spillage. Such exposure, while rare in industry, may result in acute poisoning, characterized by the narcotic action of benzene on the central nervous system. The anesthetic action of benzene is similar to that of other anesthetic gases, consisting of a preliminary stage of excitation followed by depression and, if exposure is continued, death through respiratory failure." 5/

After he instructed the pumpman and the second mate to enter the No. 9 center tank, the chief mate proceeded to educt residual tank washings from the aft section of the tank. He did not inform the other two men that he would be in the tank, post a topside watch, or otherwise assure assistance in the event of an emergency. Although he must have thought that the tank was safe for workmen, he did not properly monitor the tank environment, he failed to consider the multiple sources of lethal benzene leaks, and he did not provide an effective means of exhausting benzene vapors.

As a result of his omissions, the chief mate was overcome by a high concentration of benzene fumes. He was possibly not acquainted with the effect of acute poisoning and ignored the odor and skin irritation of benzene vapors. Or, suffering from the effects of chronic poisoning, he was unable to recognize and evade further exposure. Also, he may not have been able to circumvent the internal tank structures and escape the effects of acute poisoning quickly enough. No one was aware of his initial distress or prepared to assist.

Rescue Efforts

After emerging from the tank, the second mate and the pumpman were informed that the chief mate was in the tank. Because no emergency procedure which required a different response existed, they reentered the tank to assist their fellow crewman. Neither man used a fresh-air breathing apparatus or wore a rescue harness with lifeline attached. No backup rescue capability was provided. The second mate failed to recognize that he could not assist and refused to leave the tank without the chief mate. Other crewmen entered the tank without breathing equipment and lifelines to encourage the second mate to leave. Like the pumpman, these other crewmembers managed to exit the

5/ N. Irving Say, "Dangerous Properties of Industrial Materials," New York, Reinhold Book Corporation, 1968.

tank. The lack of an organized and trained rescue squad and the crew's unfamiliarity with the toxic effects of exposure to benzene vapors were evident.

Finally, the breathing equipment with lifeline and harness was deployed, and the master attempted a rescue. He reached the second mate, who was walking along the pipeline, and unwisely removed his mask and lifeline to aid him, whereupon both men fell from the pipeline to the tank bottom. Their falling can be attributed to the second mate's loss of coordination from benzene intoxication and to the efforts of the master to grasp the falling mate.

The initial rescue attempts by the STEELE's crew point to deficiencies in crew training in the use of emergency equipment. Coast Guard rules and regulations for tank vessels (46 CFR 30 through 40) specifically require that fresh-air breathing equipment and lifelines, safety lights, and a combustible gas indicator be provided. These requirements, however, are vague and do not clearly indicate responsibility for management, supervision, and indoctrination. Nor do they require periodic equipment examination and practice. In CG-174, A Manual for the Safe Handling of Inflammable and Combustible Liquids, the Coast Guard suggests that, regarding the use of breathing equipment, "crewmembers should, through supervised drills and instructions be thoroughly trained in the use of the equipment." However, familiarization with and adherence to the manual are not mandatory.

Subsequent rescue efforts were thwarted by a hose failure on the vessel's second fresh-air breathing apparatus. Examination of the broken hose after the accident revealed visible surface cracks. These cracks should have been evident to the Coast Guard inspector if the hose had been removed from its storage case and examined during the inspection 35 days before the accident. However, according to testimony, the apparatus was inspected by a trainee without direct supervision or guidelines, and the hose was not examined. The Coast Guard apparently has not documented specific procedures for inspecting fresh-air breathing apparatus, but has merely designated it as an item to be inspected.

Other incidents during the rescue efforts indicate that there is no assurance that emergency equipment carried on tankers is adequate or maintained in operable condition or that crewmembers know how to use the equipment. The fresh-air breathing apparatus borrowed

from the SS GULF TIGER, an American tanker, may have allowed benzene to permeate into the face mask. A line, presumably a lifeline, was too short to reach the second mate. Benzene which can be absorbed through the skin, penetrated the boots worn by the third mate. Lacking suitable equipment, the first assistant engineer had to rig a sandblaster's hood so that it would flush air through his clothing to enable him to secure the benzene leak. The lifeline finally attached to the second mate to raise his body out of the tank broke.

Hazards of Line Blinding

Line blinding is normally accomplished either by inserting a solid plate between flanges, as was attempted in the No. 9 center tank of the STEELE, or by reversing the plate of a manufactured line blind valve, as was intended in the No. 8 center tank. In either case, line blinding precludes the possibility of inadvertent actuation to which normal valves are susceptible. Both methods of line blinding, however, cause the pipeline to be opened while the blind setting is being reversed, and , thus, make the pipeline contents susceptible to spilling. The hazards attendant with such spillage outweigh the benefits of line blinding on tankers.

Line blinding is used in industrial facilities ashore to provide for a positive shutoff and to eliminate inadvertent opening of pipelines which convey hazardous products to enclosed spaces where men are working. One commonly used type of line blind valve is designed so that the reversible spectacle plate not in use, i.e., either the solid plate or the open doughnut-shaped plate, is positioned outside the pipe. Thus, inspectors, supervisors, and workmen can reliably determine at a distance whether a pipeline is open or closed. In shore facilities, safety, economy, and convenience dictate that the blinding provisions are installed exterior to the tank. Further, conventional valves are often installed adjacent to the blind to reduce the possibility of product spillage while reversing the spectacle plate.

In contrast to blinding installations ashore, aboard tankers practical considerations run adverse to safety and dictate that blinding provisions are installed within tanks and pumprooms. The sole purpose of blinding on tankers is to prevent product contamination. The commonly used methods of line blinding practiced aboard the STEELE could have routinely subjected the crew to spray as well as spillage of toxic pipeline products, such as benzene. The hazards which result from spillage in these confined spaces is greatly

increased because of the difficulty in ventilating and the obstacles to rescue. Blinding operations with manufactured line blind valves may be less hazardous than those which involve inserting a solid plate between flanges, because manufactured line blind valves can be installed in less time with fewer men. However, even with the manufactured line blind valves the ability of supervisors visually to confirm the position of the spectacle plate is greatly limited, because the plate is normally installed in the tank bottom.

The adoption of explicit operating procedures to overcome the dangers of line blinding in cargo tanks would not reliably eliminate the hazards. Any such procedures would have to vary with each loading configuration. In configurations where the cargo lines are dead ended, e.g., because of an earlier closed setting of the blind, it would not be possible to assure that the cargo line had been adequately purged of its toxic contents. Also, when a cargo line connects with a source of toxic product, such as benzene in another tank, a means of positive shutoff safe from inadvertent opening must also be provided. Conventional valves have not been relied on for this purpose, because (1) they can be inadvertently opened, (2) their settings are not readily determined by exterior observation, and (3) their seals are not sufficiently reliable.

Maintenance of conventional valves might have been relaxed if the conventional valves were no longer relied upon to provide a leak--free seal; no testimony was sought regarding the condition and maintenance of conventional valves. As happened on the STEELE, these valves developed significant leaks which allowed spillage to occur when blinding or unblinding a cargo line and also which allowed cargo to leak unknowingly into tanks thought to be gas-free. Even double valve arrangements do not afford the reliability and safety for which they are intended, since if their design and operating conditions are similar, their sealing components will wear out at about the same time.

This lack of reliance on conventional valves appears to reflect both an initial selection of valves with poor sealing qualities and the lack of an effective maintenance program. The objections to the use of conventional valves to assure safety in line blinding do not appear to reflect current valve technology. The best solution to the hazards inherent in line blinding may lie in installing high-grade valves operable from outside the tank, instituting an effective preventive maintenance program, and designing provisions against

inadvertent opening into the installation. If this were done, crewmembers would not be required to enter tanks as frequently, and most important, the hazards of line blinding would be eliminated.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the death of the chief mate was respiratory failure due to the prolonged inhalation of a highly concentrated mixture of benzene vapor and air within the tank in which he was working, and that the death of two other senior ship's officers resulted from the same cause while they were attempting to rescue the chief mate.

Factors which contributed to the entry into and prolonged stay within the tank were: (1) their lack of knowledge regarding safety precautions for working in tank spaces where the possibility of benzene spillage existed; (2) the failure to provide the supervision necessary for coordinating work within the tank; (3) the lack of proper personnel training and drills in the use of equipment for rescuing personnel incapacitated in a tank; (4) the lack of adequate emergency equipment to facilitate rescue of incapacitated personnel from tank spaces; and (5) the inadequate maintenance and inspection of emergency equipment to assure its availability.

Contributing to the presence of benzene vapors within the tank were: (1) the intentional separation of a flange joint to blank off a section of the cargo pipeline, which allowed benzene to spill; (2) the non-tight valves, which permitted benzene to continue to flow through the opened flange joint and which precluded stopping the flow quickly and safely; and (3) reliance upon an ineffective manner of ventilating cargo tanks.

The design of the STEELE's cargo-handling system contributed to the necessity for men to enter tanks to use portable eductors, to reverse line blind valves, and to separate pipeline flange joints for insertion or removal of blanking plates.

RECOMMENDATIONS

In 1972, the National Transportation Safety Board released a special study entitled Analysis of the Safety of Transportation of Hazardous Materials on the Navigable Waters of the United States. In that study the Safety Board recommended that:

> "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."

This casualty indicates that a need still exists for implementing this recommendation.

The Safety Board concurs with the Commandant's response to the Marine Board's recommendation that meaningful safety meetings and drills be frequently and regularly held aboard tank vessels so as to insure the proper instruction of all crewmembers concerning the on board and proposed cargo hazards together with the use and limitations of all safety equipment carried on board. In order to assure clear and specific requirements in this regard, the Safety Board recommends that the U. S. Coast Guard:

1. Review and revise its requirements regarding the responsibility of owners/masters to indoctrinate crews in the safe use of emergency equipment on tank vessels. (Recommendation No. M-74-25)

The Safety Board further recommends that:

2. The U.S. Coast Guard:

   a. Review and revise requirements for emergency equipment to assure that such equipment is adequate for all emergency situations which might reasonably be expected to occur within cargo tanks, and require a scheduled check procedure to insure that emergency equipment is maintained in working order. (Recommendation No. M-74-26)

   b. Establish equipment functional or location requirements which assure that piping system components on tank vessels cannot cause cargo to spill when men enter cargo tanks, regardless of the operation to be performed. (Recommendation No. M-74-27)

c. Establish detailed inspection procedures and provide proper training to its marine inspectors to assure the reliability of the required emergency equipment. (Recommendation No. M-74-28)

d. Require that a written cargo-loading plan be made and posted each time cargo is to be transferred aboard chemical tankers, and further, that a check procedure be developed to assure the desired gating is achieved. (Recommendation No. M-74-29)

e. Seek authority to establish guidelines that will, except in emergencies, prevent excessively prolonged duty periods which result in fatigue and deteriorated duty performance. (Recommendation No. M-74-30)

f. Require that all operators of chemical tank vessels be required to maintain updated operating manuals aboard each ship showing the proper operation of the piping system for anticipated transfer operations. (Recommendation No. M-74-31)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

Adopted this 7th day of August 1974:

Francis H. McAdams, Member

Louis M. Thayer, Member

Isabel A. Burgess, Member

John H. Reed, Chairman, and William R. Haley, Member, were absent and did not participate in the adoption of this report.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD (GMVI-3/83)
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE:

5943/WILLIAM T. STEELE
A-8 Bd
17 SEP 1973

Commandant's Action

on

The Marine Board of Investigation convened to investigate circumstances surrounding the deaths of three ship's officers on board the SS WILLIAM T. STEELE on 18 November 1972 at Guayanilla, Puerto Rico

1. The record of the Marine Board of Investigation convened to investigate subject casualty has been reviewed; and the record, including the Findings of Fact, Conclusions and Recommendations, is approved subject to the following comments and the final determination of the cause by the National Transportation Safety Board.

REMARKS

1. Commenting on Conclusion 2, consideration will be given to the development of a suitable rescue harness for use in emergencies such as this on all ships.

2. Although Conclusion 5 is well taken, it is pointed out that many factors contribute to the passive attitude toward safety, emergency drills, and training. The shorter transit time between ports, short turn around time, rapid crew turnovers, liberal vacations, all contribute to restricting the amount of on the job training time available to supervisory personnel on board ship. The multiplicity of hazardous products offered for transport today require more knowledge of safety and safe procedures just when modern operations allow less and less time for training. The Coast Guard will actively support the establishment of suitable shore based training programs in cooperation with managment and labor.

3. Increasing the scope of the written examination required as a prerequisite to the issuance of a license or tankerman's certificate authorizing service on tank vessels may to some degree help in the prevention of casualties of this nature. However, additional examination questions, or numerous and

updated regulations, by themselves is not the total answer. Appropriate government agencies are continuing efforts to improve shipboard personnel qualifications and minimum knowledge through examination, regulation, and training facilities. In addition to these efforts, the maritime industry, both labor and management, must strive toward optimum performance standards of personnel serving aboard petroleum and chemical tank vessels and insist upon and monitor safe practices and training programs.

ACTION CONCERNING THE RECOMMENDATIONS

1. The recommendation that meaningful safety meetings and drills be frequently and regularly held on board tank vessels so as to insure the proper instruction of all crew members concerning the on board and proposed cargo hazards together with the use and limitations of all safety equipment carried on board is concurred with. The Coast Guard will continue to encourage and assist the maritime industry in this important area and will enforce regulations requiring drills to insure optimum performance standards. In addition, wide publicity of this casualty and similar incidents will be accomplished through distribution of Marine Board Reports and by reprinting these investigations in the Proceedings of the Marine Safety Council.

2. The recommendation that all cargo piping be so arranged that routine valving and segregation are accomplished from outside the cargo tanks requires further consideration. The effects of a regulation which would accomplish this would be considerable and have not been evaluated. Regulations which could accomplish this will be evaluated and developed if appropriate.

3. The recommendation that a suitable instrument be supplied to the vessel to provide accurate information concerning the atmosphere of any confined space insofar as toxicity hazards are concerned is concurred with. Regulations will be amended to include this requirement and incorporated in Tank Vessel Regulations upon final approval.

4. The recommendation that suitable protective clothing, together with proper eye protection be worn by all personnel working with substances that are hazardous upon contact is concurred with. Regulations will be amended to include this requirement and incorporated in Tank Vessel Regulations upon final approval.

C. R. BENDER
Admiral, U. S. Coast Guard
Commandant

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE:

•5943/4732
26 February 1973

From: Marine Board of Investigation
To: Commandant (MVI)

Subj: SS WILLIAM T. STEELE, O.N. 246143; deaths of three ship's officers at Guayanilla, Puerto Rico on 18 November 1972

Findings of Fact

1. On 18 November 1972, at about 0600 AST, while the SS WILLIAM T. STEELE was moored at Guayanilla, Puerto Rico, the Chief Mate, Wallace P. Crenshaw, died while working in number 9 center cargo tank which contained a high concentration of benzene vapor. Subsequent rescue attempts resulted in the deaths of the Master, John H. Loughlin, and the Second Mate, Arthur C. Guendelsberger.

2. Description of vessel involved:

Name:	WILLIAM T. STEELE (EX THE CABINS)
Official Number:	246143
Service:	Tank Ship
Gross Tons:	12,573
Net Tons:	8,053
Length:	552.5'
Breadth:	75.3'
Depth:	39.3'
Propulsion:	Steam Turbo Electric
Horsepower:	6,000
Home Port:	Wilmington, Delaware
Owner:	Richmond Corporation 100 West 10th Street Wilmington, Delaware 19801
Operator:	Texas City Tankers, Inc. P. O. Box 1271 Texas City, Texas 77590
Master:	John Henry Loughlin 803 Roosevelt Place New Orleans, La. 70119
Certificate of Inspection:	
Last Inspection:	Biennial
Date:	14 October 1972
Port:	Houston, Texas
Document:	Consolidated Enrollment and License Temporary Certificate Number 69 Galveston, Texas Issued 30 November 1971

3. Personnel Deceased:

Name:	John Henry Loughlin Z-744750 D-2
	Height 6'04" Weight 210 lbs.
	Master
License:	359284
SS#:	010-24-1040
Address:	803 Roosevelt Place
	New Orleans, Louisiana 70119
NOK:	Wife - Vera

Name:	Wallace P. Crenshaw Z-829145 D-2
	Height 6'00" Weight 170 lbs.
	Chief Mate
License:	408656
SS#:	456-24-5665
Address:	P. O. Box 27266
	Houston, Texas 77027
NOK:	Father - Aubrey Crenshaw

Name:	Arthur Charles Guendelsberger Z-954914
	Height 5'10" Weight 140 lbs.
	Second Mate
License:	408289
SS#:	301-18-9381
Address:	800 Sistina Avenue
	Coral Gables, Florida 33146
NOK:	Wife - Vera

4. Weather Data:

There was no wind. The barometric pressure was about 29.96 inches, and the ambient temperature at the time of the casualty was about 75°F. The temperature inside number 9 center tank was an estimated 10-15 degrees higher.

5. The SS WILLIAM T. STEELE is a T-2-type tank vessel built in 1944 at Mobile, Alabama. In 1959 the vessel was rebuilt and jumboized by renewal of the entire cargo carrying midbody. After rebuilding, the vessel had 27 cargo tanks instead of the original 26. The cargo tanks are numbered 1 through 9 port, starboard and center. The center tanks measure about thirty-six feet long by forty feet wide by forty feet deep and have a capacity of approximately 9900 barrels each. The wing tanks vary in capacity and size due to the configuration of the hull, with capacities ranging from 3257 to 5500 barrels and dimensions similar to the center tanks except for widths which are about one half. Total cargo capacity of the vessel is approximately 176,000 barrels. All cargo tanks are internally coated with Dimetecote 3, an inorganic zinc silicote coating which protects steel surfaces from corrosion and provides a relatively permanent smooth gray finish which facilitates tank cleaning and gas freeing.

6. Weco/Hamer segregation blinds are installed within the twelve inch cargo lines of numbers 2, 3, 5 and 8 center tanks to facilitate positive cargo segregation. The Weco/Hamer blind valve is a manufactured spectacle type blind designed to be operated without the removal of flange bolts and nuts. The Weco/Hamer blind is triangular in shape, fitted with bolts and spool shaped nuts at the three apexes of the triangle. The spool nuts are designed to spread the flanges of the valve by cam action when turned by an operating bar. The position of the spectacle blind can be rotated to the open or blind position providing unrestricted flow or positive segregation as required. The closing or opening of a Weco/Hamer blind usually requires one or two men and on this vessel had been accomplished in less than thirty minutes working in an empty, gas free tank.

7. The SS WILLIAM T. STEELE has been principally engaged in coastwise petroleum and chemical trade for the past several years, normally loading petroleum products in Texas Gulf Ports for delivery to U. S. East Coast Ports. In recent months the vessel has been returning via Puerto Rico where benzene and xylene are loaded for shipment to Louisiana and Texas ports. Due to these frequent cargo changes, the cleaning and gas freeing of tanks has become a routine procedure as has the operation of the Weco/Hamer blinds.

8. The SS WILLIAM T. STEELE arrived at the Phillips Petroleum Company terminal in Las Mareas, Puerto Rico, at 0153 on 17 November 1972 following a routine voyage from Yorktown, Virginia. During that voyage most of the cargo tanks were cleaned and gas freed in preparation for loading. Following the acceptance of the tanks, loading of 42,619 net barrels of benzene cargo was commenced at 0430. At that time it was intended that this parcel of cargo be loaded only in tanks number 5 center, 6 across, 7 center and 8 center. The loading continued under the supervision of the Chief Mate, Mr. Crenshaw, until about 1805 when the terminal notified the vessel that the proper quantity of benzene had been delivered. Soundings then showed that number 9 center tank, which was to have been reserved for a cargo of xylene, was approximately 80 percent loaded with benzene. Ullages of the tanks upon completion of the loading of benzene, with corresponding gross barrel capacities at the cargo temperature of 86°F., were as follows:

Tank	Ullage	Barrels
5 center	42'0½"	491
6 center	16'07¼"	6698
7 center	13'06"	7439
8 center	4'02"	9709
9 center	11'05"	7912
6 port	4'02½"	5405
6 starboard	4'02"	5409
Total gross barrels		43063
Total net barrels at 60°F.		42619

9. Benzene loaded at Las Mareas flowed down through the ship's pumproom piping and then forward into the piping system which serves tanks 7 center, 6 across, and 5 across. From that system the cargo flowed to port through crossover piping (containing an open Weco/Hamer blind and two open block valves) and then aft into the piping system which serves tanks 8 center and 9 center. Positive separation of the piping system serving those two tanks was to have been achieved by the closing of a Weco/Hamer blind located in the after end of number 8 center tank. This blind, unfortunately, was overlooked and left open by the Chief Mate during the lining up of piping to receive cargo. Also left open were the two block valves and the cargo suction valve in number 9 center tank. Since there were no other valves in the piping system to restrict the flow of cargo into number 9 center, that tank inadvertently was loaded with about 7912 barrels of benzene.

10. At 1850 transfer of cargo from number 9 center tank to the forward tanks commenced, and at 2034 the vessel left the dock, en route Guayanilla. Cargo transfer operations continued through the night of 17-18 November in conjunction with cleaning of the remaining forward cargo tanks. After completion of cargo transfer from number 9 center, this tank was fresh water washed and ventilated.

11. The passage between Las Mareas and Guayanilla was made at reduced speed to allow sufficient time for tank cleaning. The vessel arrived at the Commonwealth Oil Refining Company (CORCO) Berth #3, Guayanilla, at 0254, 18 November and the draft was: 4'-05" Forward, 25'-05" Aft, and 14'-11" Mean. After determining that the tank was gas free, at about 0430, the Chief Mate directed the Pumpman, Leroy Swiger, to insert a blank in the 12 inch cargo line in number 9 center tank, between flanges just forward of the double block valves, to positively isolate that tank from the benzene tanks. This flange connection contained twelve bolts and nuts of stainless steel to facilitate the insertion of a blank, which had been required for cargo segregation prior to the recent shipyard installation of the Weco/Hamer blind in number 8 center tank.

12. Mr. Swiger entered the tank through the access trunk located on the starboard side of the tank, with ventilation being provided by Coppus steam driven blowers installed in all but one of the four Butterworth openings. The port after blower was fitted with a sock which directed the air to a point near the bottom of the tank.

13. Mr. Swiger spent about 30-40 minutes removing seven of the top bolts and slacking off the five bottom bolts when Second Mate, Mr. Guendelsberger, arrived to assist him. A small amount of benzene began to leak from the flange as the bolts were loosened. While Mr. Guendelsberger held a light, Mr. Swiger opened the flange by driving in tapered steel wedges. This immediately caused a great increase in the flow of benzene, estimated to be about 12 quarts per minute. An attempt was made to insert the blank and this was partially accomplished. The fumes, however, by this time had become so strong that at approximately 0600 the men were forced to leave

the tank with the flanges open, blank partially installed and benzene flowing freely into the tank. Due to the drag of the vessel, this product flowed aft to where, unknown to these two men, the Chief Mate was working.

14. Within minutes after the Pumpman and Second Mate came out of the tank, the Boatswain arrived and inquired as to the whereabouts of Mr. Crenshaw and they replied that they did not know. The Boatswain then informed them that the Chief Mate had entered number 9 center at about 0530 with a steam eductor to remove water from the after end of the tank. Upon looking into the tank, the Chief Mate was observed sitting on the bottom of the tank with his shirt off and his back against the after bulkhead, in spasms and apparently passed out. At this point the Boatswain told the Second Mate that the Chief Mate was dying.

15. The Second Mate immediately went to summon the Master from his quarters while the Pumpman and Boatswain went to get the emergency fresh air breathing apparatus from the after house. When the Second Mate returned, he and the Pumpman, who had returned with the breathing apparatus, went back into the tank. Neither man wore the apparatus, which was being removed from its stowage box by the Boatswain. The Pumpman remained in the tank about five minutes and then had to return topside due to the benzene fumes. The Second Mate was unable to arouse Mr. Crenshaw by calling him and would not leave the tank without him. As soon as the Pumpman returned topside, the Boatswain, without the fresh air breathing apparatus, entered the tank to assist the Second Mate. He descended to the keelson and spoke to the Second Mate, trying to get him to leave the tank. Again the Second Mate refused to leave Mr. Crenshaw, and the Boatswain returned topside before he too was overcome. After remaining on deck for a few minutes to revive himself in the fresh air, the Boatswain returned to the keelson where he again tried to prevail upon the Second Mate to get out of the tank, only to have him repeat that he could not leave the Mate. The Boatswain was nearly overcome before returning topside where he was met by the Master and two Able Seamen rigging the fresh air breathing apparatus. The Master told the Boatswain to put on the fresh air breathing apparatus and reenter the tank, but he was unable to do so because of physical exhaustion and dizziness caused by inhalation of benzene fumes.

16. The Master then put on the fresh air breathing apparatus with a safety line and entered the tank, returning before he got half way down the ladder in order to clarify or establish emergency signals using the safety line. He again entered the tank with the Boatswain observing his progress by watching through the starboard after Butterworth opening. The Master proceeded along the cargo pipeline, removed his fresh air breathing apparatus, and tried to hand it to the Second Mate. He reached for it and both men fell from the pipeline to the bottom of the ship about five feet below. The Master remained motionless after falling but the Second Mate was observed attempting to climb back on the pipe, finally falling back motionless after two attempts. The Chief Mate could also be observed from the Butterworth opening, but he was motionless sitting against the after bulkhead as before.

17. The Boatswain then went to call the Third Mate, Mr. Robert F. Wasson, Jr., from his quarters and the two men returned to the main deck in way of number 9 tank. The vessel's second fresh air breathing apparatus meanwhile had been brought to the scene from the shelter deck and it was discovered that although it had been used by the Boatswain about a week before it was now inoperative because of a broken hose at the "Y" connection leading from the main supply line to the face mask. Mr. Wasson immediately went to the SS GULF TIGER, which was moored to an adjacent pier, to borrow another fresh air breathing apparatus. While he was gone, Ordinary Seaman John Hobson, wearing a Scott air pack obtained from the dock house, entered the tank carrying a small oxygen cylinder which he opened and placed near the Master after turning him over. The alarm bell on his air pack sounded at this time and he left the tank.

18. The Third Mate returned in about 20-25 minutes with the borrowed fresh air breathing apparatus, put it on, and entered the tank at about 0730. He found the Chief Mate and Master lying at the bottom of the tank near the after bulkhead in several inches of benzene, with the Second Mate in a prone position over the Chief Mate. He went to each man to ascertain if he was alive, but no pulse or other life signs could be found. He then attempted to attach a line to the Second Mate, but was unable to do so as the line was too short. Feeling weak now and also distressed by the presence of benzene fumes within his mask, Mr. Wasson returned to the deck.

19. At about 0820 an emergency crew arrived from the CORCO Refinery and entered the tank wearing Scott Air Packs. Their rescue attempts also were unsuccessful due to limited air supply and the high concentration of benzene vapor within the tank. There was no municipal emergency squad or fire department available on the weekend in Guayanilla. At 1210 a three-man U. S. Air Force rescue team arrived via a U. S. Coast Guard helicopter from Ramey Air Force Base. This team removed the Second Mate's body from the tank at 1312 after having dropped it approximately 20 feet due to the harness failing. By then the Air Force personnel and their air supply were nearly exhausted. No further rescue attempts were made and at 1700 orders were received from the Coast Guard Captain of the Port to cease all rescue attempts until the tank was gas free.

20. On 19 November the First Assistant Engineer, R. J. Kembler, wearing a borrowed sandblaster's hood supplied by ship's service compressed air entered the tank to secure the leaking flange. He was able to only partially free the jammed blank as he was forced to return topside in about 12 minutes due to the concentration of benzene fumes penetrating his clothing and burning his skin. He described the sensation as being comparable to that of an acid burn. Benzene was still running from the partially open flange in a stream about the size of a pencil.

21. In about an hour, after ventilating the tank, Mr. Kembler reentered the tank having made some adjustment to his clothing that permitted the compressed air from the hood to blow freely under his coveralls. This

reduced the burning sensation previously experienced, and in about a half hour he was able to complete the task by removing the wedges and blank and installing sufficient bolts to stop the leak. The tank was then fresh water washed, cleaned and gas freed in the conventional manner. This cleaning operation was not completed until the following day, 20 November. At 0956 and 1050 the bodies of the Chief Mate and Master were removed from the tank by Reuben H. McLaurin, relieving Master; Herbert Mills, Able Seaman; and Jesse Jimenez, Ordinary Seaman.

22. Benzene is a volatile, colorless (water-white) liquid hydrocarbon. It floats on the top of water as it is nearly totally immiscible with water and has a specific gravity of 0.88. Benzene vapor is heavier than air and has a characteristic, sweetish odor. The principal health hazard of benzene is from the inhalation of its vapors. Benzene does not have good warning properties; i.e., detection by smell occurs at vapor concentration higher than the Threshold Limit Value. Its odor threshold, which is defined as the smallest concentration that can be detected by smell by most people, is 100 ppm of benzene by volume in air.

23. The Threshold Limit Value (TLV) of ben: lion. As stated in Coast Guard publication CG-388 : Bulk Shipment by Water, TLV refers to an air bor: oduct expressed in parts per million by volume in ntra- tion believed to be safe for 8 hours' expos: ; for prolonged periods. The susceptibility of i: od ventilation is essential in compartments or andled, to prevent the accumulation of toxic or exp: e to high concentrations of benzene vapor in air can cause poisoning and death. A vapor concentration of 3000 ppm is endurable for 30 - 60 minutes (single exposure). A vapor concentration in the order of 7500 ppm is dangerous in 30 - 60 minutes (single exposure). A concentration of 20,000 ppm has been fatal in 5 - 10 minutes.

24. The only instrument available aboard the SS WILLIAM T. STEELE for testing cargo tank atmospheres was the combustible gas indicator. This instrument provides a convenient means for determining whether the vapor inside a cargo tank is above or below the lower explosive limit. Although the instrument is suitable for determining whether or not a tank is safe for entry with respect to the danger of explosion, it has too broad a range and is not suitable for determining whether or not a tank is safe for entry with respect to the toxicity hazard presented by an aromatic hydrocarbon such as benzene. This fact can be readily appreciated when one compares the 25 ppm Threshold Limit Value of benzene with its lower explosive limit of 1.4 percent, or 14,000 ppm.

25. There was no meaningful safety program established by the ship owner or operator of this vessel for the guidance of the officers and crew. Safety meetings were not conducted aboard the vessel. During drills the emergency squad was not mustered, the fresh air breathing apparatus was not broken out and inspected, and the crew was not instructed in its use.

Conclusions

1. Chief Mate Wallace P. Crenshaw was overcome by benzene fumes while working in number 9 center cargo tank and died. Second Mate Arthur C. Guendelsberger, while trying to help the Chief Mate, was also overcome by benzene fumes causing him to fall and die in the tank. The Master, John H. Loughlin, died in his attempt to assist the Second Mate, after they both fell about five feet from a pipeline to the bottom of the tank. Since the Master did not move after falling, his death may have been caused by injuries resulting from the fall, inhalation of benzene fumes, or a combination of both.

2. This loss of life may have been averted had the rescue attempts to save the Chief Mate been initiated and carried out by a well organized and trained emergency squad, properly equipped.

3. Cargo piping arrangements which require personnel to routinely enter the tanks for the purposes of lining up and segregation, to accommodate a variety of cargoes and loading conditions, are inherently dangerous. In the case of the SS WILLIAM T. STEELE, an error in failing to close the Weco/Hamer blind in number 8 center tank, prior to loading same, set the stage for a series of events that resulted in the deaths of the three senior officers of this vessel. Other crew members were unnecessarily exposed to harmful concentrations of benzene and benzene vapor.

4. The vessel was not equipped with any instrument or device suitable for determining whether or not a space, such as an empty cargo tank or crew quarters, was safe with respect to the toxicity hazard presented by an aromatic hydrocarbon such as benzene.

5. The company and vessel safety and training program is considered inadequate. The vessel did not routinely conduct emergency drills which included inspection and use of emergency equipment, and actual personnel performance under simulated emergency conditions. The company did not provide the vessel with adequate instructions, training aids and publications for use by the officers and crew.

6. Officers and crew of the SS WILLIAM T. STEELE, in their exposure to benzene and its vapors, treated this cargo much the same as they treated a cargo of gasoline. They were generally unaware of, or disregarded, the harmful physiological effects that can accrue from the inhaling of benzene vapors.

Recommendations

1. That meaningful safety meetings and drills be frequently and regularly held on board tank vessels so as to insure the proper instruction of all crew members concerning the on board and proposed cargo hazards together with the use and limitations of all safety equipment carried on board.

2. That all cargo piping be so arranged that routine valving and segregation are accomplished from outside the cargo tanks.

3. That a suitable instrument be supplied to the vessel to provide accurate information concerning the atmosphere of any confined spaces insofar as toxicity hazards are concerned.

4. That suitable protective clothing, together with proper eye protection be worn by all personnel working with substances that are hazardous upon contact.

W. A. Montgomery

Captain W. A. MONTGOMERY, USCG
Chairman

M. E. Welsh

Commander M. E. WELSH, USCG
Member.

W. E. Whaley Jr.

Commander W. E. WHALEY, JR., USCG
Member and Recorder

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