

TREASURY DEPARTMENT
UNITED STATES COAST GUARD

ADDRESS REPLY TO:
COMMANDANT
U.S. COAST GUARD
HEADQUARTERS
WASHINGTON 25, D.C.



MVI-3
5943/MARINE SULPHUR
QUEEN a-8 Bd

17 MAR 1964

Commandant's Action

on

Marine Board of Investigation; disappearance of
the SS MARINE SULPHUR QUEEN at sea on or about
4 February 1963 with the presumed loss of all
persons on board

1. The record of the Marine Board of Investigation convened to investigate subject casualty together with the findings of fact, conclusions and recommendations has been reviewed.
2. The SS MARINE SULPHUR QUEEN, a T2-SE-A1 type tank vessel of U. S. Registry, converted to carry molten sulphur, departed Beaumont, Texas, with a full cargo of 15,260 tons on the afternoon of 2 February 1963 enroute Norfolk, Va. The ship and crew of 39 men disappeared. The vessel was last heard from at 0125 EST on 4 February 1963.
3. The ship's conversion in 1960 to a molten sulphur carrier necessitated the removal of all transverse bulkheads in way of the original centerline tanks and modification of the internal structure to accommodate one continuous independent tank 306 ft. long, 30 ft. 6 in. wide and 33 ft. high, which was internally divided by transverse bulkheads into four cargo tanks of about equal size. The external surfaces of this long independent tank were insulated with a fibrous glass material 6" thick on the top of the tank and 4 in. thick on other surfaces. A void surrounded the tank which allowed a space about 3 ft. 6 in. between the bottom of the tank and the bottom plating of the ship, 2 ft. between the sides of the tank and the original wing tank longitudinal bulkheads, and 3 ft. between the top of the tank and the weather deck. A watertight bulkhead was installed at frame 59 which divided the void into two spaces. The forward space contained cargo tanks one and two and the after space contained cargo tanks three and four. A partial or diaphragm bulkhead which did not extend to the top or bottom of the void was installed where the first and second cargo tanks were divided at frame 65 and where the third and fourth cargo tanks were divided at frame 53. Near its midpoint the tank was welded to its supporting structures at frame 59, and provision was made to permit

expansion and contraction of the tank from the midpoint toward the ends. Each void was provided with power ventilation. Steam heating coils were installed in the cargo tanks to maintain the temperature of the cargo. Each cargo tank was fitted at its after end with a port and a starboard trunk which extended through the weather deck into a common watertight pump house. There was a horizontal clearance of 4 in. between the trunk and the weather deck to allow for expansion. An asbestos apron was fitted to cover this clearance. An electric motor was mounted on the top of each trunk and connected by a vertical shaft to a deep well pump located in a sump in the bottom of the tank. A 4 in. ventilator was installed in the top of each trunk and extended through the top of the pump house. An access scuttle was also installed in each trunk. At the forward end of each cargo tank, a 6 in. vent pipe was installed which terminated about 4 ft. above the weather deck. As a portion of this vent pipe, a section of flexible stainless steel piping was installed between the tank top connection and the weather deck to provide for the expansion and contraction of the cargo tank. The forward bulkhead of the original after pump room was removed when the ship was converted. The cowl ventilators of the after pump room were retained but the ducts were removed so that they did not extend below the weather deck. The original wing cargo tanks were retained as ballast tanks and utilized to keep the ship on an even keel while loading and discharging. A fixed steam smothering fire extinguishing system was provided in the cargo tanks and the void spaces.

4. The MARINE SULPHUR QUEEN commenced operation as a bulk molten sulphur carrier in January, 1961. On 8 April 1961, a major sulphur spill occurred in the No. 1 pump house while discharging cargo. The molten sulphur flowed down through the clearance between the trunk and weather deck onto the insulation of No. 1 tank and into the void space below the tank. In June of 1961, the solidified sulphur and the sulphur-impregnated insulation were removed, and new insulation was installed. While discharging cargo on 28 December 1961, a spill occurred in the No. 3 pump house. Again, the sulphur flowed down onto the insulation of the tanks in the after void space and into the lower void. In January, 1962, the solidified sulphur and the sulphur-impregnated insulation were again removed, and the new insulation installed.

5. During the latter part of 1961, a crack was found in the steel plate which formed the starboard sump at the after end of No. 4 tank. This crack was described as being about 12 in. long and about 1½ in. below the bottom of the No. 4 tank. The amount of molten sulphur which leaked through this crack prior to its repair in January of 1962 cannot be determined because of the sulphur spill in the pump house of No. 3 tank on 28 December 1961. However, a very small leak, described as a pin-hole weep, was found in way of the repair shortly after the ship left the shipyard. Several methods were used to repair this minor leak, but none was entirely

satisfactory. In any event, the molten sulphur which did emit from the leak was confined in a bay approximately 3 ft. by 8 ft. formed by the tank foundation.

6. Commencing in the late summer of 1962 and continuing until the vessel sailed on its last voyage, molten sulphur leaked from the insulation at the after end of No. 4 tank on each loaded voyage. The amount of sulphur was so great that it was necessary for the crew to remove the solidified sulphur on each return voyage to keep it from plugging the bilge suction. When the vessel sailed on its last voyage, an estimated 20 to 70 tons of solidified sulphur remained in the bilges at the after end of No. 4 tank. A witness stated that this sulphur was either coming out of insulation which was not removed during the repairs made in January of 1962 or coming from a leaking flange.

7. The repair list prepared by the Master in October of 1962 contained an item for the renewal of the 6 in. stainless steel flexible vent line on the No. 1 cargo tank, the removal of approximately 6 tons of sulphur in the void at the forward end of the tank and the renewal of approximately 750 square feet of sulphur-saturated insulation at the forward end of No. 1 tank.

8. Numerous fires had occurred in the sulphur-impregnated insulation in the void spaces. These fires were of a local nature seldom covering an area of more than a few square feet, and caused little or no apprehension on the part of the crew. They were extinguished with the steam smothering system and fresh water. Commencing in October of 1962, these fires occurred with increasing frequency. Witnesses stated that during a voyage in the latter part of December, 1962, fires burned almost continuously in the insulation at the after end of No. 4 tank, and at least one fire occurred in the void space of No. 1 tank. Before the last voyage, the cowl type ventilators from the after pump room had been removed and canvas covers installed to reduce the loss of steam from the fixed fire extinguishing system. The power ventilation for the voids was used only in port.

9. During its operation as a molten sulphur carrier, the MARINE SULPHUR QUEEN sustained heavy weather damage on two occasions, encountered two hurricanes and suffered one minor grounding.

10. The ship was drydocked and inspected by the Coast Guard in January, 1962. It was inspected for certification by the Coast Guard in January, 1963. However, the cargo tanks, void spaces surrounding the cargo tanks, and wing tanks were not inspected at this latter time in view of the vessel's scheduled March, 1963 yard period for drydocking and repairs.

11. On 2 February 1963, the MARINE SULPHUR QUEEN completed loading a full cargo of 15,260 tons of molten sulphur at Beaumont, Texas. Cargo Tanks 1 and 2 contained dark sulphur with a carbon content of 0.14%, and Tanks 3 and 4 contained bright sulphur with a carbon content of 0.04%.

12. The ship departed Sabine Bar Seabuooy at 1900, CST, 2 February 1963, for Norfolk, Virginia, expecting to arrive at noon, on 7 February 1963. The Master had been instructed to give both a 48-hour and 24-hour advance notice of arrival to the Norfolk agent. At 0125, EST, 4 February 1963, a personal message from a crew member was transmitted by the vessel and received by RCA radio. This is the last known radio contact with the vessel. At this time the estimated position of the ship was 25°45' N, 86°W. At 1123, EST, 4 February, RCA radio made the first of two unsuccessful attempts to contact the ship. The estimated position of the ship at this time was 24°40' N, 83°19' W. Weather conditions prevailing along the track of the MARINE SULPHUR QUEEN are known to have been rough. The wind was northerly 25 - 46 knots; northerly seas with a height of about 16 ft. and slightly abaft the vessel's port beam, and the period of encounter of the waves was within about 10 percent of the ship's period of roll.

13. At 2100, EST, 7 February 1963, the SS MARINE SULPHUR QUEEN was reported overdue to the Commander, 5th Coast Guard District, Portsmouth, Va. An intense air and surface search was mounted along the trackline of the ship from Beaumont, Texas, through the Straits of Florida to Norfolk, Va. During the period 8 - 13 February 1963, Coast Guard, Navy, Marine Corps, and Air Force aircraft participated in 83 flights, flying 500 hours and searching a total of 348,400 square miles. In addition, other federal agencies determined that the vessel was not in Cuban waters. All efforts were without success and the search was discontinued on 13 February 1963.

14. On 20 February 1963, a life preserver and fog horn stencilled with the MARINE SULPHUR QUEEN's name were retrieved by a U. S. Navy vessel 12 miles southwest of Key West, Fla. A second search was commenced concentrating on the eastern part of the Gulf of Mexico, the Straits of Florida and the Bahamas. The U. S. Navy conducted an underwater search for the vessel's hulk during the period 20 February through 13 March 1963. During the search additional debris was retrieved and identified as coming from the SS MARINE SULPHUR QUEEN. On 14 March 1963, after all efforts to locate the ship had failed, the search was again discontinued.

REMARKS

1. In view of the vast search operations conducted and the debris found and identified as coming from the MARINE SULPHUR QUEEN, the ship and her entire crew of 39 men are presumed to be lost.
2. Concurring with the Board, the vessel apparently was lost on 4 February 1963 on its approach to, or in the vicinity of, the Straits of Florida.
3. Further concurring with the Board, in the absence of survivors or physical remains of the ship, the exact cause of the loss of the MARINE SULPHUR QUEEN cannot be determined.
4. The Board considered many possibilities which may have caused the loss of the ship and rightly declined to assign any order of probability to these causes. In its conclusions the Board commented on the following possible causes:
 - a. An explosion may have occurred in the cargo tanks
 - b. A complete failure of the vessel's hull girder may have caused it to break in two
 - c. The vessel may have capsized in synchronous rolling
 - d. A steam explosion may have occurred as the result of a rapid filling of the void space with water.

The record contains ample evidence to support the Board's suppositions.

5. Another possible cause for the loss of the vessel and one which the Board did not comment upon concerns the possibility of an explosion in the void space surrounding the cargo tanks. Hydrogen sulphide and carbon disulphide gases released by agitated molten sulphur as well as sulphur vapor could have entered the void spaces in sufficient quantities to have formed an explosive mixture. The recent history of fires in the insulation of No. 4 tank indicates that a source of ignition existed. A continuing study of this possibility is being made.
6. The Board's findings include a detailed description of the structural arrangement and scantlings of the vessel. This description has been reviewed for general correctness. The structural arrangement and the scantlings of the vessel can also be dealt with by reference to the pertinent plans. The following plans are considered to be in this category and will be filed with the original record of the investigation:

Bethlehem Steel Co., Baltimore Yard Plan No.

- a. 43933 Alt. 1 - General Arrangement
- b. 44302 Alt. 2 - Midship Section Modifications
- c. 44303 Alt. 2 - Mod. to Existing Bhds. & Webs
- d. 44304 Alt. 0 - New W.T. Longitudinal Bhds. - Frs. 71 to 73
- e. 44305 Alt. 0 - Mod. to Cent. Vert. Keel and Deck Girder
- f. 44307 Alt. 2 - Swash Bhds. for Sulphur Tanks
- g. 44308 Alt. 2 - Sulphur Tank No. 1 Structural Details
- h. 44309 Alt. 2 - Sulphur Tanks No. 2, 3 & 4 Structural Details
- i. 44310 Alt. 0 - Foundations for Sulphur Tanks
- j. 44311 Alt. 0 - Expansion Connections for Sulphur Tanks
- k. 44323 Alt. 0 - Sumps for Sulphur Tanks Arrgt. & Dets.
- l. 44324 Alt. 0 - Sump Arrgt.
- m. 44331 Alt. 5 - Arrangement of Sulphur Cargo Piping

7. The Board's recommendation that the same conversion of another T2 type tanker should not be approved is concurred in. However, its further recommendation that no other conversion of this type vessel should be approved which deviates from the originally designed features for the carriage of normal petroleum products requires considerable qualification. First, the acceptability of any conversion must be considered on its individual merits, having regard for the existing condition of the vessel and the proposed cargo, route, and service. Secondly, the objection to the conversion of an existing T2 or another tanker of comparable age is associated with the probable condition of the vessel, particularly the cargo portion, due to age, as much as it is due to design considerations. Thus, there might be no objection to conversion of such an existing vessel if it were, in fact, found to be fully in satisfactory condition, and if the conversion design requirements were compatible with the existing structure. In accordance with the foregoing principle, the use of an existing T2 tanker bow and stern, if in satisfactory condition and properly joined to a suitable new cargo middlebody, is considered acceptable.

8. The Board's recommendation which would require molten sulphur carriers to install a device to automatically record the temperature of steam entering the heating coils is not fully concurred in. If the source of supply of the steam is such as to provide inherent temperature control, no temperature measuring or recording device or alarm is considered necessary. If this is not the case a temperature gauge and an alarm should be required. If the temperature of these coils is unnecessarily high, the explosive risk may be increased and, additionally, heat transfer may be reduced due to the increase in viscosity of sulphur adjacent to the coils. In any event, there is need to separately monitor the cargo temperature since the temperature of the heating coils must be higher than the desired cargo temperature.

9. Due to the high corrosion rate which may result from the use of water or steam in fighting sulphur fires and the impracticability of effectively manning fire stations in the restricted void spaces, the Board's recommendation that fire hose stations be required in the void spaces surrounding the cargo tanks is not concurred in.
10. The Board's recommendation that instrument manufacturers be advised of the need for the development of a suitable explosimeter that will accurately measure the explosive gases emanating from molten sulphur in order that frequent checks of the gas content in the tank can be made by the ship's personnel is concurred in only insofar as it applies to improving existing equipment and the development of suitable gas monitoring systems. Such a system is also needed to check for explosive gases in the void spaces. Reasonably accurate instruments are now in use. Proposed regulations would require such instruments on all tank vessels. Consideration is being given to extending this requirement to freight and passenger vessels which carry limited quantities of inflammable or combustible bulk cargoes.
11. Concurring in another of the Board's recommendations, regulations are being developed for submission to the Merchant Marine Council which would require operators of molten sulphur carriers to provide appropriate instructions and indoctrination for vessel personnel concerning hazards of molten sulphur cargoes.
12. It was further recommended that the results of studies being made by the U. S. Bureau of Mines concerning the chemical and physical properties of molten sulphur be reviewed for their impact on U. S. vessels approved for the carriage of such cargo. Concurring in the Board's recommendation, the report is being carefully considered.
13. The Board's recommendation that the Commandant establish procedures to ensure that Coast Guard Marine Inspection Offices are furnished timely information regarding significant areas requiring inspection and special cargo features of vessels uniquely designed to transport exotic cargoes is concurred in. Action has already been taken to ensure that molten sulphur carriers are frequently inspected, and special instructions have been given to Marine Inspection Officers in ports where these vessels call. Additional inspection procedures are being developed for the inspection of all vessels carrying exotic cargoes.
14. The recommendation that a company seeking the approval of a vessel designed to carry exotic cargoes be required to submit reasonable studies concerning all of the chemical and physical properties of the cargoes and that, when necessary, such properties be given full consideration in the design of the vessel is concurred in and will be referred to the Merchant Marine Council for consideration.

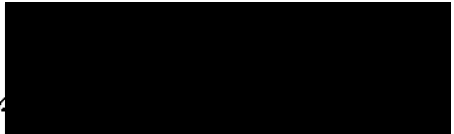
15. The Board recommended that problem areas concerning the construction of cargo tanks and the chemical properties of molten sulphur be resolved prior to the construction or conversion of another vessel to a molten sulphur carrier. Since the loss of the MARINE SULPHUR QUEEN, a continuing study has been made of all of the problems involved in the carriage of molten sulphur. During the recent conversion of a T2 tankship for the carriage of molten sulphur, a completely new midbody was installed, individual independent cargo tanks were designed to reduce the problems associated with thermal expansion, and the cargo tank vent pipes were designed so that the flexible section was eliminated. On an existing vessel the flexible vent lines have been removed, and a continuing inspection program conducted to ensure that dry sulphur or any other combustible material is not permitted in the void spaces surrounding the cargo tanks. The Department of Health, Education and Welfare will be requested to determine if there is a health hazard to personnel employed on vessels carrying molten sulphur.

16. With regard to the Board's recommendation that procedures be established which would provide the owners, agents or operating companies with daily positions of their vessels, it is considered that the final responsibility in this regard rests with each vessel's management.

17. The Board was of the opinion that Recommendation 48 of the International Convention for the Safety of Life at Sea, 1960, concerning the carriage of an emergency Position Indicating Radio Beacon should be implemented at the earliest practicable date. The recommendation is being actively considered on an international basis.

18. The Board recommended that a portable emergency radio transmitter be kept in the vicinity of the after lifeboats and that an inflatable life raft be carried in the vicinity of the forward and after deck houses. Proposed regulations to implement both of these recommendations are being considered by the Merchant Marine Council.

19. Subject to the foregoing remarks the record of the Marine Board of Investigation is approved.



Edward J. ...
Admiral, U.S. Coast Guard
Commandant

TREASURY DEPARTMENT
UNITED STATES COAST GUARD

ADDRESS REPLY TO:
COMMANDANT
U.S. COAST GUARD
HEADQUARTERS
WASHINGTON 25, D.C.



FUG 23 1963

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

Subj: SS MARINE SULPHUR QUEEN; disappearance of at sea on or about
4 February 1963

1. At about 1830, CST, 2 February 1963, the SS MARINE SULPHUR QUEEN, with a crew of 39 and a full cargo of approximately 15,260 long tons of molten sulphur, took departure from Sabine Sea Buoy on a voyage from Beaumont, Texas to Norfolk, Virginia and subsequently disappeared at sea without the transmission of a radio distress message.
2. The SS MARINE SULPHUR QUEEN, O.N. 245295 (Ex-ESSO NEW HAVEN) was an all-welded T2-SE-A1, tankship; of 7240 gross tons and 4057 net tons; length 504 ft., breadth 68.2 ft., and depth 39.2 ft.; built at Sun Shipbuilding and Drydock Co., Chester, Pa. in 1944 and converted to a molten sulphur carrier at Bethlehem Steel Co. Shipyard, Baltimore, Md., during the latter part of 1960. The vessel was single screw, powered by a 7240 shaft horsepower turbo-electric drive manufactured by Westinghouse Elec. & Mfg. Co. The vessel was owned by Marine Sulphur Transport Corporation and operated under a bareboat charter by Marine Transport Lines, Inc., both companies being located at 11 Broadway, New York, N.Y. The conversion to a molten sulphur carrier was accomplished in accordance with plans approved by the U. S. Coast Guard and the American Bureau of Shipping.
3. The vessel was certificated by the U. S. Coast Guard at Baltimore, Md. on 18 January 1961 for the carriage of "Grade E liquids at elevated temperatures" and classed by the American Bureau of Shipping as to hull and machinery. The vessel was recertificated by the U. S. Coast Guard at Beaumont, Texas on 17 January 1963 and retained in class by the American Bureau of Shipping at the same time. The vessel had valid load line certificates, both International and Coastwise, issued by the American Bureau of Shipping and valid radio certificates issued by the Beaumont, Texas office of the Federal Communications Commission covering both the installed radio equipment and the lifeboat portable radio.

4. In general, the conversion to a molten sulphur carrier consisted of the removal of all the transverse bulkheads in the way of the original T-2 centerline tanks and the installation of an independent tank 306 ft. long, 30 ft. 6 in. wide and 33 ft. high, internally divided by sulphur-tight transverse bulkheads into four tanks with No. 1 being 83 ft. long; No. 2 being 73 ft. long; No. 3 being 73 ft. long; and No. 4 being 77 ft. long. To accommodate the sulphur cargo tank it was necessary to cut away part of the original No. 1 cargo tanks, port and starboard, as well as part of the original forward bulkhead of the after pump room. The existing structure of No. 1 tanks was cut away from frame 71 forward to frame 72½ including the centerline bulkhead and the transverse bulkhead for a distance of 17 ft. 6 in. on either side of the centerline. The remaining portions of the No. 1 tanks were changed to void spaces by enclosing them with non-watertight longitudinal wing tank bulkheads. The after pump room forward bulkhead at frame 47 was cut out to permit the tank to extend into the pump room to frame 46½ and thus, in essence, the pump room became a part of the void space surrounding the tank. The original wing tanks, 2 through 9 inclusive, were left intact and fitted as water ballast tanks. As the cargo tanks were loaded, the wing tanks were deballasted and the reverse procedure was followed when offloading, thus minimizing the change in draft during these operations.

5. The sulphur tank was of rectangular cross section, constructed of mild steel meeting American Bureau of Shipping requirements for steel to be welded. A longitudinal swash bulkhead ran the full length of the major tank and each of the four individual tanks were fitted with a transverse swash bulkhead at approximately their mid-length. At normal temperatures the transverse sulphur-tight bulkheads and the transverse swash bulkheads coincided with the original center tank transverse bulkheads.

6. In the construction of the tank, the sides, ends, and sulphur-tight transverse bulkheads were constructed of steel plate 7/16 in. at the top increasing to 11/16 in. plate at the bottom, all having 10 in. x 3/4 in. web frames fitted as stiffeners. The top was made of 3/8 in. plate with 8 in. x 7/16 in. web frames fitted as stiffeners. The bottom was 11/16 in. plate with 9 in. x 5/8 in. web frames fitted on the exterior thereof as stiffeners. The centerline and transverse swash bulkheads were 7/16 in. plate throughout with 8 in. x 7/16 in. web frames fitted as stiffeners. All the above stiffeners were fitted at approximate 2 ft. 6 in. frame spacing. To support the sides, ends and sulphur-tight transverse bulkheads there were installed two horizontal web plate stringers 5 ft. x 1/2 in. plate faced with a 21 in. x 1 in. plate and bracketed by a 1/2 in. plate with 3 in. flange at the 9 ft. and 18 ft. 6 in. levels. These stringers were bracketed on 7 ft. 6 in. centers, and at the normal ship frame spacing of 12 ft. 2 in., a tie beam, 12 in. x 12 in. x 1-1/4 in. web frame, was fitted from the upper stringer to the centerline swash bulkhead. At the

after end of each tank there was fitted a port and starboard sump of the same thickness as the tank bottom, 2 ft. 6 in. in width and 18 in. deep near the centerline and sloping up to 5 in. near the sides. Additionally, each tank top was fitted at the after end with a port and starboard expansion trunk approximately 5 ft. square and 4 ft. in height of 1/2 in. plate which extended through the weather deck into a watertight pump house. The inboard sides of both the sumps and trunks were approximately 2 ft. 7 in. off the centerline of the ship. At the forward centerline of each tank there was fitted a 6 in. vent leading to the weather deck and extending approximately 3 ft. above with a U-bend. The vents were steam jacketed and were fitted with stainless steel flexible piping between the tank tops and the weather deck. In each of the expansion trunks there was a 4 in. vent which terminated in a U-bend approximately 2 ft. above the top of the pump house. These vents were also steam jacketed and fitted with stainless steel flexible piping between the trunk tops and the overhead of the pump house. At the top of each expansion trunk, which was closed with 1/2 in. plate, there was fitted a 2 ft. diameter entrance scuttle and a 1 in. thick annular ring 25 in. inner diameter and 32 in. outer diameter serving as a foundation for a deep well pump electric motor.

7. In effecting the installation of the major tank, the height of the center vertical keel from frames 46 1/2 to 72 1/2, was cut down from 7 ft. 6 in. to a constant height of 3 ft. 4 in. and a 17 in. x 1 in. flange plate was welded to the top thereof. To accommodate the cargo tank the transverse web frames, or floors, in the bottom of the ship were cut down to a constant horizontal plane of 3 ft. 4 in. above the flat keel plate and were fitted with 15 in. x 1 in. flange plates welded to the top thereof. On either side of the centerline vertical keel the bottom longitudinals, 7 ft. 6 in. and 15 ft. off the centerline port and starboard, were extended up to this same 3 ft. 4 in. horizontal plane by the addition of 1/2 in. plate with an 8 in. x 1 in. flange plate welded to the top. The bottom of the sulphur tank was fitted with 5 longitudinal stringers of 1/2 in. plate faced with 8 in. x 1 in. flanges. The longitudinals fitted to the bottom of the tank and the flange plates of the ship's bottom longitudinals were bolted together, except between frames 58 and 60, with a 1/2 in. thick 8 in. wide phenolite laminated plastic installed between the flanges as a heat isolator. To permit free expansion and contraction of the tank, these bolts, 1 in. in diameter, were mounted in 1-1/16 in. holes in the tank longitudinals passing through 1-1/16 in. x 3-1/2 in. slots in the plastic heat isolator and the flanges in the ship's bottom longitudinals. Because of the increased expansion at either end of the tank, the slots were increased in length to 4 in. for the last 10 ft.; this increase in length of the slots was not reflected in the vessel's plans. Nuts were screwed onto the bolts hand-tight, tightened 1/4 turn and spot welded to the bolt body. All bolt holes were drilled with 10 in. centers, a single row on each of the outboard longitudinals and a double row on the centerline longitudinal. The bolts and nuts

were mild steel except for the centerline rows which were ASTM A-235, high strength material. Between frames 58 and 60, a distance of 24 ft. 4 in., the five longitudinals fitted to the bottom of the tank were welded to the five ship's bottom longitudinals after a 1/2 in. thick plate was inserted to compensate for the absence of the heat isolating material in these areas. After the conversion was completed heat was applied to the tanks, utilizing the heating coils hereinafter discussed. The air temperature within the tanks at this time was determined to be between 240° F to 252° F. While no precise measurements of the actual expansion of the tank were made at this time, one witness recalled the ends of the tank had expanded so that the bolts were within 1/4 to 3/8 of an inch from the ends of the 4" slots. During this test and later at various times during the actual operation of the vessel, loud noises were heard throughout the vessel. These noises were caused by the expansion and contraction of the tank.

8. Similarly, the centerline deck longitudinal girder was cut from its 5 ft. original depth to 2 ft. 8 in. except in the way of frames 58 to 60 where the depth was 3 ft. 6 in. and where this girder was welded directly to the top of the tank. Where the girder was cut to a depth of 2 ft. 8 in., a 15 in. x 1 in. face flange was welded to the bottom thereof. On the tank top at the centerline, there were fitted at each frame between frames 47 to 71 inclusive, except for the welded portion between frames 58 to 60, bracketed webs 1/2 in. thick with face plates 8 in. x 1 in. x 12 in. long. Here, like the bottom connection, 1 in. bolts were mounted in 1-1/16 in. holes in the tank connections up through similar slotted holes in the 1/2 in. heat isolator material and the deck girder flange plate, each connection being made with two bolts and nuts of ASTM A-235 material staggered on either side of the centerline of the deck girder.

9. At frame 59 a complete watertight bulkhead surrounded the tank so that a void space then existed fore and aft of this bulkhead. This watertight bulkhead was made up of 1/2 in. steel plate. At frames 53 and 65 diaphragm plates, 3/8 in. thick, were fitted between the tank sides and the wing tank longitudinal bulkhead, both on the port and starboard sides. These diaphragm plates extended from 4 ft. 6 in. above the tank bottom to within 1 ft. 6 in. of the top of the tank. At about the 20 ft. level above the tank bottom, access holes, port and starboard, 15 in. x 36 in. were cut out of the diaphragm plates to permit access along a cat walk, which together with appropriate vertical ladders, permitted personnel to descend from the weather deck to the void space surrounding the tank. On each side of the tank at frames 47, 50, 56, 62, 68 and 71, tank expansion connections were fitted. These expansion connections were made up in two pieces, each 6 ft. x 1 ft. 3 in. x 1/2 in. plate faced with a 4 ft. x 12 in. x 3/4 in. flange. One piece was welded to the sulphur tank and the other to the wing tank longitudinal bulkhead. The piece welded to the sulphur tank had 8 1-1/16 in. holes and the piece welded to the wing tank had 8 2-7/16 in. horizontal slotted holes. Here again, 1/2 in. plastic heat isolator material was used between the flange plates and 1 in. mild steel bolts and nuts were fitted to join the two parts of the expansion connection. These expansion connections were located such that top of the connection was about 1 ft. 6 in. below the top

of the sulphur tank.

10. To reduce thermal losses through the sulphur tank structure, the entire tank exterior was insulated with a blanket of Owens-Corning Armaglas PF-335, 4 in. thick on the bottom, sides, ends and around the expansion trunks and 6 in. thick on the top. The insulation was held in place with Nelson welding pins and covered with #18 gauge galvanized wire netting secured in place with clips over the Nelson pins. Prior to the installation of the insulation the entire tank exterior was painted with aluminum paint. The tank interior was not given any protective coating.

11. To maintain the desired temperatures within the tanks, steam heating coils made up of 2 in., schedule 80, ASTM A-53 steel pipe were fitted in the bottom, sumps, sides and ends of the tank. Tank No. 1 had 18 coils in all, 4 each in its forward end, two sides and bottom, with one coil for each of its two sumps. Tank No. 4 was similarly fitted, except the end coils were at its after end in lieu of its forward end. Tanks Nos. 2 and 3 each had 14 coils in all, since there were no end coils in these tanks. Each coil had its own individual steam supply line entering the tank at the top and leaving the tank at the bottom port side through a steam trap. The steam to these coils came from the desuperheater line from the main boilers reduced to a pressure of 35 to 40 pounds per square inch while in port; and from the 70 pounds per square inch bleed-off stage from the main turbine reduced to a pressure of 35 to 40 pounds per square inch while at sea. No thermometers were installed in either of these two steam supply lines. The steam condensate return line to the engine room terminated in an atmospheric tank where the condensate could be sighted visually for discoloration. The heating coils were made up for a working pressure of 60 pounds per square inch and were tested hydrostatically to a pressure of 200 pounds per square inch. All shop made coil joints were electric arc welded and x-rayed; all coil joints made on the ship were gas welded. Each of the four cargo tanks were fitted with thermocouples, on the port and starboard sides, located about half way up from the tank bottom. The temperatures were automatically recorded on a tape in the engine room. Testimony was received that this recorder was inoperative during the period October 1962 to January 1963; it was then repaired and placed back in operation. The temperature recorder was not considered to be essential for the safety of the vessel because the steam pressure and the resultant temperature to the heating coils could be carefully controlled. The ship was also provided with portable recording thermometers to ascertain the temperature of the cargo.

12. As noted before, the expansion trunks in each of the four individual sulphur cargo tanks extended through the weather deck. To permit expansion an opening in the weather deck was cut out, then adequately reinforced with a doubler plate and web frame stiffeners. This cut out was of such size that a 4 in. opening was allowed all around the periphery of the trunks. This 4 in. opening was, at normal atmospheric temperatures, filled with a 4 in. layer of Armaglas insulating material which surrounded the trunks. The trunk and deck were connected by means of a canvas boot, later changed to asbestos cloth, to insure a gas tight seal and to provide the necessary flexibility when the tank moved. To insure watertight integrity of the hull, a combination pump and controller house was constructed over the expansion trunks at the after end of each cargo tank. Each house was approximately 25 ft. x 12 ft. 10 in. x 8 ft. high with a 3 ft. wide controller house on the port side incorporated therein but separated from the pump house by a watertight bulkhead. The pump room and controller room were each fitted with a watertight door. At the after end of each controller house the weather deck had a 2 ft. x 3 ft. cut out for the purpose of ventilating the voids surrounding the cargo tanks. This cut out led into a space approximately 2 ft. x 3 ft. x 6 ft. high separated from the controller room by bulkheads, and the air was discharged therefrom through a louvered opening at the rear of the house. At the original conversion each pump house had two removable plates 4 ft. x 4 ft. bolted to the top of the house to give additional ventilation at the time of loading and discharging. In June 1961 these plates were replaced with hinged watertight scuttles at Bethlehem Steel Co. Shipyard, Beaumont, Texas.

13. The vessel's cargo piping consisted of two 10 in. discharge and fill headers running athwartship of the weather deck at frame 67 that could be connected either port or starboard to Chiksan joints at the loading and discharge docks. From the headers one 10 in. line ran aft to load and discharge tanks No. 1 and No. 2; another parallel 10 in. line ran aft to load and discharge tanks No. 3 and No. 4. A 10 in. crossover line led into each of the four pump houses. From the crossover line an 8 in. fill pipe was run down through the port side expansion trunk top to within a few inches of the bottom of the tank, ending in a 90° ell. The necessary valves were installed in the system so that each tank could be filled independently. To discharge the cargo of molten sulphur each sump was fitted with a deep well pump driven by an explosion-proof electric motor, the motor being mounted on top of the expansion trunk cover. The discharge lines from the pumps were 6 in. pipe connected into the 10 in. crossover lines in the pump houses which in turn led into the 10 in. lines on deck. The discharge piping was originally fitted only with plug cocks and during one discharge operation sulphur was diverted into another cargo tank causing a spill. Following that spill, at Bethlehem Steel Co. Shipyard, Beaumont, Texas in June 1961, the discharge lines were fitted with swing check

valves to prevent further spills of this nature. All cargo piping was steam jacketed by running the cargo piping through a larger pipe size; i.e. 10 in. pipe inside of 12 in. pipe, 8 in. pipe inside of 10 in. pipe, and 6 in. pipe inside of 8 in. pipe. All valves were steam jacketed as well. Stainless steel expansion joints were fitted in the loading and discharge piping within the cargo pump houses, these being steam coil wrapped. All cargo piping was schedule 40, ASTM A-53 steel pipe.

14. Upon the completion of the installation of the main sulphur tank and its insulation, there existed a void space fore and aft of frame 59 completely surrounding the tank. At the sides approximately 2 ft. of space existed, at the bottom approximately 3 ft. 6 in. of space existed, at the top approximately 3 ft. of space existed, and at the ends approximately 6 ft. of space existed. The bottom vertical foundation girders and the main deck girder all had lightening holes which permitted the free movement of air across the bottom and top of the tank. Power ventilation was installed utilizing two 11,000 cubic feet per minute fans in each of the two void spaces. These fans with explosion-proof and watertight electric motors, were mounted on the starboard side of the weather deck at frames 53, 59, 60 and 65, and discharged air through ventilation ducts near the bottom of the cargo tank; the air then swept under the tank and was discharged as previously described in paragraph 12, through the openings cut out of the weather deck in the controller houses. The original king post ventilators located, port and starboard, at frame 47 and extending down into the after pump room, now a part of the void, were left intact, except that all sheet metal ducting below the weather deck was removed. The dampers in these king posts were kept in the "closed" position at all times and just prior to the last voyage the cowls were removed and canvas covers were installed.

15. Relative to the fixed fire extinguishing system fitted on the MARINE SULPHUR QUEEN the original fire main was left intact as built, and the steam smothering system was modified as necessary to provide protection to the sulphur cargo tanks. At the time of conversion, the original steam smothering system to all cargo tanks was removed and a new installation was made to the four sulphur cargo tanks. Essentially, the new cargo tank system consisted of a run of 2 in. pipe from the main steam smothering line to a header at each tank at frames 67½, 64½, 56, and 50 respectively from which four 1½ in. branch lines penetrated the weather deck and then led into the top of the four cargo tanks. In addition, steam smothering was piped to the void space on either side of the cargo tanks at frames 64½ and 52½. During the first year of operation it was found that the sulphur was plugging up the nozzles where they entered the sulphur tank top, so at the shipyard availability in February 1962, the system was altered. This

alteration consisted of leading new piping to the cargo tanks at each of the expansion trunks. The piping was led from the deck line, through each of the four pump houses and thence into the top of the trunks. Additionally, a clean out fitting was installed in each piping lead. The old piping penetrating the weather deck into the cargo tanks was disconnected and blanked off at the weather deck. The new system was tested to the satisfaction of a U. S. Coast Guard inspector.

16. At the time of the conversion certain renewals and repairs of the vessel's structural parts were accomplished. Keel plates Nos. 5, 6, 7 and 14 were renewed, all deck longitudinals in way of the sulphur cargo tank were renewed, and all deck longitudinals and transverse web frames in the wing tanks were renewed as necessary. Flat bar stiffeners in way of No. 3 wing tank vertical brackets, port and starboard, were installed to strengthen these structural members. Additional repairs consisted of building up eroded welding in bottom plates, repair of a fracture in the stern frame skeg, and repair of scattered leaking welds in the rudder plates.

17. In October 1961, the MARINE SULPHUR QUEEN was at the Bethlehem Steel Company yard, Beaumont, Texas for repair of storm damage allegedly sustained during hurricane "Carla" on 7, 8 and 9 September 1961, while enroute from Beaumont, Texas to Carteret, New Jersey. This damage consisted essentially of fractures in web frames, bilge brackets, shell longitudinals and bulkheads in the way of No. 5 wing tanks, port and starboard; No. 7 wing tanks, port and starboard; No. 9 wing tanks, port and starboard; and No. 3 port, No. 2 starboard, and No. 4 port wing tanks. At this time an 18 in. fracture was found in shell plate "F" strake at web frame No. 61. All fractures were repaired as necessary. Testimony was received that this fractured shell plate was replaced in February 1962.

18. In February 1962 the vessel underwent U. S. Coast Guard reinspection and was also drydocked at that time at the Bethlehem Steel Co. yard at Beaumont, Texas. During this period the bulbous bow section was repaired and internals cropped out and replaced as necessary. All sea chests and sea valves were opened up for examination and the necessary repairs or renewals were made; including the renewal of two 4 in. sanitary valves in the shaft alley and the 24 in. main condenser discharge valve. The tailshaft was drawn, subjected to a magnetic particle examination and found satisfactory; the liner was lightly scored and a light polish cut was taken on the liner; stern tube bearing was renewed, and the stern tube gland was repacked. Upon completion of this yard availability the vessel was found to be seaworthy by both the U. S. Coast Guard and the American Bureau of Shipping.

19. On 16 January 1963 the vessel, while loading cargo at Beaumont, Texas, commenced U. S. Coast Guard biennial inspection for certification. The general alarm system, steering gear, engine telegraph, fire hose, navigation light panel were tested and found satisfactory; all portable fire extinguishers were serviced and found satisfactory; life preservers were examined and found satisfactory; 11 of 18 ring buoys were replaced; lifeboats were examined and repairs thereto completed to satisfaction of the inspector; all accessible spaces were examined and found satisfactory; port boiler opened up and fire side and water side and boiler mounting examined and found satisfactory; hydrostatic test held on port boiler and found all tight; all machinery examined and tested as necessary to prove satisfactory. The vessel was issued a new Certificate of Inspection to expire on 17 January 1965 and a Form CG-835 "Notice of Requirements" issued to the Master. On 1-2 February 1963 the vessel was again boarded in Beaumont and the starboard boiler and mountings were examined and found satisfactory; boiler was hydrostatically tested and found tight. The remaining outstanding requirements against the ship at this time, to be completed at next drydocking or within 90 days, whichever is sooner, were:

- "(a) Replace or repair relief valve on ship's service air compressor.
- (b) Make permanent repairs to various lube oil cooling and motor cooling lines, main condenser by-pass and other lines as outlined by C. G. Inspector."

At the same time as the above U. S. Coast Guard inspection, the American Bureau of Shipping made the regular annual survey on hull, machinery and boilers, and upon completion thereof the vessel was found to be seaworthy and fit to retain her present class with the American Bureau of Shipping. The load line certificate was endorsed by the American Bureau of Shipping Surveyor on 1 February 1963. The Officer in Charge, Federal Communications Commission, Beaumont, Texas, inspected the radio equipment installed on the vessel, together with the lifeboat portable radio on 3 January 1963 and found all satisfactory.

20. During the operation of the vessel between 18 January 1961 and its disappearance in February 1963, testimony from previous crew members disclosed that there had been numerous fires on board the MARINE SULPHUR QUEEN. A review of the ship's deck and engine room smooth logs disclosed mention of four specific fires and the use of the steam smothering system on 8 other days, which substantiates this testimony. These log entries were made on 24 August 1961, 7 October 1961, 8 October 1961, 15 February 1962, 16 October 1962, 20 October 1962, 3 November 1962, 22 December 1962, 26 December 1962, 27 December 1962, 28 December 1962 and 29 December 1962. All of these reported fires occurred in the void space with the exception of the fire logged on 24 August 1961.

This latter entry concerned a possible fire within No. 3 cargo tank while the vessel was discharging at Carteret, New Jersey. However a later examination of the tank disclosed no evidence that there had been a fire therein. The fires in the void spaces were described as having occurred in the tank insulation, of "pie" shape and size. These fires were usually not completely extinguished by the use of the steam smothering system. In almost all cases either the Master or a crew member, using a fresh air mask, descended into the void space and finally extinguished these fires by dousing them with fresh water. The source of ignition of these fires was not determined. These previous crew members testified that there was little or no apprehension on their part of any danger as a result of these fires. In addition they testified that the general alarm was not sounded at any time.

21. The vessel suffered one incident of grounding. This occurred at Tampa, Florida on 13 October 1961 when she grounded twice; the first time she was aground from 0523 to 0804, the second time she was aground from 0915 to 1440. The American Bureau of Shipping issued a "Certificate of Seaworthiness" on 13 October 1961 following this incident. On 29 January 1962 the vessel was in drydock at Beaumont, Texas and the damage alleged to have occurred in this grounding consisted of:

- (a) 3 of the 4 blades of the propeller nicked in various amounts
- (b) Fairwater missing
- (c) Rudder side plating fractured in several locations
- (d) Tailshaft subject to shock

All of the above were satisfactorily repaired at that drydocking, except that in the case of the tailshaft no damage was found.

22. There were three minor collisions reported in the ship's logs, none of which resulted in any significant damage.

23. Two instances of storm damage and two significant instances of operation in heavy weather were found in the vessel's logs:

- (a) On 28 January 1961 heavy weather was encountered which damaged the insulation on the cargo piping located on the main deck when seas swept over the bow. The insulation was originally protected by a covering of canvas. As a result of this damage, at the Bethlehem Steel Co. shipyard, Beaumont, Texas in June 1961, all the cargo piping on the main deck was covered with thin aluminum sheets and a breakwater was installed just forward of the cargo manifold for further protection.

- (b) The vessel was at sea during hurricane "Carla" on 7, 8 and 9 September 1961 and the damage sustained at that time has been discussed in paragraph 17 above.

This particular voyage commenced at Beaumont, Texas on 5 September 1961. Log entries for the three days of "Carla" showed winds of up to force 9, Beaufort Scale, and the seas were described as "very rough." At 1245, 7 September 1961, the log shows that the vessel was turned about to the reciprocal course, but no entry was found as to when the vessel again resumed its original course.

- (c) The vessel suffered no other storm damage, but one entry of particular interest was found in the log of 4 March 1962, which states, "From 1747, 3-2-62 to 0630, 3-4-62, vessel on various reduced speeds to ease vessel in high seas and very deep swells noted to put racking stress on the vessel. A thorough search of compartments to be made to ascertain if vessel suffered damage as a result of this heavy weather." The log indicates that during this period the vessel encountered force 7 winds with very rough seas primarily from nearly dead ahead. The log fails to reveal that the vessel sustained any damage as a result of the heavy weather.

- (d) The vessel also encountered hurricane "Ella", 18, 19 and 20 October 1962 along the Atlantic coast line with winds and seas primarily from dead ahead, maximum force 7, seas very rough. No damage was reported as having been found.

24. There was one incident of machinery failure which occurred on 9 February 1962 when on the first day out from Beaumont, Texas, the outboard auxiliary generator failed. The vessel returned to Beaumont and a reconditioned unit was installed on 14 February 1962. The inboard auxiliary generator was tested that same day and megger readings were found to be low. As a result, this generator was replaced by a reconditioned unit on 27 February 1962 at Beaumont, Texas.

25. The cargo tank insulation was contaminated with sulphur on the following occasions:

- (a) A major sulphur spill occurred on 8 April 1961 when, during discharge of cargo at Carteret, New Jersey, the cargo pumps in No. 1 tank tripped out and the cargo pumps from No. 2 tank pushed sulphur into the No. 1 tank, causing it to overflow. To rid the No. 1 pump house of the spilled sulphur, the crew punched holes in the canvas boots around the expansion trunks

and the sulphur flowed down and onto the tank insulation. Approximately 4500 sq. ft. of insulation found to be impregnated by the overflow was replaced at the shipyard on or about 6 June 1961. At the same time, solidified sulphur, 10 in. deep covering 100 sq. ft. on the ship's bottom in the vicinity of No. 1 tank; and 8 in. deep covering 400 sq. ft. between frames 63 and 66 in the way of No. 2 tank was removed.

(b) On 28 December 1961, while discharging sulphur the cargo pipe expansion joint in No. 3 pump house leaked and the crew rid the pump house of sulphur by punching holes in the canvas boots around the expansion trunks with resultant sulphur penetration of the tank insulation. This insulation was replaced at the shipyard in February 1962.

26. In the latter part of 1961 a crack was found in the after end of No. 4 cargo tank, starboard side in the way of the weld of the sump to the tank bottom. This crack also permitted sulphur to impregnate the tank insulation. This leak was of such size that sulphur accumulated in the ship's bottom in that area to a depth of several inches. The ship's crew was engaged in its removal on several voyages prior to its repair at Beaumont during the shipyard availability in February 1962. During this availability, the crack described as about 12 in. in length and of an undetermined width was veed out, welded on both sides and a 1/2 in. x 4 in. x 14 in. doubler was welded on the inside of the tank. The insulation replaced at this time totaled approximately 4,000 sq. ft. Another crack later developed in the same general area as that described above, and this was to be repaired at the vessel's next availability period, on or about March 1963. The sulphur from this leak accumulated in the ship's bottom and was variously estimated to be in the amount of 20 to 70 tons. This crack was peened over by the Chief Engineer in Beaumont while loading cargo for the voyage commencing on 2 February 1963 and found tight. Testimony was received from several of the previous crew members of the MARINE SULPHUR QUEEN that on numerous occasions, while on loaded voyages in a heavy seaway, sulphur would spew out of the forward 6-inch cargo tank vents. The molten sulphur, on striking the weather deck, would freeze and accumulate to a depth of a foot or more under the vents. Also, in some instances, the sulphur would build up inside the vents, even though fitted with steam heated coils. Following such a spill it was necessary to chip the sulphur off the deck and to strike the vents with a hammer to free them of the sulphur.

27. An inclining test of the MARINE SULPHUR QUEEN was performed on 14 January 1961 under U. S. Coast Guard supervision. On 19 January 1961 the vessel was issued a temporary stability letter by the Officer in Charge, Marine Inspection, Baltimore, Maryland that stated in part that: "The 'Preliminary Trim, Stability and Load Stress Booklet' for T-2 Sulphur Tanker SS MARINE SULPHUR QUEEN prepared by Bethlehem Steel

Shipbuilding Division, Baltimore, Maryland, dated January 1961 and bearing U. S. Coast Guard approval stamp dated 19 January 1961 is applicable on a temporary basis to subject vessel. The hull stress information contained in the booklet has been furnished voluntarily by the company and while not requiring Coast Guard approval should be strictly adhered to by the Master. Operation of the vessel under loading conditions which result in a hogging (or sagging) numeral in excess of the 100 level is not authorized." A naval architect, an employee of the operators of the vessel, was requested by the Board to make loading stress calculations for all voyages. Due to the lack of specific cargo loading figures for the first four voyages, calculations for these voyages could not be made. However, of the remaining 60 voyages, it was calculated that while in a loaded condition the sagging numeral exceeded 100 in 52 instances varying from 100.55 to 104.66. The hogging numeral on all fully loaded voyages varied from 47.63 to 55.01 with increased numerals of up to 91.27 when in a partially loaded condition. While in ballast the numerals did not exceed 100 at any time. The calculated stress numerals at the time of the vessel's departure from Beaumont, Texas on 2 February 1963 were 54.37 in hog and 101.01 in sag. On the other hand, the company naval architect and the Coast Guard naval architect both testified that in their opinion this repeated small over-stress in sag was not significant. However, they both agreed that it would have been preferable to operate the vessel at or below the 100 stress numeral at all times.

28. During the period from September through December 1961, the Master was ordered by the operating company to experiment with ballasting arrangements in order to reduce the departure draft from the discharge port. Prior to this period, wing tanks 2 through 8, port and starboard, were pressed up. In this three month period, the ballast arrangement was 2, 4, 5, 6 and 8 wing tanks, port and starboard, pressed up and the remainder empty. The hog and sag stress numeral was computed for these voyages, 7 in number; the hog stress numeral varied between 71.91 and 74.48, and the sag stress numeral varied between 72.88 and 75.00. On one voyage only, wing tanks 2, 4, 6 and 8, port and starboard, were pressed up and on that voyage the hog stress numeral was 88.74 and the sag stress numeral was 57.85. At the conclusion of this three month experimental period the vessel was ballasted as before filling all wing tanks. In any event, it was found necessary to fill all wing tanks prior to arrival at Beaumont, Texas so that the vessel's draft would permit making up the cargo loading joints.

29. Considerable testimony was received from the operating company personnel pertaining to instructions to the Master, requirements and reports of shipboard safety meetings, and the duties and responsibilities of company personnel with respect to the vessel. This testimony brought out that the MARINE SULPHUR QUEEN was treated as a normal T-2 type

tankship even though the cargo, molten sulphur, in such an unusual vessel arrangement and quantity was a "first" for Marine Transport Lines. No one in the company office was assigned specifically to become knowledgeable with respect to the properties and carriage of molten sulphur. This aspect was left to the judgment of the senior officers aboard the vessel, namely the Master, Chief Mate and Chief Engineer, all of whom spent several days at the Beaumont plant of Texas Gulf Sulphur Co. The Master was not provided any specific instructions with respect to molten sulphur and in fact, he received only the same letter of designation as Master and the same general instructions issued by the company to masters of all its tank vessels. With relation to the "Trim, Stability and Loading Booklet" prepared by the Bethlehem Steel Co. shipyard, Baltimore, dated January 1961, the Master received no guidance as to its use and no requirement was placed upon him to report to the company the loading numerals for each voyage. Further no one in the company ever made any independent calculations of such numerals. However, it was determined that there was a requirement for such reports by masters of tankers which the company operated under an operating contract with the Military Sea Transportation Service. The company officials were also questioned extensively on the subject of the fires that had been testified to by previous crew members. A few of these fires were known to these officials but apparently they never required a full report with respect thereto from the master, nor did they otherwise make any attempt to determine the possible cause of these fires. However, the vessel was visited at irregular intervals by port engineers and port captains employed by the company who on these occasions did conduct inspections of various parts of the vessel. Further, the company had an active safety program with membership comprised of personnel from the Operations Department, Marine Department, Personnel Department and the Personal Injuries Section. Shipboard safety meeting minutes were received in the Operations Department and copies made for each committee member. Files of the MARINE SULPHUR QUEEN contained only the minutes of three such shipboard meetings. These minutes, except for the mention of one fire, were found to have no bearing on this casualty.

30. The Board received testimony from three chemists on the properties of molten sulphur. While there were minor conflicts in their testimony, it was determined that molten sulphur is a relatively safe product to store and handle. Further, molten sulphur has been transported for more than two decades in railway tank cars, pipe lines, tank trucks, and barges. Transportation by ship is a relatively new operation, having had its inception approximately five years ago when a Liberty type vessel had independent tanks installed in two of its cargo holds. Pipe lines and storage tanks constructed of mild steel, used for many years to contain molten sulphur, have been found on inspection to evidence no appreciable amounts of corrosion.

31. Numerous studies have been made on the property of molten sulphur, and the results thereof have been published in various trade periodicals and manuals. There is general agreement that molten sulphur has a freezing point of approximately 238° F, and since its viscosity increases abruptly above a temperature of about 318° F it is normally handled at temperatures between 250° and 310° F. The density of molten sulphur at 250° F is approximately 112.6 pounds per cubic foot which decreases slightly with an increase in temperature and/or the presence of hydrocarbon impurities.

32. These studies show that all naturally occurring sulphur contains small quantities of hydrocarbon impurities. These react with the sulphur to produce hydrogen sulphide and carbon disulphide. In a quiescent state, such as in a storage tank, these two gases are liberated at a very slow rate and moderate venting ordinarily prevents the buildup of an explosive mixture even though both gases are heavier than air. Agitation or aeration of molten sulphur, however, can result in a rapid liberation of the two gases; under such conditions a poisonous and explosive atmosphere can be formed.

33. The Bureau of Mines pamphlet 6185 entitled "Gas Explosion Hazards Associated with the Bulk Storage of Molten Sulphur" describes tests to determine (1) the nature and rate of release of such vapors by commercial molten sulphur, and (2) the flammability characteristics of these vapors. Experiments were conducted with both bright and dark sulphurs in a laboratory closed system and in two commercial storage tanks. Neither grade of sulphur was identified as to its carbon content. In the laboratory closed system a one pound sample of dark sulphur produced the following results:

<u>Time in Hours</u>	<u>Cumulative Volume in Milliliters</u>	
	<u>Hydrogen Sulphide</u>	<u>Carbon Disulphide</u>
20	0.009	0.052
105	4.10	0.186
175	9.05	0.332
239	12.51	0.425

Bright sulphur produced the following results:

<u>Times in Hours</u>	<u>Cumulative Volume in Milliliters</u>	
	<u>Hydrogen Sulphide</u>	<u>Carbon Disulphide</u>
23	0.002	None
48	0.002	None
118	0.004	None
280	0.005	None

From an analysis of the vapor space in the two commercial storage tanks in which the sulphur had been stored for 14 days, the dark sulphur showed 0.29 volume-percent of hydrogen sulphide and 0.02 volume-percent of carbon disulphide. For bright sulphur these readings were 0.12 for hydrogen sulphide and a trace of carbon disulphide. The low concentrations of the gases found in these storage tanks, as compared with the concentrations obtained in the laboratory closed system, are attributed to the use of vented tanks even though both gases are heavier than air. In unvented tanks with small vapor spaces, the concentration of these gases would be higher. Further, although the gases were fairly well mixed in these storage tanks it is considered possible that layering could occur under certain conditions. In this eventuality flammable mixtures would then be formed more quickly than if these gases were thoroughly mixed. With a 2.8 volume-percent of carbon disulphide the spontaneous ignition (auto-ignition) temperatures were determined for carbon disulphide in hydrogen sulfide air atmospheres. It was found that with 0% hydrogen sulphide the carbon disulphide ignites at 212° F and this auto-ignition temperature gradually increases to 356° F with 2.5 volume-percent of hydrogen sulphide. Thus, an increase in the hydrogen sulphide content increases the auto-ignition temperature of the mixture. At the same time an increase in ambient temperature requires an increase in the hydrogen sulphide concentration to suppress ignition. Auto-ignition will occur only if the combustible concentration exceeds the lower limit of flammability (about 1 percent). The minimum concentration of carbon disulphide in air necessary to auto-ignite at 275° F was found to be 1.4 volume-percent; with this concentration of carbon disulphide, 0.05 volume-percent of hydrogen sulphide was sufficient to suppress ignition. The laboratory results with the dark sulphur indicate that initially, carbon disulphide was evolved at a higher rate than was hydrogen sulphide. After approximately one day in the molten state, however, the evolution rate of carbon disulphide decreased and that of hydrogen sulphide continued for several days. The end result was that at first the vapors were rich in carbon disulphide, but later they were rich in hydrogen sulphide. This situation would create two different types of explosion hazards. The first explosion hazard could exist if sufficient carbon disulphide vapors are present in a storage tank; the vapors could then ignite spontaneously, for the auto-ignition temperature of this combustible is only 212° F and the steam coils in tanks are maintained in the range of 275° - 300° F. However, the spontaneous ignition of carbon disulphide would probably only occur shortly after filling a tank with fresh molten sulphur, for the spontaneous ignition of the carbon disulphide would be suppressed by the hydrogen sulphide which is also formed at these elevated temperatures. The second explosion hazard could exist during long-term storage in a closed system. Specifically, this hazard could be created as the hydrogen sulphide builds up to its lower concentration limit of flammability; as the vapor space is decreased, the time required to reach the lower limit concentration is also decreased. In the case of

hydrogen sulphide in a tank with an air-to-sulphur height ratio of 0.1, the lower limit would be reached after the second day of storage; if the height ratio is increased to 0.7, six days would be required to reach the lower limit. In conclusion, this Bureau of Mines report states that sulphur in itself does not create an explosion hazard under the conditions found in the commercial handling of molten sulphur. However, a flame initiated by the ignition of carbon disulphide or a flame propagating through a flammable hydrogen sulphide and air mixture could in turn ignite the molten sulphur. With respect to these gases evolved from molten sulphur, the experts agreed that there is no completely accurate device perfected to date that will measure the explosivity of atmospheres over liquid sulphur.

34. The Board received in evidence, a paper entitled "Safe Handling of Molten Sulphur" presented by [REDACTED], Monsanto Chemical Co, to the St. Louis Section of the American Institute of Chemical Engineers. In this paper, Mr. [REDACTED] discussed three case histories of fires and moderate energy explosions involving molten sulphur.

(a) In the first case a barge was being loaded with molten sulphur. The filling nozzle for the barge tank did not extend into the tank. An explosion occurred in one of its tanks. At the time of the explosion the vapor space in the tank was approximately 4 feet. The hatch cover was not fastened and blew off, the deck over the tank was bulged upward about one foot and the tank wall was split. Approximately 65 tons of sulphur were blown through this split into the barge interior. There were no personal casualties and material damage was estimated at \$50,000.00. The cause of the explosion was not definitely determined. It was surmised that the free falling sulphur released hydrogen sulphide rapidly enough to build up an explosive mixture with air in the ullage space. The source of ignition of this explosive atmosphere was surmised to be an electrostatic spark generated by the falling stream of sulphur; possible use of superheated steam in the heating coils within the tank; or by pyrophoric iron sulphide present on the tank walls.

(b) In the second case, molten sulphur was being transferred from a barge to a tank truck. Shortly after transfer began there was a minor flash and burning sulphur was ejected from the open dome of the tank truck. Some of this burning sulphur hit the terminal attendant and the truck driver who were standing on a platform about ten feet from the truck. There was no material damage to the truck. The surface of the sulphur in the tank truck was burning and was immediately put out using a steam hose. As in the first case, free falling sulphur was believed to have liberated hydrogen sulphide and the flow of sulphur built up an electrostatic charge to trigger the explosion.

(c) In this third case, a 2000 ton storage tank was being filled from a tank truck when an explosion occurred within the tank. The conical cover of the tank, 40 feet in diameter, was blown 57 feet above the top of the tank and did considerable damage in falling. There were no personal injuries. On the day of the explosion the tank contained about 1600 tons of molten sulphur. The four inch top vent had been checked that day and was clear. No cause for this explosion was given.

35. The Board also received information concerning an explosion on a foreign flag T-2 type tank vessel which had been converted to a molten sulphur carrier similar to the MARINE SULPHUR QUEEN. However, due to channel depths, this vessel could only load a partial cargo resulting in a vapor space within the tanks of about two feet in Nos. 1, 3 and 4 tanks and 12 feet in No. 2 tank. The Master's statement with respect to this explosion was: "June 27, 1962 - at 0432 an explosive-like report was heard and a violent shock was felt throughout the vessel, lasting about five seconds. At that time also heavy sulphur fumes were seen coming from No. 3 cargo tank forward vent, which same comes up through No. 2 pump room. This pump room, when opened, was filled with sulphur fumes. In about 15 minutes the emission of fumes from No. 3 tank vent became normal. Some sulphur fumes were observed coming from No. 2 cofferdam (void) forward manhole, but were quickly dissipated on opening the after manhole cover, so creating a draft. No. 2 cofferdam (void) was then inspected, and it was found that No. 3 cargo tank sides from frames 57 to 58½ upper part were bulging outwards to extent of about 10 in. on both sides. Opening and inspecting from other manholes, it was noted that the top of No. 3 tank over the bulging parts appeared to be slightly indented. All pumps were run and found working. Heating coils showed no leakage. Vent lines were all clear, cargo temperatures normal, and cofferdams (voids), fore and aft, completely dry." No personal casualties resulted from this explosion and material damage was approximately \$160,000. The material damage suffered was confined almost solely to the sides, top, and bottom of No. 3 cargo tank. The sides, top and bottom of the tank were bulged out; the side, top and bottom tank stiffeners were buckled; and, the swash bulkheads and stiffeners were buckled. Of particular interest to this Board was the description of the venting on the cargo tanks of this foreign vessel, which was modified following this explosion. Each tank is fitted at its forward and after end on the centerline, with an 8 in. pipe steam-jacketed vent, terminating in an inverted "U" shape approximately 24 inches above the level of the top of the pump houses. The vent at the after end of No. 2 tank and the vent at the forward end of No. 3 tank are both made up to a 10 in. pipe vent which is unlagged but which is heated internally with a steam line; this vent extends approximately 30 ft. above the deck. Its purpose is to create a "chimney effect," inviting a flow of air over the surface of the molten sulphur in No. 2 and 3 cargo tanks. It has been reported that the vent has achieved the desired effect, and observed to be very definitely conducting great

quantities of fumes from the two tanks so fitted. There have been no further reported explosions on this vessel.

36. The MARINE SULPHUR QUEEN commenced loading a full cargo of molten sulphur at 1915, 1 February 1963 and completed loading at 0600, 2 February 1963. The cargo loaded was as follows:

<u>Tank No.</u>	<u>Temp. °F</u>	<u>Tons</u>	<u>Ullage</u>	<u>Type</u>	<u>Carbon Content</u>
1	273	4135	2.31 ft.	Dark	0.14
2	274	3640	2.09 ft.	Dark	0.14
3	274	3637	2.16 ft.	Bright	0.04
4	276	3848	2.15 ft.	Bright	0.04
		<u>15,260</u>			

As the vessel was completing the U. S. Coast Guard inspection of the starboard boiler and the port engineer was attending to several minor crew complaints, the vessel did not depart Beaumont, Texas until 1330, 2 February 1963. In addition to the full cargo, the vessel had on board 3830 barrels of fuel, 100 tons of water and the draft in fresh water was 29 ft. 11 in. forward and 32 ft. 9 in. aft. The vessel proceeded to sea under the direction of a licensed pilot. During the approximate 4½ hours he was aboard, the pilot stated that there was no difficulty with the steering gear, gyro compass or engines. The pilot departed the vessel at the Sabine Bar Sea Buoy sometime between 1800 and 1830 CST, 2 February 1963. The departure message from the MARINE SULPHUR QUEEN to the operating company, Marine Transport Lines, advised that the vessel departed the sea buoy at 1900 CST, route Sabine, Texas direct via 24.4°N 83.0°W to 24.8°N 80.2°W to 31.2°N 79.2°W to 35.1°N 75.3°W to Cape Henry, Virginia with an estimated time of arrival at Norfolk at 1200 noon, EST, 7 February. The master of the vessel had been instructed to give both a 48 hour and 24 hour advance notice of arrival to the Norfolk agent.

37. The vessel at the time of her departure on the instant voyage was properly manned by personnel holding the requisite U. S. Coast Guard licenses and documents. In addition, the Master, licensed officers, and key unlicensed crew members, with minor exceptions, had all experienced previous service aboard the vessel and appeared to be reasonably qualified to competently discharge their duties. There is no evidence to indicate that any crew member was lacking in loyalty to the vessel.

38. At 0125 EST, 4 February 1963 a personal message from a crew member was transmitted by the vessel and received by RCA Radio. At this time the estimated position of the ship was 25°45'N, 86°W, based on an estimated speed of advance of 14.5 knots. Commencing at 1123, 4 February, RCA Radio commenced the first of two unsuccessful attempts to contact the vessel

by radio. At this time the MARINE SULPHUR QUEEN if she had continued on her voyage would have been at an estimated position of 24°40'N, 83°19'W. The weather the vessel probably encountered is indicated by two exhibits received in evidence. At noon on 3 February, the SS TEXACO CALIFORNIA was at position 26°57.5'N, 88°20'W in the Gulf of Mexico on a voyage to Port Arthur, Texas where it arrived on the following day. At this same time the estimated position of the MARINE SULPHUR QUEEN was 27°12'N, 89°W, approximately 40 miles distant. The log of the TEXACO CALIFORNIA indicates that on 3 February the vessel experienced generally northerly winds from force 6 to 11, Beaufort Scale, very rough northerly seas and her decks were awash. The hindcast prepared by the U. S. Navy Oceanographic Office on the weather conditions prevailing along the projected track of the MARINE SULPHUR QUEEN during the period, 2000 EST, 3 February to 1300 EST, 4 February for the area between 88°W to 82°W indicates that the vessel may have encountered seas with a maximum wave height of 16.5 feet slightly abaft the port beam. Additionally, the winds would have been generally northerly in direction with a maximum force of 25 knots and gusting to 46 knots, also slightly abaft the vessel's port beam. The vessel's period of roll has been calculated to be of 8.5 seconds. The period of the waves was included in the hindcast and was within 10% of the vessel's period of roll.

39. The first information that the MARINE SULPHUR QUEEN was overdue was received by the Commander, Fifth Coast Guard District at 2100 EST, 7 February 1963. This information was immediately sent to the Rescue Coordination Center, U. S. Coast Guard Commander Eastern Area in New York via "hot line." At 2145 EST the Eastern Area Rescue Coordination Center was called by a representative of the Marine Transport Lines, New York Office, reporting that the vessel was overdue, together with a description of the vessel. At 2218 EST, 7 February, the Commander Eastern Area initiated a communication check by an "All Ships Urgent Broadcast" which was repeated three times daily until 16 February 1963. At 2220 EST, 7 February, RCA Radio was contacted as to information on delivery of message to and from the vessel during the period 2 - 7 February, with the results previously stated.

40. Based on the above, a surface and air search was planned to commence at 0800 EST, 8 February providing that the communication check failed to locate the vessel. At 0138 EST, Coast Guard units in the 5th, 7th, and 8th Coast Guard Districts were alerted as to the search plan, and at 0800 EST when the communication check was negative, the search was commenced. The search comprised the following:

- 8 February - Day search - trackline from Beaumont through Florida Straits to Norfolk, a distance of 1630 miles. Seven aircraft were used in 72 flight hours, searching about 58,000 square miles. This trackline search covered 30 miles on either side of the vessel's estimated track.

- 8-9 February - Night search - three aircraft flew 23 flight hours and searched 22,000 square miles.
- 9 February - Day search - since vessel was not found along proposed track, a considerably expanded search plan was used. Nineteen aircraft flew 114 flight hours and searched 95,000 square miles.
- 9-10 February - Night search - two aircraft flew 12 flight hours and searched 8,300 square miles.
- 10 February - Day search - nineteen aircraft flew 136 flight hours and searched 76,700 square miles.
- 11 February - Day search - fourteen aircraft flew 86 flight hours and searched 55,000 square miles.
- 12 February - Day search - ten aircraft flew 42 flight hours and searched 22,000 square miles.
- 13 February - Day search - two aircraft flew 16 flight hours and searched 11,000 square miles.

This concluded the initial search for the MARINE SULPHUR QUEEN. During the period 8-13 February 1963, Coast Guard, Navy, Marine Corps and Air Force aircraft participated in 83 sorties, flying 499.6 hours and searched a total of 348,400 square miles with negative results. Further efforts to locate the MARINE SULPHUR QUEEN during this initial search utilized the Coast Guard Atlantic Merchant Vessel Reporting system which located 42 vessels that could possibly have sighted the MARINE SULPHUR QUEEN on 4 and 5 February. All of these vessels were checked out by Coast Guard personnel with negative results. Several telephone calls were received by Coast Guard units during this initial search phase with information that the ship would be found in Cuba or in Puerto Rico. These leads were checked out by other Federal agencies with negative results.

41. On 20 February, a U. S. Navy torpedo retriever boat operating about 12 miles southwest of Key West, Florida sighted and picked up a fog horn and life jacket stencilled with the vessel's name. The second phase of the search for the MARINE SULPHUR QUEEN was then instituted, confined primarily to the area just west of Dry Tortugas Island, thence through the Straits of Florida, along the axis of the Gulf Stream, including the Bahamas Islands, and the east coast of Florida to Cape Canaveral. This search with seven ships and 48 aircraft sorties flying 271.4 hours covered an additional 59,868 square miles. The probability of sighting during both search phases was computed to be 95% for a vessel, 70% for a metal lifeboat and 65% for a liferaft. The U. S. Navy conducted an underwater search for the vessel's hulk during the period of 20 February through

13 March in an area from the shoals to the 100 fathom curve between Key West and 24°35'N, 83°30'W, using six Navy vessels for 523 hours on the scene and 17 aircraft sorties flying 57 hours with possibility of detection of 80% for the hulk. During this period, additional debris was recovered and identified as coming from the MARINE SULPHUR QUEEN. At 1740 EST, 14 March 1963, having received negative reports from all participating units, the search for the vessel was discontinued.

42. The material recovered and identified as from the MARINE SULPHUR QUEEN consisted of 8 life jackets, 5 life rings, 2 name boards, 1 shirt, 1 piece of an oar, 1 storm oil can, 1 gasoline can, 1 cone buoy, and 1 fog horn. This material was deposited with the Coast Guard at Miami, Florida and later shipped to Washington, D. C. where it was examined by experts from the Bureau of Standards, the Coast Guard, and the Bureau of Fisheries. The consensus of opinion was that possibly two life jackets had been worn by persons and that the shirt tied to a life jacket had also been worn by a person. Numerous tears on the life jackets indicated attack by predatory fish. Further examination was made of certain of the debris by the Federal Bureau of Investigation who determined that the shirt bore no laundry marks, visible or invisible, and that no trace of sulphur particles was evident on any of the material. Visual examination of the material disclosed no trace of either explosion or fire.

43. On 29 April 1963, the Coast Guard Air Detachment, Corpus Christi was given a note that was reported to have been in a whiskey bottle found on or before that date by a Spanish speaking man in Laguna Madre, near Corpus Christi at approximate position 27°39.5'N, 97°15.4'W. The bottle was broken to get the note out. A search for pieces of the bottle at that time were negative. However, the Board received the bottom of the purported bottle with no sealife attached thereto on 13 June 1963. This note written with ball point pen on a piece of manila paper, similar to a paper bag, was unsigned and referred to an explosion and two men hurt. The piece of paper also had a crude map of the Gulf of Mexico, Florida Straits and Cuba with a circle surrounding an "X", and the word "SHIP." This "X" was near the western approach to the Florida Straits. The note was turned over to a Federal examiner of questioned documents who stated in his opinion, based upon crew signatures and a letter from one crew member to his sister, that it was written by a particular crew member. The matter of this note in the bottle was also referred to the Coast and Geodetic Survey, Washington, D. C., and the Director of that agency stated that the bottle could not possibly have reached the Corpus Christi area if the bottle was dropped into the water at any place east of 85°W, unless a strong southeasterly wind had been blowing for several days before and after the dropping.

44. The following is a complete crew list of the vessel:

<u>Name</u>	<u>Position</u>	<u>Z Number</u>	<u>Next of Kin</u>	<u>Address</u>
1. [REDACTED]	Master	[REDACTED]	Wf- [REDACTED]	[REDACTED]
2. [REDACTED]	Ch. Mate	[REDACTED]	Wf- [REDACTED]	[REDACTED]
3. [REDACTED]	2nd Mate	[REDACTED]	Wf- [REDACTED]	[REDACTED]
4. [REDACTED]	3rd Mate	[REDACTED]	Wf- [REDACTED]	[REDACTED]
5. [REDACTED]	Radio Off.	[REDACTED]	Wf- [REDACTED]	[REDACTED]
6. [REDACTED]	Ch. Engr.	[REDACTED]	Wf- [REDACTED]	[REDACTED]
7. [REDACTED]	1st Asst Eng	[REDACTED]	Wf- [REDACTED]	[REDACTED]
8. [REDACTED]	2nd Asst Eng	[REDACTED]	Wf- [REDACTED]	[REDACTED]
9. [REDACTED]	3rd Asst Eng	[REDACTED]	Wf- [REDACTED]	[REDACTED]
10. [REDACTED]	Jr. 3rd Asst Eng	[REDACTED]	Wf- [REDACTED]	[REDACTED]
11. [REDACTED]	Bosun	[REDACTED]	Wf- [REDACTED]	[REDACTED]
12. [REDACTED]	DM/AB	[REDACTED]	Wf- [REDACTED]	[REDACTED]
13. [REDACTED]	AB	[REDACTED]	Sis-Mrs. [REDACTED]	[REDACTED]
14. [REDACTED]	AB	[REDACTED]	Wf- [REDACTED]	[REDACTED]

<u>Name</u>	<u>Position</u>	<u>Z Number</u>	<u>Next of Kin</u>	<u>Address</u>
15.	AB		Sis- [REDACTED]	[REDACTED]
16.	AB		Sis- [REDACTED]	[REDACTED]
17.	AB		Dau- [REDACTED]	[REDACTED]
18.	AB		Mo- [REDACTED]	[REDACTED]
19.	OS		Sis- [REDACTED]	[REDACTED]
20.	OS		Mo- [REDACTED]	[REDACTED]
21.	OS		Wf- [REDACTED]	[REDACTED]
22.	Pumpman		Wf- [REDACTED]	[REDACTED]
23.	Oiler		Wf- [REDACTED]	[REDACTED]
24.	Oiler		Wf- [REDACTED]	[REDACTED]
25.	Oiler		Wf- [REDACTED]	[REDACTED]
26.	FWT		Bro- [REDACTED]	[REDACTED]
27.	FWT		Wf- [REDACTED]	[REDACTED]
28.	FWT		Wf- [REDACTED]	[REDACTED]
29.	Wiper		Mo- [REDACTED]	[REDACTED]
30.	Wiper		Wf- [REDACTED]	[REDACTED]

<u>Name</u>	<u>Position</u>	<u>Z Number</u>	<u>Next of Kin</u>	<u>Address</u>
31. [REDACTED]	Wiper	[REDACTED]	Wf- [REDACTED]	[REDACTED]
32. [REDACTED]	Ch. Stew.	[REDACTED]	Wf- [REDACTED]	[REDACTED]
33. [REDACTED]	Ch. Cook	[REDACTED]	Dau- [REDACTED]	[REDACTED]
34. [REDACTED]	2nd Cook & Baker	[REDACTED]	Wf- [REDACTED]	[REDACTED]
35. [REDACTED]	Galleyman	[REDACTED]	Wf- [REDACTED]	[REDACTED]
36. [REDACTED]	Messman	[REDACTED]	Sis- [REDACTED]	[REDACTED]
37. [REDACTED]	Messman	[REDACTED]	Mo- [REDACTED]	[REDACTED]
38. [REDACTED]	Utilityman	[REDACTED]	Sis- [REDACTED] [REDACTED]	[REDACTED]
39. [REDACTED]	Utilityman	[REDACTED]	Wf- [REDACTED]	[REDACTED]

Conclusion

1. The MARINE SULPHUR QUEEN disappeared on a voyage which commenced on 2 February from Beaumont, Texas and which was due to terminate on 7 February 1963 at Norfolk, Virginia. Since nothing was ever heard from the vessel after her departure, with the exception of the transmission of a personal message of a crew member, and further, in the light of the finding of scattered items of debris identified as coming from the vessel it is concluded that the MARINE SULPHUR QUEEN and her entire crew of 39 seamen must be presumed lost.
2. The evidence indicated that the vessel apparently encountered high winds and rough seas on 3 February while in the Gulf of Mexico and on 4 February while approaching the Straits of Florida. Further, the evidence shows that the vessel transmitted the personal radio message at 0125, EST on 4 February 1963 on behalf of a crew member and could not be contacted by the shore radio station commencing at 1123, EST, 4 February 1963. These facts in addition to the location of the scattered items of debris from the vessel would indicate that the vessel foundered some time on 4 February 1963 on the approach to or in the vicinity of the Straits of Florida.
3. In view of the absence of any survivors and the physical remains of the vessel, the exact cause for the disappearance of the MARINE SULPHUR QUEEN could not be ascertained.
4. In the absence of any evidence indicating a failure of the vessel's radio equipment, the failure to transmit a distress message would appear to justify the conclusion that the loss of the vessel occurred so rapidly as to preclude the transmission of such a message. On the other hand, the evidence does indicate that a few life jackets subsequently recovered appeared to have been worn by crew members. Under the circumstances, it is considered possible that these life jackets were worn by watch standers who had them readily available.
5. The Board has considered many causes for the disappearance of the vessel. However, these causes remain only possibilities and the available evidence precludes the assignment of any order of probability to these causes. In the conclusions which follow no attempt is made to exhaust all possible causes for the vessel's disappearance. It is not the intent of the Board to negate the possibility that this casualty was occasioned by other causes which in the light of experience have been found to have resulted in the foundering of vessels.
6. Much evidence was received as to the general properties of molten sulphur and the gases formed in and liberated from this product with a view to assessing the possibility that the cargo contributed to the casualty. At the outset, it must be recognized that both grades of sulphur carried

on this voyage were fairly pure with relatively small quantities of carbon impurities; the bright product containing .04% carbon and the dark .14% carbon. This fact would result in the formation of a smaller volume of gases than a product containing greater carbon impurities. Moreover, it appears that on this voyage the four cargo tanks were full into the trunks and that essentially the only air spaces in these tanks would be in the trunks themselves. Accordingly, it would appear that the total area of the spaces available for the collection of the gases was relatively small.

7. The evidence indicates that at least two explosive gases, namely hydrogen sulphide and carbon disulphide, are formed due to the reaction of the molten sulphur with organic matter normally contained in commercial sulphur. Although fairly soluble in the sulphur some of these gases are normally liberated from the mass of the sulphur. It is generally agreed, however, that agitation of the mass of the sulphur acts to increase the amount of the gases liberated from solution. It is concluded that the sulphur was agitated as the vessel worked in the rough seas which she apparently encountered on this voyage even though the tanks were fitted with swash bulkheads and were full into the expansion trunks. It, therefore, follows that this agitation of the molten sulphur increased the volume of these gases liberated from the molten sulphur.

8. Although each tank had one forward 6" vent and two 4" vents over the expansion trunks, the fact that all tanks had a full load of cargo on this voyage, being loaded into the trunks, prevented a free flow of air across the surface of the molten sulphur. Because of this, and the further circumstance that both hydrogen sulphide and carbon disulphide are heavier than air, it appears that on the instant voyage the venting arrangement was not too effective in clearing off these gases. Further, the evidence indicates that in rough weather, such as the vessel probably encountered on this voyage, the molten sulphur would pour out of the forward vents of the cargo tanks at least partially obstructing these vents as the sulphur solidified. If this condition existed on this voyage, it would further serve to impair the effectiveness of the venting arrangement.

9. The evidence further indicates that the auto-ignition point of carbon disulphide in concentrations within the flammability limits is 212°F. However, it appears that the other gas, hydrogen sulphide, having an auto-ignition point of 500° F, suppresses the carbon disulphide and acts to raise the auto-ignition point. Whether a layering of these gases can ever result has not been positively established. A study of the four reported explosions, made a part of the record of this Board, involving a barge, tank truck, storage tank and another ship all carrying or containing molten sulphur, fails to reveal the source of ignition of the gases. From all the evidence available, it is concluded that it could be possible that an explosion of the gases in the vapor space of one of the cargo tanks occurred. At the present state of knowledge, the source of ignition of

such a possible explosion is only conjectural. The record contains tentative opinions of experts that the source of ignition of these explosions may be an electrostatic discharge, the presence of pyrophoric iron sulphide on the interior surfaces of the tanks, or the use of superheated steam in the heating coils. In this connection, it is to be noted that although a close inspection of the debris identified as coming from the vessel fails to show any evidence of charring or of an explosion, this fact by itself does not completely discount the possibility that an explosion did occur.

10. Although an explosion of the gases in one of the cargo tanks cannot be discounted, it would appear that such an explosion, if it occurred, would not be of a sufficient destructive force to account for the complete loss of the vessel without the intervention of other causes, perhaps, resulting from the initial explosion. It seems to be a generally accepted fact that an explosion of these gases is, relatively speaking, and dependent upon the factors of quantity and space, not of a high order. This view is supported by the explosion which occurred on board a foreign flag T-2 type tanker converted to carry molten sulphur. In this case, despite a much larger air space, the explosion merely distorted the cargo tank without rupturing it. A consideration of other causes which may have been set in motion by a possible explosion of the gases in a cargo tank of the MARINE SULPHUR QUEEN would be purely conjectural. At this juncture it is pertinent to observe that the results of experiments being conducted by the Bureau of Mines into the properties of molten sulphur are not known and, accordingly, the present conclusions may have to be modified in the light of the results of these experiments.

11. Evidence has been received which indicates that on or before 29 April 1963 a note was found in a bottle on a spoil island in Laguna Madre off the Texas coast. This unsigned note purportedly written by a crew member speaks of two crew members being hurt as a result of an explosion. An examiner of questioned documents has stated his opinion that this note was written by a specified member of the crew on this voyage. On the other hand the Director of the Coast Geodetic Survey has stated that in his opinion the bottle could not have reached the site where it was found if dropped into the water at any place east of the 85th west meridian, unless a strong southeast wind was blowing for several days before and after the incident. The evidence indicates that on 3 and 4 February 1963 the wind was generally northerly. Also it would appear likely that the vessel had proceeded east of the 85th meridian before it foundered. Further, it is to be noted that all of the debris positively identified as coming from the vessel has been found off the southern tip of Florida.

Finally, it is apparent that the preparation of this note, its insertion in the bottle, taping the bottle, and dropping it into the water must in all have consumed some considerable time. Without knowing all the facts existing at the time, it is difficult to explain why in this period of time, no radio distress message was transmitted from the vessel. For all these reasons, it is concluded that it is unlikely that this note was dropped into the water by a crew member of this vessel before it foundered.

12. The Board has extensively considered the possibility that the casualty to this vessel was caused by a complete longitudinal failure of the vessel's hull girder causing it to break into two. There are many factors bearing on this issue. Basically, insofar as this type vessel is concerned, the evidence indicates that there have been ten known cases of complete fractures of T-2 type tank vessels. That this type of casualty has persisted after the problem has been thoroughly studied and measures taken to prevent the same, tends to support the view held by some that this type of vessel has basic design imperfections which cannot be feasibly corrected. Additionally, it is now rather generally recognized, although previously a contrary view was held, that the age of a vessel has some relationship to structural failure. This instant vessel was about 17 years old at the time of the conversion and about 19 years old at the time of her disappearance.

13. As a result of her conversion, the center vertical keel of the MARINE SULPHUR QUEEN was cut down more than half its original height and deck centerline girder was cut down slightly less than half its height in the way of the cargo tanks. Further, one expert testified that in his opinion the slotted holes permitting the cargo tanks to expand were of an insufficient length and that even if of adequate length and properly aligned, the expansion of the tanks would add about 2,000 psi tensile stress to the hull. Also, the evidence indicates that on at least 52 loaded voyages of the 64 voyages made by this vessel after conversion, the sag numeral of 100 was somewhat exceeded, and that on the present voyage the sag numeral was 101.01 at the time of the vessel's departure from Beaumont. Finally, it appears the fairly rough seas which the vessel in all likelihood encountered on this instant voyage subjected the vessel to some longitudinal stress, despite the fact that it was essentially a beam sea.

14. On the other hand, the cutting down of the center vertical keel and the centerline deck girder was compensated for by adding substantial flange plates to these members and also by the construction of the cargo tank and its foundation. Calculations made after the conversion indicate that the section modulus of the vessel was increased about 2% in the deck and about 1% in the bottom as contrasted to the original section modulus. It is also to be noted that during conversion all the longitudinal deck girders in the way of the center tanks and many of these girders in the way of the wing tanks were renewed. Finally, it is concluded that the excess of the sag numeral over 100 on the 52 voyages in question was so slight and that even the cumulative effect thereof would not appreciably

affect the longitudinal strength of the vessel.

15. A major issue is whether or not the cargo tank was free to expand to the limits of its normal thermal expansion. This issue involves a consideration among other things of the adequacy of the length of the expansion slots in the longitudinal face plates. The evidence indicates that these slots were $3\frac{1}{2}$ inches long except for the last ten feet on each end of the tank where the slots were 4 inches long. Mr. [REDACTED] the naval architect employed by the shipyard where the conversion took place, testified that his calculations and his inspection of the tank, after being heated by air to a temperature between 240° and 252° for 48 hours, indicated that the slots were of sufficient length. In this connection it is to be noted that no precise measurements of the actual expansion of the tank after this heated air test were made. Mr. [REDACTED], however, recalled that with respect to the slots near the ends of the tank, the bolts were between $\frac{3}{8}$ of an inch to $\frac{1}{4}$ of an inch from the end of the slots. Mr. [REDACTED], the Coast Guard naval architect, testified that his calculations indicated that some of these slots were not of adequate length.

16. The Board has made its own calculations of the thermal expansion of the tank on the assumption that there was proper alignment of the expansion slots and the bolts. These calculations are not conclusive primarily because of the difficulty in determining the correct figure to be used for the temperature differential. Theoretically, the temperature differential is determined by subtracting the average temperature of the metal of the tank at the time it was constructed and fitted in place from the highest temperature the metal of the tank attains in the actual service of carrying molten sulphur. It is noted that Mr. [REDACTED] used a temperature differential of 200° F in his calculations on the assumption that the average temperature during the conversion work was 75° F and the highest temperature in service was 275° F. The temperature differential employed by Mr. [REDACTED] appears to be 240° F.

17. Using a temperature differential of 200° F the Board calculations indicate that the slots were adequate in length provided proper alignment existed. However, using a temperature differential of 240° F the Board calculations indicate the possibility that some slots, especially the $3\frac{1}{2}$ inch slots nearest the ends of the tank, were inadequate even assuming proper alignment. Moreover, in view of the great number of slots and bolts involved, consideration must be given to the possibility that in fact there was not proper alignment of all these slots and bolts at the time of conversion.

18. According to the testimony of Mr. [REDACTED] which is confirmed by a study of the plans, no provision was made for the transverse and vertical thermal expansion of the tank on the assumption that these dimensions

were small enough to permit the element of thermal expansion to be completely discounted. Were it not for this feature of the bolt and slot arrangement designed to take care of the longitudinal expansion, this assumption would probably be valid. However these bolts were 1 inch in diameter fitted in holes 1-1/16 inches in diameter and in slots 1-1/16 inches wide. Even the small amount of transverse and vertical thermal expansion would far exceed 1/16 of an inch and might well cause a binding of the bolts in the holes and slots.

19. On the other hand, the evidence does indicate that on every trip south after discharging the cargo the Chief Officer made an inspection of the void spaces with particular attention to the slots and bolts on the bottom of the tank. Furthermore, such an inspection was occasionally made by the port engineers employed by the operating company. The evidence unequivocally indicates that at no time were any sheared bolts found, nor was any binding of the bolts in the slots ever noted. However, even assuming these inspections were most thorough and competent, the results thereof do not affirmatively establish that the tank was in fact expanding freely to the limit of its normal thermal expansion. As a practical matter, this could only have been verified by a careful comparison of precise measurements of the actual expansion under controlled conditions with the calculations of thermal expansion at related points of the tank. This was in fact never done. Accordingly, when consideration is given to all these factors, it is concluded that it is possible that due to the inadequate length of some of the slots, the binding of the bolts in some of the slots due to transverse and vertical thermal expansion, the further binding of the bolts in some of the slots due to the motion of the vessel at sea, the lack of proper alignment, or a combination of these conditions, that the tank was not expanding freely in a longitudinal direction to the limits of its normal thermal expansion. This possible loss of free movement to the degree that it was restricted would increase the compression stress of the tank and consequently the tension stress of the hull. Accordingly, on the basis of all the available evidence, it is concluded that it is possible that the casualty to the vessel originated with a complete longitudinal fracture of its hull girder. In reaching this conclusion the Board is not unmindful of the fact that in all previously known cases of a complete fracture of this type vessel, at least one section of the vessel has remained afloat. However, the conversion of this vessel significantly altered its basic characteristics and there is the further consideration that its cargo may have contributed to the rapid sinking of both sections, if in fact the vessel broke in two.

20. The evidence indicates that the vessel had a metacentric height in its loaded condition within the satisfactory range. However, the concentration of the weight of cargo within approximately 15 feet on either side of its centerline reduced the vessel's radius of gyration and,

accordingly, its period of roll was faster than another vessel with the same metacentric height. The hindcast prepared by the U. S. Naval Oceanographic Office indicates the possibility that while the vessel was approaching the Straits of Florida it encountered seas with a maximum wave height of 16.5 feet slightly abaft its port beam. This hindcast further indicates the possibility that the period of encounter of the seas was within 10% of the vessel's period of roll, which was 8.5 seconds. Under these circumstances, heavy rolling of the vessel could be expected, accompanied by yawing, lurching and difficulty in steering. If such a situation developed, prompt appreciation of the danger by the watch officer and an immediate and drastic speed and/or course change would have been most vital. If complete resonance was approached, the vessel could have experienced several violent rolls in a minute's time. Accordingly, although no known reliable data is available to determine what the ultimate rolling of the vessel might have been, it is concluded that the possibility that the vessel capsized without previous structural damage cannot be discounted. Finally, it is possible that the capsizing of the vessel might have been preceded and caused in part by the partial failure of and some lateral displacement of the cargo tank due to the stresses previously and hereafter discussed.

21. The sea conditions which the vessel in all likelihood encountered on 3 and 4 February, also have a definite bearing on another possible cause for the vessel's disappearance. As a result of the conversion, nine transverse bulkheads in the way of the original center tanks were practically eliminated and the transverse web frames in the same area were cut down to accommodate the cargo tank. In the place of these original transverse strength members, one watertight bulkhead which completely surrounded the cargo tank was added at frame 59, two diaphragm bulkheads were added at frames 65 and 53 which connected merely the sides of the cargo tank with the longitudinal wing tank bulkheads, and top connections fitted with a bolt and slot arrangement were added at frames 71, 68, 62, 56, 50 and 47. In short, at the nine frames where originally there had been a watertight bulkhead in the amidship section of the vessel, after conversion there was one watertight bulkhead, two diaphragm bulkheads and six top connections. However, it is apparent that the replacement members did not possess the strength of the original watertight bulkheads. Moreover, the reduction in the height of the web frames was not completely compensated for by the addition of the flange plates. Therefore, it is concluded that the vessel after conversion did not possess the same transverse strength and stiffness as it had originally. Accordingly, it is considered possible that the moments induced by this racking may have contributed initially to cracking in the web frames or floors with displacement of the bottom structure and resulting cracking of the bottom shell. At the temperatures which reasonably could be expected at this time, the fractures up to this point could have been of the ductile slow type and could have occurred without causing noticeable sound or shock. As to what may have happened thereafter is conjectural. However, it is possible that this condition in turn

brought into play other causes discussed herein which acting together may have produced the final major fracture of the vessel's hull. In this eventuality, it cannot be discounted that the foundering of the vessel could have occurred quite suddenly.

22. One factor which may have some relationship to the disappearance of the vessel could not be properly evaluated because of the lack of accurate information with respect thereto. This factor concerns the nature of the reaction resulting from the contact of large quantities of sea water and molten sulphur. As indicated by the Section 402 of the NFPA Code No. 655 (1950), a Code for the Prevention of Sulphur Dust Explosion and Fires, there originally was some support for the view that the contact of these two liquids in a confined space would result in a steam explosion. However, the more recent thinking appears to discount the possibility of this reaction with the rationalization that the relatively cool sea water would quickly cool and solidify a layer of the sulphur which in turn would act to insulate the mass of the sulphur and the heat therein from further contact with the water. Nevertheless this later view does not completely discount the possibility of a steam explosion provided there is a rapid and very thorough dispersal and contact of the two liquids in a confined space. A related factor concerns the reaction resulting from the contact of sea water with the heated outside surfaces of the cargo tanks

23. Both these factors may be of considerable significance in explaining the vessel's apparent sudden disappearance. One of the possible causes heretofore considered or some other cause may have resulted in sea water entering the void spaces surrounding the cargo tanks and coming into direct contact with the outside surfaces of the tanks, or with the sulphur itself, in the event of a rupture of a tank or tanks. Considering the state of the known knowledge on this subject a proper evaluation of these factors cannot presently be made. However, reference is again made to the experiments being conducted by the Bureau of Mines with the thought that the results of these experiments may permit a definitive evaluation of these factors to be made.

24. Considerable stress was placed during the investigation on the cause or causes for the several fires which occurred over a period of time in the void spaces surrounding the cargo tanks. The evidence does not permit any conclusion to be drawn as to the cause of these fires. It has been suggested that the spilled sulphur might have been ignited by coming into contact with short unlagged sections of the steam return lines from the heating coils at the bottom of the tanks. It has also been suggested that the auto-ignition temperature of sulphur may be reduced by the presence of contaminants and that the insulation surrounding the cargo tanks might be contaminated with oil or other organic materials reducing the auto-ignition temperature of the sulphur to the range of temperatures normally experienced on the outside of the cargo tanks. The inability to definitively establish the cause of these known fires in the void spaces very cogently demonstrates

the lack of complete and reliable information concerning all the properties of molten sulphur.

25. The plans for the conversion of the MARINE SULPHUR QUEEN to a molten sulphur carrier were prepared by a competent shipyard and were approved both by the American Bureau of Shipping and the U. S. Coast Guard. After the conversion the vessel was inspected and approved by these same agencies. Thereafter, both agencies inspected the vessel in October 1961 after she sustained heavy weather damage and approved the repairs made at that time. Subsequently both agencies inspected and approved the vessel in the early part of 1962 when she was subjected to a drydock and a Coast Guard mid-period inspection, and in January and February 1963 at which time the Coast Guard biennial inspection was held. Additionally, the vessel was inspected frequently by competent personnel serving on board and from time to time by port engineers and port captains employed by the operating company. The evidence indicates that after her conversion was commenced in 1960, all repairs required by the American Bureau and the Coast Guard were accomplished by the operating company within the allotted time. Further, there is no evidence to indicate that the operating company ever failed to make repairs requested or suggested by the Master. At the time of her disappearance the vessel had a valid certificate of inspection issued by the Coast Guard and was classified by the American Bureau of Shipping. On the basis of all this evidence, it is concluded that the operating company took all the customary precautions necessary to maintain a vessel associated with the carriage of petroleum products in a safe condition.

26. However, the MARINE SULPHUR QUEEN was not a conventional tanker carrying petroleum products. As a result of the conversion she was fitted with a fairly unique, massive, expanding tank and was carrying a cargo which up to that time had not been exclusively carried by a self-propelled vessel. It could, therefore, reasonably be expected that this new trade would involve new and unusual problems. Viewed against this background, the evidence indicates that the operating company failed to pursue good operating practice by not giving instructions or assistance to the Master of the vessel on many aspects of these problems and also failed to keep itself informed as to matters affecting the vessel's safety. In general, the only instructions given to the Master of this vessel were the same as those given to a Master of a conventional tank vessel. Specifically, among other things, no instructions were given as to the method of loading and discharging cargo and the proper use of the Trim, Stability and Loading Booklet, safety procedures and tests to be observed during cargo operations, the temperature of the steam entering the heating coils, the temperature at which the cargo was to be maintained, tests of the cargo while at sea, the care and inspection of the venting systems to the cargo tanks and void spaces, inspection of the cargo tanks, void spaces and tank foundations, the temperature to be maintained on the empty cargo tanks, and the method and manner of ballasting the

vessel. With respect to the failure to keep itself fully informed, it is significant that the operating company did not require a report from the Master as to the loading numerals for each voyage, despite the fact that this was required from all vessels which this same company operated on behalf of the Military Sea Transport Service. Further, it appears that while some of the personnel of the operating company had generally heard that a few fires had occurred in the void spaces, they were not fully informed as to all these fires and they never initiated any study in an attempt to determine the cause thereof. In summary, once the conversion was completed, except for a few minor details, the operating company treated this vessel as a conventional tank vessel. In so doing, it perhaps satisfied its responsibility under the law by permitting the duty for the safety of the vessel to devolve almost exclusively upon the Master. However, it is manifest that in handling exotic cargoes, of which molten sulphur is only one, that no mariner possesses the requisite expertise to solve all problems associated therewith. It is concluded that operating companies involved with such cargoes should thoroughly familiarize themselves with all the related problems and dangers involved, should if necessary seek outside expert advice, and should actively instruct and guide the Master in all aspects of handling the cargo and associated problems.

27. The operating company failed to give timely notice to the Coast Guard concerning the lack of communication from the vessel. The evidence indicates that the Master of the vessel had a reputation for punctuality in the transmission of arrival messages. The company rationalized the failure to receive the 48 hour and 24 hour arrival message on the basis of bad weather conditions and then delayed several hours beyond the expected time of the vessel's arrival in Norfolk before notifying the Coast Guard. Needless to say, as a result of this delay, very valuable time was lost in instituting the search for the vessel and/or possible survivors.

28. The Coast Guard search for the missing vessel was most thorough and covered all possible areas in which the vessel could have been, if afloat, or in which debris and survivors could be reasonably expected, if sunk. The subsequent phase of search for the sunken vessel in the area of the Florida Straits, conducted by the United States Navy at the request of the Coast Guard, was most thorough and most unusual in its extent.

29. Relative to the approval of the conversion, the Merchant Marine Technical Division of Coast Guard Headquarters in its letter to Bethlehem Steel Company dated 13 May 1960, while raising some issues as to the transverse strength of the vessel, approved the plans and specifications with the basic reservation that they be satisfactory to the American Bureau of Shipping and that compliance be had with all requirements

of that society. This conditional approval by the Coast Guard is expressly authorized by the provisions of 46 CFR 31.10-1 (c). The evidence further indicates that the American Bureau of Shipping by its letter dated 21 June 1960 subsequently approved the conversion and the basic reservation of the Coast Guard approval was thus satisfied.

30. On the basis of hindsight, issue could be taken with the approval of the conversion of the vessel. However, in assessing these approvals, reference should be made only to the facts and information available at the time such approval was given. Furthermore, it must be borne in mind that the issue of the structural efficiency of a vessel's hull involves many imponderables and is not susceptible to precise and exact measurement. In the light of these considerations, it is concluded that no reason appears to question the approvals thus granted at that time. However, based on all the facts and information now available, the Board concludes that the same conversion of another T-2 type tanker should not be approved at this time, nor should any other conversion be approved that deviates from the originally designed features for the carriage of the basic petroleum products.

31. The evidence indicates that during the course of the vessel's mid-period inspection in 1962 and the biennial inspection in 1963, the Coast Guard marine inspectors, although conducting, in general, a very thorough and conscientious inspection of the vessel, failed to make a sufficiently detailed inspection of the cargo tanks, tank fittings and surrounding void areas. This failure appears to have been primarily attributable to unfamiliarity on the part of the inspectors with the basic designed cargo tank arrangements of the vessel and the properties of the cargo that she carried. It would appear that the Coast Guard inspectors proceeded on the assumption that the MARINE SULPHUR QUEEN was a conventional tanker fitted for the carriage of "Grade E cargoes" with certain relaxations permitted by 46 CFR, Part 36. Even though the evidence indicates that inspection of the cargo tank, fittings and surrounding void areas were made periodically by vessel and company personnel, a more careful inspection of these members and spaces should have been made by the Coast Guard inspectors to adequately assess the condition of the vessel.

32. Viewed realistically the responsibility for this failure cannot be placed exclusively on the inspectors themselves or their immediate commanding officer. They were summoned to conduct inspections of this vessel without any intimation that this vessel was not merely a conventional tanker modified for "Grade E cargoes" and without being informed that the vessel had a unique cargo arrangement which required close scrutiny. In the future, it would appear preferable to treat vessels of this type as unique vessels rather than as modified conventional tankers. Moreover, with respect to these unique vessels, which apparently will become more numerous in the future, consideration should be given by the Commandant to the establishment of procedures to insure that field officers in their inspection of these vessels place greater emphasis on the safety of the cargo and the related design features.