U.S. Department of Transportation
United States Coast Guard

MARINE CASUALTY REPORT

SS AMERICAN EAGLE, O.N. 278327

EXPLOSION IN THE GULF OF MEXICO ON 26 FEBRUARY 1984 AND SUBSEQUENT SINKING ON 27 FEBRUARY 1984 WITH LOSS OF LIFE

U.S. COAST GUARD

Marine Board of Investigation Report
and
Commandant's Action

REPORT NO. USCG 16732/0001 HQS 84

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16. Abstract

At 1045 February 26, 1984, the American tankship SS AMERICAN EAGLE suffered a major cargo tank explosion while enroute in ballast from Savannah, Georgia to Orange, Texas. The explosion occurred while several crew members were cleaning and gas-freeing the number 3 center cargo tank of the last cargo of gasoline. Although the SS AMERICAN EAGLE suffered major structural damage, the vessel remained afloat until February 27, 1984, when the vessel broke up and the Master ordered the crew to abandon ship. The surviving crew members were rescued by three offshore supply vessels and a Coast Guard helicopter. As a result of the explosion, 3 crewmen lost their lives and 4 were injured. During the abandonment and rescue efforts 2 additional crew members lost their lives and 2 remain missing and are presumed dead; also 5 more crew members were injured. The proximate cause of the casualty was the introduction of steam into number 3 center cargo tank through an ungrounded air mover with a plastic sleeve attached. The use of steam resulted in an electrostatic discharge which ignited the hydrocarbon vapors in the number 3 center cargo tank. The Coast Guard has issued warnings regarding the use of steam and portable venturi-type blowers in nongas-free atmospheres.

This report contains the U. S. Coast Guard Marine Board of Investigation Report and the Action taken by the Commandant to determine the proximate cause of the casualty and provide a response to the recommendations to prevent recurrence.

17. Key Words Air mover, explosion, tanker, gas-freeing, electrostatic charge, ISGOTT, inert gas systems, tank washing machines, steam, venturi-type blowers, butterworth plates, ventilator, static electricity	18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22121

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SS AMERICAN EAGLE, O.N.278327, EXPLOSION IN THE GULF OF MEXICO ON 26 FEBRUARY 1984 AND SUBSEQUENT SINKING ON 27 FEBRUARY 1984 WITH LOSS OF LIFE

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U.S. Department of Transportation
United States Coast Guard

Commandant
United States Coast Guard

Washington, DC 20593
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16732/AMERICAN EAGLE
8 July 1985

Commandant's Action

on

The Marine Board of Investigation convened to investigate the circumstances surrounding the explosion on board the SS AMERICAN EAGLE, O.N. 278327 in the Gulf of Mexico on February 26, 1984, and subsequent sinking on February 27, 1984, with multiple loss of life.

The report of the marine board of investigation convened to investigate the subject casualty has been reviewed and the record, including the findings of fact, conclusions and recommendations, is approved subject to the following comments:

REMARKS

1. In concurrence with the board, the proximate cause of the casualty was the introduction of steam into number 3 center cargo tank through an ungrounded air mover with a plastic sleeve attached. The use of steam resulted in an electrostatic discharge which ignited the hydrocarbon vapors in the number 3 center cargo tank. However, the specific origin of the electrostatic discharge cannot be determined. Although the discharge may have been from the air mover to the deck as concluded by the board, the possibility that the discharge may have been from the plastic sleeve to the tank or from a vapor cloud to the tank cannot be eliminated. This casualty illustrates the need for personnel involved in tank cleaning and tank venting operations to be aware of the dangers of static electricity and to observe stringent safety precautions which is paramount in preventing this type of casualty.

2. Contributing causes to the rapid breakup and sinking of the AMERICAN EAGLE include a combination of the following:

(a) the rapid deterioration of weather and sea conditions on February 27, 1984; and

(b) the failure to secure all cargo tank hatches and Butterworth plates after the explosion.

3. Contributing causes to the loss of life include a combination of the following:

a. the adverse weather and sea conditions which held the lifeboat in the lee of the wind-driven ship. This situation instilled fear in the crew members that the ship would roll over the lifeboat which prompted them to jump into the water; and

b. the delay in the evacuation of nonessential personnel from the vessel after the explosion occurred. A thorough assessment of the extent of structural damage to the vessel, which was not conducted after the explosion, may have led to a more timely and orderly evacuation.

COMMENTS ON CONCLUSIONS

1. Conclusion 12: That there is some question as to whether all precautions associated with the Lamb air mover ventilator were being observed. The warning label states that the device should be grounded; however, testimony verified that the device was not properly grounded.

Comment: This conclusion is concurred with. The air mover should have been properly grounded in accordance with the manufacturer's instruction in the warning label. However, proper grounding of the air mover would not have eliminated the risk of electrostatic discharge from the plastic sleeve or the vapor cloud.

2. Conclusion 16: That the Chief Mate and the Master should have been aware of the hazards associated with introducing steam into nongas free tanks as stated in the International Safety Guide for Oil Tankers and Terminals (ISGOTT).

Comment: This conclusion is concurred with. Chapter 8 of the ISGOTT on tank cleaning and gas freeing clearly warns against injecting steam into tanks where there is any risk of the presence of a flammable atmosphere. Contrary to the guidance contained in the ISGOTT, the Mine Safety Appliances Company (MSA) data sheet provided as Appendix A to the board's report indicates that the air mover is suitable for use with steam in the blower mode in potentially explosive atmospheres when properly grounded. A copy of this report will be provided to MSA with a recommendation that literature describing the air mover be revised to reflect the hazards of introducing steam into a flammable atmosphere.

3. Conclusion 22: That had the Master secured all cargo tank hatches, Butterworth plates and watertight doors at the time he ordered all valves to be shut, the vessel may not have sunk as rapidly, allowing more time for an orderly evacuation.

Comment: This conclusion is concurred with in part. Neither the findings of fact nor the record established that the watertight doors were not secured nor is it clear to what extent, if any, the watertight doors influenced the outcome of this casualty.

4. Conclusion 42: That the American Foreign Steamship Company did not have a formal safety program.

Comment: This conclusion is not concurred with in that it is not supported by the findings of fact.

ACTION CONCERNING THE RECOMMENDATIONS

1. Recommendation 1: That the Coast Guard issue precautions on the use of steam in tanks that are not gas free. Steam should not be injected into nongas free tanks. All personnel involved in tank cleaning/gas freeing operations should be made aware of the hazards.

Recommendation 2: That the Coast Guard publish a safety advisory to alert seamen who serve aboard tank vessels of the need to ground cargo tank ventilating blowers. This is particularly important with respect to portable venturi air mover ventilators as used aboard the AMERICAN EAGLE.

Action: Recommendations 1 and 2 are concurred with. Within days after the casualty, the Coast Guard issued a service-wide warning regarding the use of portable venturi air mover blowers or exhaust units in nongas free atmospheres. Specifically, the warning addressed the need to ensure a positive grounding of the device and the hazards of using steam to ventilate tanks due to the generation of electro-static charges. All the Coast Guard field offices to which the warning was addressed disseminate this type of information to the marine industry within their area of responsibility via numerous methods. This warning was also published in the June 1984 "Proceedings of the Marine Safety Council" which has a substantial distribution. The preliminary findings on this casualty and the associated precautions were also disseminated internationally.

2. Recommendation 3: That the ISGOTT be endorsed by the Coast Guard and that a copy be required aboard all U.S. tank vessels and those foreign tank vessels entering U.S. waters.

Action: The intent of this recommendation is concurred with. The International Maritime Organization (IMO) Subcommittee on Fire Protection recently recognized the ISGOTT (2nd edition) as a valuable guide for tank cleaning procedures on tank vessels not fitted with inert gas systems (IGS). The Coast Guard concurs with this assessment of the ISGOTT by the IMO Subcommittee and intends to reference ISGOTT in a forthcoming revision to the fire protection regulations.

3. Recommendation 4: That consideration be given to requiring the inerting of cargo tanks containing flammable products such as gasoline. Present regulations only require inerting of cargo tanks containing crude oil on existing vessels of tonnages similar to the AMERICAN EAGLE.

Action: The intent of this recommendation is concurred with. The requirement for IGS on all vessels carrying crude oil or product such as gasoline has been considered on national and international levels. The applicable regulations in 46 CFR 32.53 correspond to the international standards as published in the International Convention for the Safety of Life at Sea, 1974, as amended. Tank vessels currently required to have an IGS include all crude oil carriers, new and existing, of 20,000 dead weight tons (DWT) or more; all existing product carriers of 40,000 DWT or more; and all existing product carriers between 20,000 DWT and 40,000 DWT with high capacity (60 cubic meters per hour) tank washing machines. Existing product carriers less than 40,000 DWT with low capacity tank washing machines are not required to have IGS. The AMERICAN EAGLE falls within the latter category and was not required to have IGS.

When the international community considered requiring IGS on existing product carriers in the 20-40,000 DWT range, it was felt that these ships had a relatively good safety record and that introduction of IGS piping and associated equipment on an existing vessel could potentially prove to detriment instead of contribute to safety. The IMO Subcommittee on Fire Protection has been periodically reviewing serious tank vessel casualties and will continue to do so with a view toward reevaluation of the IGS requirements.

4. Recommendation 5: That the use of portable venturi air mover ventilators, when operated in the blower mode, be prohibited in any spaces which are not gas free.

Action: This recommendation is not concurred with. There is no evidence to indicate that the air mover, if used properly, is unsafe in a nongas free atmosphere. However, in such an atmosphere, certain precautions are appropriate. As prescribed by the manufacturer and indicated by a warning label, proper use of the air mover requires grounding the device. Although the MSA air mover data sheet indicates that it may be used with either air or steam, the hazards involved with introducing steam into a nongas free atmosphere are well-known and discussed in various publications including the ISGOTT, a copy of which was aboard the vessel. Additionally, the use of a plastic sleeve provided a nonconductive surface on which the static charge could be accumulated. The casualty most likely would not have occurred had appropriate attention been given to these concerns.

5. Recommendation 6: That portable venturi air mover ventilators be used in accordance with provided warning labels.

Action: This recommendation is concurred with. Due caution should always be exercised to observe the manufacturer's safety warnings. Mariners engaged in tank cleaning should also be familiar with authoritative publications providing guidance and safety information on this subject.

6. Recommendation 7: That manufacturers of portable venturi air mover ventilators provide a practical and positive method of grounding these devices.

Action: This recommendation is concurred with. Although normal placement of metal equipment on a deck cleared of high resistance materials such as gaskets will normally provide an adequate leakage path to eliminate an electrostatic discharge, this recommendation will be forwarded to MSA and other manufacturers of portable venturi air mover ventilators for their consideration. Ultimately, the equipment operator is responsible for ensuring that all safety precautions including grounding of the equipment are observed.

7. Recommendation 8: That this report be given wide dissemination to the marine industry by means of the Proceedings of the Marine Safety Council after

final action by the Commandant and the National Transportation Safety Board. This marine board believes that by publicizing the factors which led to this casualty, many mariners will relate them to their own shipboard operations and perhaps recognize and correct potential hazards.

Action: This recommendation is concurred with. This report will be given wide dissemination. An appropriate article describing the various factors which led to this casualty will be published in the "Proceedings of the Marine Safety Council."

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

PART II

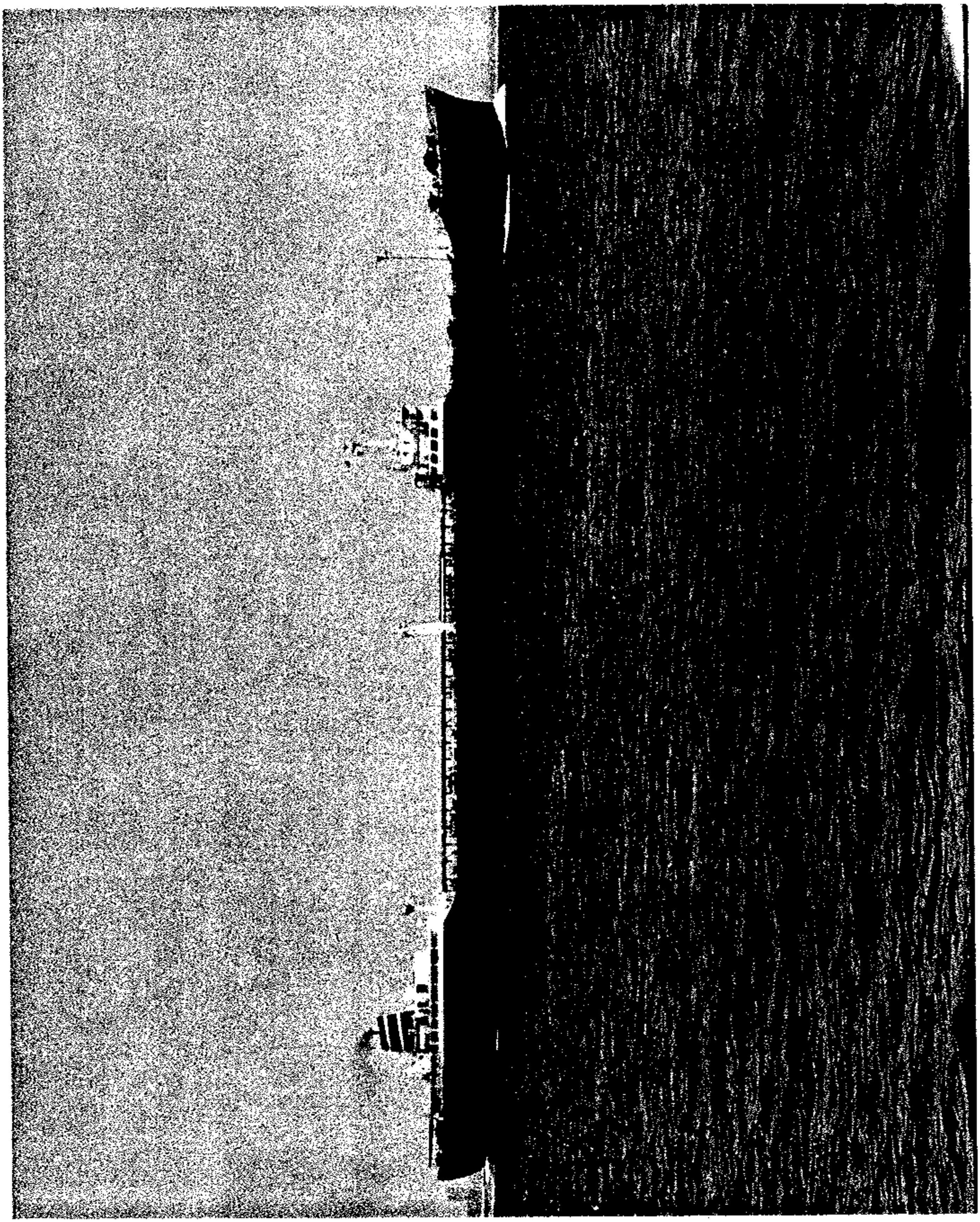

Figure 1

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U.S. Department of Transportation
United States Coast Guard

COMMANDER (m)
Seventh
Coast Guard District

51 S.W. 1st Avenue
Miami, FL
33130

16732/AMERICAN EAGLE
6 February 1985

From: U. S. Coast Guard Marine Board of Investigation
To: Commandant (G-MMI)

Subject: SS AMERICAN EAGLE, O.N. 278327; explosion on board on 26 February 1984, and subsequent sinking in the Gulf of Mexico on 27 February 1984, with loss of life.

FINDINGS OF FACT

1. At or about 1045 (all times are +6 zone description, unless otherwise noted, and are based on a 24 hour clock) on 26 February 1984, the U.S. tankship AMERICAN EAGLE, on a ballast voyage, suffered a major cargo tank explosion approximately 110 miles South-Southwest of Grand Isle, Louisiana. Three crewmen were killed and four were injured. The AMERICAN EAGLE suffered major structural damage in way of cargo tanks #2, #3 and #4 as a result of the explosion. The vessel remained afloat, after the explosion, with no appreciable change in list or trim. During the afternoon of 27 February 1984 the drifting AMERICAN EAGLE was setting down on several oil drilling rigs anchored in the area. To prevent the AMERICAN EAGLE from colliding with one of the oil rigs, an anchor-handling supply boat attempted to tow the AMERICAN EAGLE, stern first, clear of the anchored rigs. Approximately 30-45 minutes after the towing operation commenced, the bow section of the AMERICAN EAGLE began to break away, at which time the tow line was cut. When the bow started to break away, the Master ordered the crew to abandon ship. The crewmen entered the starboard aft #3 lifeboat. The boat was lowered, however it stopped short of the water and could not be lowered the remaining distance to the water. Several of the crewmembers jumped from the boat, those remaining in the boat operated the releasing gear and the boat dropped into the water. Difficulty was experienced in getting the boat away from the ship, so the remaining people jumped into the water from the lifeboat. All of the surviving crewmembers, with the exception of two, were eventually recovered from the water, either by the three offshore supply vessels standing by or by the Coast Guard helicopter on scene. The stern section of the AMERICAN EAGLE sank at approximately 1735 that same day. The bow section remained afloat for some time and presumably sank during the night. As a result of this casualty five crewmen lost their lives, two crewmen remain missing and are presumed dead, and nine crewmen were injured.

2. Vessel data:

Name	AMERICAN EAGLE
Official number	278327
Service	Oil tanker
Gross Tons	20520
Net tons	12662
Deadweight tons	33054
Length overall	661.00 feet
Length (between perpendiculars)	630.00 feet
Breadth (molded)	90.00 feet
Depth (molded)	45.25 feet
Propulsion	Steam turbo-reduction
Horsepower	13600
Homeport	New York, New York
Owner	American Foreign Steamship Corp. 80 Broad Street New York, NY 10004
Operator	American Foreign Steamship Corp. 80 Broad Street New York, NY 10004
Date built	17 March 1959
Where built	Sparrows Point, Maryland
Built by	Bethlehem Steel Corporation
Master	Francis P. Powers 130 Lanford Road Spartanburg, SC 29301
Age	61
License	Master, steam and motor vessels, any gross tons upon oceans, also radar observer
License number	008307
Issue	4-6
Merchant Mariners Document	Z-1127412

Coast Guard Certificate of Inspection data:

Date of issue	22 July 1983
Place of issue	Port Arthur, Texas
Expiration date	22 July 1985
Drydocked	Norfolk, Va (hauled out 14 Jun 83) Pt Arthur, TX (completed 22 Jul 83)

Cargo Ship Safety Equipment Certificate:

Issued by	U.S. Coast Guard
Date of issue	22 July 1983
Place of issue	Port Arthur, Texas
Expiration date	22 July 1985

3. Record of dead, missing, and injured

The following crewmembers were killed as a result of the explosion on 26 February 1984.

NAME	POSITION	AGE	HOME ADDRESS	NEXT OF KIN
MALLON Edward J.	Chief Mate MMD# 274267	62	Zion Montgomery Road Route #1 Box 58-D Neshanic Station N.J. 08853	Wife Charlotte
CAMPBELL Jack R.	Bosun MMD# 400-44-1698	48	P.O. Box 59 Carrabelle FL, 32332	Wife Agnes
CARTER Roy D.	Pumpman MMD# 257-38-3526	60	Route #1 Box 1-A Sycamore GA, 31790	Wife Flora

The following crewmembers died after abandoning the AMERICAN EAGLE on 27 February 1984.

NAME	POSITION	AGE	HOME ADDRESS	NEXT OF KIN
FOTOPOULOS Andrew	Steward MMD# 1172037	62	14275 Hampton Drive Turah Montana	Son Andrew
SYLVIA Antone G.	Messman/ Utility MMD# 431323-D1	59	134 Blackmer St. New Bedford MA, 02744	Wife Mary

The following crewmembers are missing and presumed dead;

NAME	POSITION	AGE	HOME ADDRESS	NEXT OF KIN
BURNEY Steger R.	Able Seaman MMD# 263-32-7196	56	3013 Highway 301 Box 1 Riverview FL, 33561	Wife Mildred
WARREN Earsel	Ordinary Seaman MMD# 721-16-1357	55	1175 W. Third Street Jacksonville FL, 32209	Wife Beatrice

The following crewmembers were injured as a result of the explosion on 26 February 1984.

NAME	POSITION	AGE	HOME ADDRESS
SALSBURY John B.	Second Mate MMD# 139997-D2	66	34722 Ophir Road Gold Beach OR, 97444
VANEK Aloyz	Third Mate MMD# 701833	58	P.O. Box 103 Bronson TX, 75903
CONKLIN Fred E.	Radio Operator MMD# 425050	58	262 Shady Shores Drive Mabank TX, 75147-9133
POOLE Richard W.	Able Seaman MMD# 305862	61	11 Thompson Road Beverly MA, 01915

The following crewmembers were injured while abandoning the AMERICAN EAGLE on 27 February 1984.

NAME	POSITION	AGE	HOME ADDRESS
ECCLES James W.	Chief Engineer MMD# 976307	49	1611 Southwest 56th Ave. Plantation FL, 33317
JONES Ellis E.	First Assistant Engineer MMD# 435-34-5326	57	8017 Coach Dr. Oakland CA, 94605
MATIAS Mike S.	Chief Cook MMD# 586-01-988	65	36383 Cherry St. Newark CA, 94560
WOLDVEDT Omar	Second Assistant Engineer MMD# 501-12-3526	63	4312 Vasser St. Port Arthur TX, 77640
DELGADO Francisco	Messman MMD# 036-48-6304	41	123 Atwood Av. Pawtucket RI, 02860

Vessel description:

4. The AMERICAN EAGLE was of steel construction and had a two house tankship configuration, which was typical for tankships built at that time. The midships (forward) house contained the navigating bridge, radio room, and quarters for the deck officers. This house consisted of three decks and was centered over the #3 and #4 cargo tanks. The bridge deck (lower most deck) contained the ship's office, officer's lounge, chief mate's day room, chief mate's stateroom, owner's stateroom, and staterooms for three other mates. The upper bridge deck (second deck up) contained the Captain's office, Captain's stateroom, radio room, radio operator's stateroom, and several small rooms. The radio room was located on the port side aft. The navigating bridge deck contained the wheelhouse, gyro and chartroom (one space), and the Captain's sea cabin. An enclosed shelter deck area was located on the main deck below the lower most deck of the house. This shelter deck area housed a 40 ton potable water tank, Butterworth and cargo hose storage racks, Bos'n stores, mates stores, and a slop chest. There were eleven (11) Butterworth openings for the #3 and #4 cargo tanks located within the shelter deck area.

5. The after house contained quarters for the remainder of the crew, as well as the galley, officer's mess, and crew's mess. It was located directly over the machinery spaces. The main deck contained quarters for the unlicensed personnel. The poop deck contained quarters for the licensed engineers, steward, cooks, bosun, and pumpman. The officer's mess and crew's mess were both located on the poop deck forward. The officer's mess was located on the starboard side and the crew's mess was on the port side, with the galley located on the centerline between the messes. The two mess rooms were connected by the pantry, which is located directly aft of the galley. The pantry provided open communication between the two mess rooms.

6. The machinery spaces consisted of the engine room and boiler room, with the engine room located forward of the boiler room. These spaces contained the boilers, main propulsion turbines and reduction gears, ships service generators, and necessary associated auxiliary machinery.

7. The AMERICAN EAGLE was a dedicated product carrier with a cargo capacity of 280,455 barrels. The ship was divided into ten cargo compartments. Each of the ten compartments contained a center tank with port and starboard wing tanks for a total of thirty individual cargo tanks. These thirty tanks were grouped into four sections with each section being served by individual discharge and loading pipelines. Each section was capable of being loaded or discharged independently, using four individual cargo pumps. It was also possible to cross connect any of the cargo sections and/or tanks. All of the cargo tanks were equipped with heating coils. Venting of the cargo tanks was accomplished by independent pressure/vacuum (P/V) valves which

were fitted to each tank expansion trunk and terminated approximately five feet above the main deck.

8. The cargo pumproom was located on the centerline directly aft of the #10 cargo tanks. The port and starboard fuel oil tanks were located outboard on either side of the pumproom. The pumproom contained four main cargo pumps, each having a capacity of 7000 barrels per hour. It also contained four stripping pumps and associated piping, valves, and crossover connections necessary to load, discharge, strip, and ballast the cargo tanks.

9. The AMERICAN EAGLE was not equipped with either crude oil washing, inert gas, or segregated ballast. Since the vessel was not carrying crude oil and was not equipped with high capacity tank washing machines it was not required by Coast Guard regulations to have an inert gas system (IGS) installed. The requirements for crude oil washing and segregated ballast for this type vessel don't become applicable until 1 January 1986.

10. The owners, American Foreign Steamship Corp., had requested an exemption from the IGS requirements for the carriage of crude oil in accordance with 46 CFR 32.53-3 on 29 April 1983. Coast Guard Headquarters (G-MTH) reviewed the request and briefed the Chief, Office of Merchant Marine Safety who denied the request for an exemption. The vessel therefore, was precluded from carrying crude oil after 1 June 1983.

11. The AMERICAN EAGLE was equipped with four lifeboats and two inflatable liferafts. Two lifeboats were located on the upper bridge deck of the midships house, one port and one starboard. The other two lifeboats were located, port and starboard, on the boat deck of the after house. The lifeboats were identified numerically as boat #1 through #4. All of the lifeboats were twenty-four feet in length. Each was rated and outfitted for a capacity of 25 persons. The #1 boat was diesel motor propelled and was manufactured by the Marine Safety Equipment Company (MASECO) of fiberous glass reinforced plastic (fiberglass). The #2 and #3 lifeboats were oar propelled of riveted steel construction, manufactured by the Lane Lifeboat Company. The #4 lifeboat was also oar propelled and constructed of riveted steel; it was manufactured by the Welin Boat and Davit Company. Each boat was equipped with a Rottmer type releasing gear, manufactured by the Welin Boat and Davit Company. The lifeboat davit and winch assemblies were also manufactured by the Welin Boat and Davit Co. The two inflatable liferafts were manufactured by the Switlick Parachute Company. One inflatable liferaft had a capacity for 20 persons and the other a capacity for 15 persons. The 15 man raft was located on the upper bridge deck of the midships house, on the port side. The 20 man raft was located on the boat deck of the after house, port side aft of the #4 lifeboat. The inflatable liferafts were last serviced by an approved servicing facility and inspected by the Coast Guard on 27 June 1983.

Last Voyage:

12. On 13 February 1984, the AMERICAN EAGLE loaded a partial cargo of regular leaded gasoline and No. 2 fuel oil at Coastal States Marketing, Corpus Christi, Texas. The vessel then shifted berths and loaded regular leaded gasoline and regular unleaded gasoline at the Champlin Petroleum Company, Corpus Christi, Texas. The loading was completed at 1645 on 15 February 1984. The quantity and location of cargo loaded on the AMERICAN EAGLE was as follows:

CARGO	QUANTITY (approx)	LOCATION
#2 fuel oil	44,911 bbls	#1 & #2 PCS
unleaded gasoline	124,857 bbls	#3 thru #7 PCS
leaded gasoline	75,089 bbls	#8, #9 & #10 PCS

13. When loading operations were completed the AMERICAN EAGLE sailed for Port Everglades, Florida, departing Corpus Christi at 1942 on 15 February 1984. The voyage to Port Everglades was uneventful. Upon arrival at Port Everglades at 0712 on 19 February 1984, approximately 43,245 barrels of unleaded gasoline were discharged to lighten the vessel for Jacksonville, Florida.

14. While cargo was being discharged at Port Everglades, the vessel was boarded by a boarding officer from the Coast Guard Marine Safety Office, Miami, Florida. During his inspection, the boarding officer noted several safety violations including; a firehose missing from its fire station, fire hoses disconnected from fire hydrants, and deteriorated flame screens on several ullage openings. The Master, Francis Powers, was advised of the discrepancies, and was given a copy of the boarding report. Captain Powers testified that he had given the list of discrepancies to the Chief Mate for corrective action. He further testified that he did not know when or if the Chief Mate had corrected any or all of the discrepancies, but he was of the opinion that they had been corrected.

15. At approximately 2042 on 19 February 1984 the AMERICAN EAGLE departed Port Everglades enroute Jacksonville, Florida, arriving at 1630 on 20 February 1984. Approximately 129,906 barrels of cargo were discharged at Jacksonville. The vessel departed Jacksonville at 1940 on 21 February enroute Savannah, Georgia, where it arrived at 0736 on 22 February 1984. The remainder of the cargo on board was discharged at Savannah.

16. The Master, Francis Powers, testified that he had received orders, to proceed to Orange, Texas, where the vessel was to be laid up for lack of a charter. He was further instructed to clean (butterworth) and gas free the cargo tanks prior to arrival at Orange, Texas. Additionally, he was advised that a gas chemist would meet the ship with the pilot upon arrival at Sabine Pass. The gas chemist was to conduct the necessary tests to verify that the cargo tanks were gas free and issue a gas free

certificate before the vessel arrived at the layup berth in Orange, Texas.

17. The AMERICAN EAGLE departed Savannah, Georgia, at 0800 on 23 February 1984 enroute Orange, Texas. The Master, Francis Powers, testified that he was not certain when the tank cleaning and gas freeing operations began. He was of the opinion, however, that the Chief Mate, Edward Mallon, probably started getting the necessary equipment on deck as soon as the vessel departed Savannah, Georgia.

18. Cleaning and gas freeing of cargo tanks is an operation that requires the successful completion of each of several steps. These steps include tank washing or butterworthing, blowing out of the heating coils, and finally ventilating the tanks until they are free of flammable or combustible vapors. There are many industry accepted practices for these procedures. These procedures vary from ship to ship depending on the preference of the person in charge of the operation. There were no specific procedures provided by American Foreign Steamship Corp. to the AMERICAN EAGLE.

19. Tank washing aboard the AMERICAN EAGLE was accomplished using low capacity portable Butterworth tank cleaning machines. The first step in the procedure would be the removal of the Butterworth plates on the tanks to be cleaned. The plates when removed expose the Butterworth opening, which is a hole in the deck (approximately 12" in diameter) through which the Butterworth machine is lowered into the tank. The center tanks on the AMERICAN EAGLE were each fitted with four Butterworth openings and the wing tanks had three openings each. In addition the machines could be lowered through the expansion trunk opening, if necessary. To thoroughly clean a tank it would be necessary to operate machines in each of the openings of the tank. Normally more than one machine is used in each tank simultaneously with several drops (lowering of the machine) made in each opening. Each Butterworth machine is connected to and lowered into the tank through the Butterworth opening by it's hose and a manila line and is suspended in the tank during the washing operation. The hose and attached line are secured to a stand or saddle positioned above the Butterworth opening. The hose is connected to the fire main which is piped to the Butterworth pump. The Butterworth machines are fitted with two nozzles which are each oriented 180 degrees from the other, (opposing nozzle). The two nozzles are connected to a common hub. The entire nozzle and hub assembly rotates on a horizontal axis. Rotating motion is generated by the velocity of the water flowing through and being emitted from the nozzles (similar to a rotating lawn sprinkler). The rotating motion of the hub, through shafting and gearing, is also used to rotate the body of the machine, including the hub and nozzle assembly, around a vertical axis. The rotating motion on two axes provides for complete washing coverage of all tank surfaces within range of the water jets. Water, under pressure (up to 180 psi), is provided by the Butter-

worth pump which takes suction from the sea. Depending on the previous products carried, and the preference of the chief mate in charge of the operation, the Butterworth water could be used at ambient sea temperature, or could be heated by the Butterworth heater, before going to the Butterworth machines. Several drops are normally made in each opening to clean tanks on a ship the size of the AMERICAN EAGLE. Normally a machine would initially be lowered into the tank approximately ten (10) feet from the main deck. After washing at that level for a given length of time the machine would be lowered deeper into the tank usually at 10 foot intervals per drop. This procedure would continue until the entire tank, including the bottom, was washed by the machine. The Butterworth hose is marked every 10 feet to assist in gauging the depth of the machine at any given time. The number of drops made and the washing time at each drop would be dependent on the previous cargo carried, temperature of the washing water, and preferences of the chief mate. As the tanks are being washed they must be continually pumped or stripped to thoroughly clean the bottom and prevent a buildup of residue. A stripping pump is normally used during tank cleaning operations to remove the residue (slops).

20. It is necessary to blow out all of the cargo tank heating coils prior to tank washing to assure that they are free of product and/or product vapors whenever the cargo tanks are to be gas freed; such as in a layup situation. The heating coils aboard the AMERICAN EAGLE during this particular gas freeing operation were blown clean using steam. A steam hose was connected from the deck steam line to each cargo tank heating coil manifold individually. The fixed steam piping to the manifold had been blanked off because the heating coils had not been used for the most recent cargoes. A hose was also connected to the condensate, or return side of the heating coil manifold. This hose, depending on tank location, was either led to the slop tank (#10 center) or to a 55 gallon drum on deck. Steam was admitted to each coil individually and allowed to blow through until clean condensate came out of the return line. Testimony from the Chief Engineer, James Eccles, indicated that approximately 50% of the heating coils blown out by the engineers showed evidence of product in them. The product, from previous cargoes, entered the coils through leaks in the coils.

21. Ventilating cargo tanks is usually accomplished by placing one or more high volume blowers over Butterworth openings to displace a gaseous or oxygen deficient atmosphere with fresh air. Normally, all tank openings would be open during this procedure. One of the most common types of blowers used for gas freeing operations is a Coppus blower. Coppus is a trade name of a small steam turbine driven vane type blower. These blowers are portable and fit directly over Butterworth openings. They are powered by low pressure saturated steam normally available on the deck of steam tankships, such as the AMERICAN EAGLE. The spent steam is exhausted to the atmosphere and does not enter the cargo tanks.

22. Cargo tank gas freeing on 26 February 1984 was being accomplished using a steam driven Coppus turbine blower and a Lamb air mover (Figures 12 and 13) to ventilate the cargo tanks. The Lamb air mover ventilator is a lightweight portable venturi type ventilator marketed by the Mine Safety Appliances Company (MSA). The operation of the Lamb air mover ventilator is pictorially depicted in Appendix A. The units carry a warning label (Figure 14) which states: "This air mover should be properly grounded to prevent static discharge when used in atmospheres containing combustible gases, vapors, or dusts." A new air mover, made available to the Board for examination, carried the warning label, however there were no provisions available for grounding, i.e. grounding cable or lug. Similar devices, manufactured by other manufacturers, do have grounding connections.

23. The two six inch Lamb air movers aboard the AMERICAN EAGLE were relatively new additions to the ship, having been purchased and brought aboard in December of 1983. In his testimony, Captain Powers indicated that the air movers were purchased to provide ventilating air to personnel working in tanks. The devices were purchased after Powers and the Port Engineer for American Foreign Steamship Corp., Mr. Ray Butler, discussed the merits of the air movers. In reading the advertising literature the Captain noted that since the devices were suitable for use in hazardous atmospheres, he felt they would be safe for use on a tanker. In response to a question as to whether the air mover would be appropriate for use on the AMERICAN EAGLE, Captain Powers responded "Well, if they were inappropriate, I wouldn't have had them brought aboard the ship. I looked at it (the brochure) and I was satisfied with it". Further in response to a question "so you evaluated the device from the ads and decided it was appropriate---?" he responded, "yes, sir". The Master was also queried as to whether at any time prior to the explosion he had relayed to the Chief Mate that the air mover should only be used if it had been properly grounded. He said he felt that the metal to metal contact (device to deck opening) would cause the device to be grounded. The Master stated that if any instructions were pertinent they would have come with the device and would have been in the possession of the Chief Mate.

24. An air mover was being used to supplement the one operational Coppus blower in the gas freeing operations on 26 February 1984. The other blowers on board were not operational and were in need of repair. The air mover in operation at the time of the casualty was being operated with steam. When asked why it was decided to operate the air mover with steam rather than compressed air, Captain Powers said, "Well, the...again this air situation." In further testimony he added that the air movers use a "fabulous amount of air" and the AMERICAN EAGLE's supply of compressed air was limited. The air movers were designed to operate effectively on compressed air or steam. Since there was a limited supply of compressed air on board and an unlimited supply of steam, steam was used.

25. The AMERICAN EAGLE was equipped with four air compressors. One was dedicated to operating the boiler management system and air operated regulating valves in the machinery spaces. Of the remaining three air compressors only two, according to the Chief Engineer, were operational on 26 February 1984. The 95 CFM (cubic feet per minute) compressor was on the line for ships service air and the 80 CFM compressor was on standby, presumably to be used for soot blowing operations. The large 200 CFM air compressor was out of service because of mechanical problems. Normal air pressure on deck would be approximately 110 PSI. A performance chart published by MSA, indicates that a six inch air mover would consume 670 CFM of compressed air at 100 PSI.

26. The air movers used on board the AMERICAN EAGLE were both six inch models. The Board, on a visit to a sister vessel, the SS AMERICAN OSPREY, opened up a Butterworth opening and placed an identical air mover in the opening. The Board found that the air mover horn, when rigged for blowing into the tank, would fit through the Butterworth opening. The air mover bell flange would rest on the deck, inside the Butterworth opening's circle of stud bolts. It was noted that if the Butterworth gasket remained in place on the deck, it was possible for the air mover to lay on the gasket without having a metal to metal contact with the deck of the ship.

27. The tank cleaning and gas freeing operations continued as the AMERICAN EAGLE proceeded from Savannah, Georgia, to Orange, Texas. On Sunday morning the 26th of February 1984, the gas freeing operations were nearly complete with approximately four cargo tanks remaining to be cleaned and gas freed. Richard Poole, an able bodied seaman, stated he recalled the four remaining tanks to be #2 center, #6 port and starboard, and #8 or #9 center. Mr. Salsbury, the Second Mate, thought that #2 center, #3 center, #6 port or starboard and #9 center remained to be cleaned and gas freed. Both witnesses agreed that four cargo tanks remained to be cleaned and gas freed before the vessel arrived at Orange, Texas. The First Assistant Engineer, Jones, testified that the Chief Mate had told him at breakfast on Sunday morning that he (the Chief Mate) would probably have to blow #3 center again, because it wasn't gas free.

28. As the tank cleaning and gas freeing operations progressed some difficulty was experienced in stripping the dirty wash water from tanks in the midships section. According to Joseph Foster, an able bodied seaman, they had put all four stripping pumps on #6 starboard, on Saturday evening and still were unable to pump the water out. The Master confirmed that the Chief Mate had some problems stripping tanks in the midships section. He testified that the Chief Mate had used a main cargo pump on Sunday morning to remove some of the tank washing water (slops).

THE CASUALTY

29. During the morning of 26 February 1984, the AMERICAN EAGLE was underway in the Gulf of Mexico enroute to Orange, Texas, on a course of 291 degrees true at an estimated speed of 13 knots. The engines were turning approximately 75 RPM's. The ETA (estimated time of arrival) at the pilot station was 0300 on 27 February 1984. The weather, according to the testimony of the Master and the Third Mate, was hazy with a visibility of 5-6 miles. The wind was out of the South at 10-12 knots. The seas were 3-4 feet. The water temperature was 13 degrees Celsius (65 degrees fahrenheit). See analysis section of report for more detailed weather information.

30. The Third Mate, Aloyz Vanek, had the bridge watch from 0600-1200 on the morning of 26 February 1984. Vanek and the Second Mate, Mr. Salsbury, divided up the Chief Mate's watch, each standing six hours on and six hours off during tank cleaning operations. This practice allowed the Chief Mate to devote all of his time to the tank cleaning operation. The morning watch was divided between AB Jose Del Rio and AB Richard Poole. Del Rio had the wheel watch from 0800 to 1000, Poole relieved him at 1000 and was to remain on watch until 1200. Third Mate Vanek and AB Poole were on watch when the explosion occurred.

31. The 0800-1200 engineroom watch consisted of Third Assistant Engineer Lou O'Neal and Engineman, Samuel Winburn. The First Assistant Engineer, Ellis Jones, was working on deck repairing a steam line for the midships house heating system. The steam line was located on the main deck between the two houses. Jones repaired the line by installing a longer section of pipe between two dresser couplings. Hot work was not involved in this repair. Jones completed his repairs around 1040 and then went aft to the boiler room. Jones and the 0800-1200 engineroom watch were in the machinery spaces when the explosion occurred.

32. The Chief Engineer, James Eccles, was on the main deck forward of the midships house repairing another steam line during the morning of 26 February 1984. He was making temporary repairs to the branch steam line which supplies steam to the #2 cargo tank heating coil manifold. Eccles made the repairs using a commercial pipe clamp designed to make temporary repairs. Hot work was not involved in making this repair. He completed his repairs between 1015 and 1030, at which time he went aft to the fuel oil settling tanks where he was transferring fuel oil. When the explosion occurred Eccles was in the port alleyway of the aft house on his way to get a drink of water. The Chief Engineer stated he did not know if there was any tank cleaning operations in progress on the main deck when he was making his repairs. He also said the only person he saw on the foredeck was the Master.

33. On the morning of 26 February 1984, the Master after having completed some ship's paperwork, went out on deck to observe the progress of the tank cleaning operations. At approximately 0900, he had a short discussion with the Chief Mate, who had just climbed out of #5 center cargo tank, where he examined a main cargo valve. Sometime later Powers went to the foredeck area. On the foredeck he met Eccles, the Chief Engineer, in the process of repairing a steam line. Powers and Eccles carried on a conversation while Eccles repaired the steam line. Powers stated he saw the air mover in operation in the #2 port cargo tank. He also said he walked over to the air mover and felt the flow of air being drawn through the unit. He noted that the air mover was being operated by steam. He did not see a grounding cable or wire connecting the air mover to the ship. Powers testified that, with the exception of the Chief Engineer, he did not see anyone on the foredeck. He also said it was coffee time, so whoever may have been working on the foredeck area, would probably have been aft having coffee. After he examined the air mover, Powers went aft, through the port side of the shelter deck. Powers met the Pumpman on the after deck and had a brief discussion with him concerning the problems encountered in stripping #6 starboard cargo tank. The Pumpman then went forward through the shelter deck to the foredeck. Captain Powers was in the vicinity of the #6 port and center cargo tanks when the explosion occurred.

34. Able Bodied Seaman, Richard Poole, relieved Jose Del Rio of the wheel watch at approximately 0950 on 26 February 1984. The vessel was on auto pilot, so it was not necessary for Poole to actually steer the vessel. Shortly after relieving the watch, Poole looked out of the forward pilot house windows and saw three men working on deck; they were Edward Mallon, the Chief Mate, Jack Campbell, the Bosun, and Roy Carter, the Pumpman. He also saw an air mover in a #2 port Butterworth opening operating on steam, blowing air and steam into the tank. After coffee break, at approximately 1030, Poole, looking out an open pilothouse window, observed the Bosun and Pumpman remove the air mover from #2 port. Watching the operation from the pilothouse it appeared to Poole that the air mover was too hot for the men to handle, so they pulled it out with a rope. As they removed it, he saw a plastic sleeve attached to the horn of the air mover. It was his opinion that this plastic sleeve probably extended to within a couple of feet from the bottom of the tank. After the plastic sleeve was pulled out of #2 port, the Bosun cut off approximately two feet of the plastic sleeve. Poole then observed the Bosun lowering the remaining plastic sleeve into the port Butterworth opening of #3 center cargo tank. Poole presumed that the air mover, with attached plastic sleeve, was placed in the #3 center cargo tank in the same manner that it had been in the #2 port cargo tank, with the conical part or horn inside the tank. While the Bosun and Pumpman were busy with the air mover, the Chief Mate was in the process of blowing the heating coils in the #2 across cargo tanks. After the Bosun put the plastic sleeve, which was attached to the air mover, in #3 center tank, Poole

stepped back from the window. A few seconds later a tremendous explosion occurred. Poole assumes the next thing the Bosun or Pumpman did after relocating the air mover, was to open the steam valve supplying steam to the air mover. The air mover was seen laying on deck in the vicinity of #1 starboard cargo tank after the explosion.

35. At approximately 1045 on 26 February 1984 the AMERICAN EAGLE suffered a major explosion in one or more cargo tanks forward of the midships house. The vessel was located 110 miles South-Southwest of Grand Isle, Louisiana, in approximate position 27-30N, 91-30W when the explosion occurred.

36. The force of the explosion threw Poole into the air with his head hitting and breaking some of the pilothouse overhead panels. He then fell down and landed on the platform behind the wheel. Poole, dazed from the explosion, picked himself up and sat in a chair. Vanek, the Third Mate, assisted Poole to the chair, then immediately put the engine order telegraph on stop. Poole and Vanek looked out of the bridge window and observed the damage to the ship from the explosion. In addition, they saw the Chief Mate, the Bosun, and the Pumpman lying on the foredeck in the vicinity of the #2 and #3 cargo tanks, all apparently killed by the explosion. Poole, Vanek, and the Radio Operator, Fred Conklin, were severely injured by the explosion. The Second Mate, John Salsbury, was also injured.

37. The area forward of the midships house was severely damaged as a result of the explosion. The main deck was upset with a large separation in the deck on the port side, extending from the focsle to aft of the midships house. In addition several holes were blown out on both sides of the hull and a tear in the starboard side shell plating extending from the focsle, aft to somewhere in the vicinity of #5 starboard cargo tank. This tear was located about 1/3rd the way between the main deck and the waterline. The port side shell plating was bulged out in way of the #3 and #4 port cargo tanks. The port wing of the midships house was partially collapsed and the forward port lifeboat was hanging from the after davit. The forward starboard lifeboat was hanging at a 45 degree angle, with the bow down, but still being supported by both davits. Figures 2-5 show much of the damage. Most of the quarters and offices in the midships house were left in a shambles as a result of the explosion. Apparently no damage occurred to anything aft of the midships house. Cargo tanks #6 through #10 across appeared to be intact with all tank openings (Butterworth and expansion trunks) in the open position, having been left open after the tanks were gas freed.

38. The Master, Francis Powers, after hearing and feeling the shock of the explosion, observed the port wing of the pilothouse collapse; he also saw orange smoke. He immediately proceeded to the pilothouse where he found Vanek and Poole injured and the bridge in a shambles. He quickly assessed the situation and after being certain there was no fire, quickly went to the radio

room to insure an S.O.S. signal was sent. He later determined that the orange smoke he had seen was from a quick release ring buoy smoke float that was activated by the force of the explosion.

39. The general alarm was not sounded after the explosion, nor were fire hoses led out, nor was a fire watch set. The ship's whistle did blow, however this was later determined to be as a result of the explosion damaging the control cables. The whistle continued to blow until the First Assistant Engineer secured the steam to it. According to witness testimony it was not blowing at full strength, however it was loud enough for the entire crew to hear. When asked why the general alarm was not sounded nor a fire watch set, the Master said he didn't feel there was any danger of fire. He added that after the explosion the vessel stabilized on an even keel and he was quite certain it was not in danger of sinking.

40. When Powers arrived at the radio room, he found the Radio Operator, Fred Conklin, on the deck with his head laying against the transmitter bench. He was severely injured and the radio room was in complete disorder. He inquired if the Radio Operator could send out an S.O.S. signal, to which the radio operator replied, "Captain, I have tried but nothing works". Powers then proceeded aft to send a distress signal on the portable emergency transmitter, which was stowed in the officers mess, in the aft house. When he reached the after house, he found that some of the crew were already in the process of setting up the transmitter on the poop deck. A long wire antenna was rigged, and a ground connection was made. Captain Powers with the assistance of other crewmembers went through the steps to operate the emergency transmitter. After going through the steps several times, Powers was not sure the transmitter was operating properly. He felt he did not get all of the proper indications or responses as he followed the step by step procedures of the operating instructions. They continued operating the emergency transmitter for approximately one and one half hours.

41. Salsbury, the Second Mate, having had the 0000-0600 watch, was asleep when the explosion occurred. His room was located in the midships house, first deck, forward on the port side. Salsbury was awakened by the explosion and thrown from his bunk. He heard a blast, felt a shock, and at the same time his bunk was overturned, throwing him to the deck between his bunk and the bulkhead. He immediately went outside, looking for any signs of fire which he did not see. Salsbury noted that both the #1 and #2 lifeboats were hanging at an angle, apparently by one fall. Seeing the condition of the forward boats, he immediately went aft to ready the #3 and #4 lifeboats for lowering and abandoning ship. He found several crewmembers clearing the #3 lifeboat when he arrived. Both after lifeboats were readied for lowering. When he realized that the vessel appeared to be steady, with no noticeable change in list or trim, he discontinued the operation and left the lifeboats ready for lowering, but did not lower them.

42. After working with the emergency transmitter for some time, Captain Powers went forward to give Conklin, the Radio Operator, an injection of morphine to ease his pain. At that time Conklin told Powers that he had heard him transmitting a weak signal on 500 KHZ from the emergency transmitter. After a brief discussion with Conklin, Powers went to the radio room and attempted to operate the battery powered emergency transmitter. He was unable to get it to operate. Powers then tried the 2182 transmitter. When he depressed the transmit button he could hear a change in the noise level of the radio. He attempted to transmit a voice S.O.S. on it. After several attempts without receiving a reply, he went up to the flying bridge where he found the antenna broken. He jury rigged an antenna and tried again. After several attempts the radio went dead. Powers then attempted to use a VHF radio on channel 13; that effort also proved to be futile.

43. The Radio Operator, Fred Conklin, was on watch in the radio room when the explosion occurred. The force of the explosion threw Conklin to the overhead, severely injuring his neck. Conklin believes that there were a series of successive explosions. He was uncertain how many there were, but was sure there were no less than three separate explosions. Conklin was severely injured and unable to get up from the floor. He was able to get on his knees, and attempted to operate some of the radio equipment, without success.

44. Powers then went to the main deck where some of the other crewmembers were attempting to signal a distant passing ship with rocket propelled parachute flares. Some difficulty was experienced in using these flares. The Chief Engineer received burns to his right hand when one of the flares fired through the bottom rather than firing normally. According to witness testimony most of the flares used failed to operate properly (See analysis section). In addition to the pyrotechnics, an attempt was made to signal a passing ship with a mirror. All attempts to signal other vessels using visual signals failed.

45. Unable to attract attention with flares, Powers returned to the radio room and examined the multi-channel VHF radio. The radio had been blown off it's wall mounting bracket and was laying on the deck with the electrical connections pulled free of the chassis. Powers reconnected the electrical and antenna connections, turned on the power, and the radio came on.

46. Powers and the Second Mate, Salsbury, went to the bridge and using the remote unit for the multi-channel VHF radio, began sending mayday messages on channel 16. They broadcast a mayday several times and received a faint reply from someone who said they were in San Francisco. A workable line of communication was not established between the AMERICAN EAGLE and the party in San Francisco. Shortly thereafter the M/V MOBIL VALIANT responded to the mayday. Satisfactory communications on channel 16 were maintained thereafter.

47. Captain Powers requested that the MOBIL VALIANT contact the Coast Guard and Mr. Harry Marshall of American Foreign Steamship Corporation. The initial message relayed to the Coast Guard advised that the AMERICAN EAGLE had suffered an explosion on the forward main deck, was in position 27-30N, 91-30W and was stopped; there was no fire; three casualties to be evacuated by helicopter if possible, and the AMERICAN EAGLE was having communications problems due to the damaged radio room. In response to a Coast Guard query, the AMERICAN EAGLE passed via the MOBIL VALIANT that the ship had a fracture in the hull and was inoperable. In a later transmission the Coast Guard was advised that the AMERICAN EAGLE was stopped and in no immediate danger.

48. At approximately 1543, the M/V FORT EDMONTON was within radio range of the AMERICAN EAGLE and relieved the MOBIL VALIANT as a communications relay. The FORT EDMONTON arrived at the AMERICAN EAGLE's position at approximately 1624. It remained on scene and acted as a communications relay and standby vessel.

49. During the afternoon of 26 February 1984 the Master, Francis Powers, directed the Chief Engineer, James Eccles, to take several crewmen and secure all of the cargo valves. The Chief went down in the cargo pumproom with several crewmembers and insured that all of the valves were secured. The individual cargo tank valves were also secured. There was no effort made by the Master or any other person to close the open cargo tank expansion trunk hatches or Butterworth openings. The cargo tank hatch covers remained in the open position and were open when the vessel sank the following day.

50. The bodies of the Chief Mate, Edward Mallon, the Bosun, Jack R. Campbell, and the Pumpman, Roy D. Carter, were looked at by the Second Mate, John Salsbury shortly after the explosion. He did not examine them closely but from their general appearance, they appeared to be dead. Salsbury indicated that all three of the bodies were in the vicinity of #2 and #3 center cargo tanks. Later in the day some crewmembers were sent forward to cover the bodies. The Master, Francis Powers, stated that he had intended to move the bodies aft, however due to other priorities and procrastination on his part, the bodies were not moved on 26 February 1984. The following day with the weather deteriorating and the increased movement of the hull he considered it unsafe to do so. The bodies were not moved and remained on the fore deck and were lost at sea or went down with the vessel.

51. In preparation for the Coast Guard helicopter to evacuate (medivac) the injured crewmen, Powers directed the #3 and #4 davits to be swung in and the lifeboats stowed. He was concerned that the rotor wash from the helicopter might damage the boats if they were left hanging from the davits. In addition, he lashed down the inflatable liferaft stowed on the port side aft. This lashing was subsequently removed after the medivac. Three of the four more seriously injured personnel (Salsbury was ambulatory and remained on the ship) had been previously moved

from the forward house to the after house. The Coast Guard Helicopter (CG-1485) arrived on scene at approximately 1648, and lowered a Hospital Services Technician (HS) to treat the injured prior to moving them. The injured were then hoisted aboard the helicopter. Before the HS returned to the helicopter, Powers requested her to go to the forward deck area and look at the three people presumed killed by the explosion. She verified that all three were dead, and returned to the after deck where she was hoisted aboard the helicopter. The helicopter departed the AMERICAN EAGLE with the three injured crewmembers at 1813. The injured crewmembers were transported to Meadowcrest Hospital, Belle Chasse, LA, for treatment after the helicopter landed at the Naval Air Station, Belle Chasse, Louisiana.

52. A radio watch was maintained on the bridge by John Salsbury, the Second Mate, during the afternoon of 26 February 1984. Because of the severe damage to the forward portion of the ship as a result of the explosion, the Captain was reluctant to allow anyone to remain in the midships house during the night. He did, however want to maintain communications with the FORT EDMONTON throughout the night. After some preliminary discussions with the Chief Engineer and the Second Mate, the Captain decided to move the VHF radio from the radio room to the Officer's mess in the after house. The radio move was successfully accomplished and communications were again established with the FORT EDMONTON at approximately 2000.

53. The routine aboard the AMERICAN EAGLE was relatively normal throughout the night of 26 February and during the morning of 27 February. Regular watches were maintained in the engineroom, with both boilers on the line and auxiliaries operating normally. The main turbine had steam on and was turning at approximately 7 or 8 RPM's, to keep the engine warm and prevent the turbine shafts from warping. The stewards department continued to provide regular meals. During the night a lookout watch was maintained on the fantail by the deck department. The Master and the Second Mate alternated standing a radio watch in the Officers mess.

54. Mr. Harry Marshall, Vice President in Charge of Operations, for American Foreign Steamship Corporation was notified of the explosion at approximately 1600 (eastern standard time) by the M/V MOBIL VALIANT through MARISAT. Shortly thereafter the Coast Guard Operations Center in New Orleans called Mr. Marshall and confirmed the information concerning the explosion. Mr. Marshall immediately began making arrangements for a salvage tug and a repair yard to which the AMERICAN EAGLE could be towed. He was able to engage the salvage tug SMIT NEW YORK and made arrangement for it to proceed to the AMERICAN EAGLE and tow it to Galveston, TX. The SMIT NEW YORK departed Port Arthur, TX, at around 2200 with an initial ETA at the position of the AMERICAN EAGLE at 1200 on 27 February 1984. The SMIT NEW YORK arrived on scene at approximately 1900 on 27 February 1984.

55. Exploratory oil drilling was being conducted in the Gulf of Mexico in vicinity of the reported position of the AMERICAN EAGLE when the explosion occurred on 26 February 1984. There were several drilling rigs operating within a 40 mile radius of the reported position of the explosion. During the early morning of 27 February 1984, at approximately 0100, the AMERICAN EAGLE drifted by, within one mile of the MODU (mobile offshore drilling unit) ZAPATA LEXINGTON. The anchored position of the ZAPATA LEXINGTON was 22 miles north of the initial reported position of the disabled AMERICAN EAGLE.

56. The weather continued to deteriorate throughout the night and morning of 27 February 1984. The FORT EDMONTON relayed a weather report on the morning of 27 February which predicted winds of 30 knots and 18 foot seas. As the weather deteriorated, the movement and grinding noises of the damaged bow section increased. Several witnesses testified they could see the bow section move independently of the remainder of the hull as early as 1300 on 27 February 1984. The disabled vessel continued to drift with the wind and seas. At 0800 on 27 February the FORT EDMONTON reported the AMERICAN EAGLE drifting on a course of 071 degrees at three knots. The AMERICAN EAGLE was rolling in the trough, broadside to the seas.

57. At approximately 1000 on 27 February, personnel on board the MODU SEDCO 702 became concerned that the AMERICAN EAGLE might drift down on the anchored rig and advised the M/V ENTERPRISE (an offshore supply vessel standing by and working for the SEDCO 702) to be on the lookout for it. The M/V OCEAN BONITA, an offshore supply vessel on a towline (180 feet at 280 degrees) to the SEDCO 702, reported the AMERICAN EAGLE at a bearing (radar) of 263 degrees, with a range of 8 miles. The range continued to decrease with the bearing remaining relatively constant. The ENTERPRISE was ordered to proceed to the AMERICAN EAGLE and offer to assist. The Master of the AMERICAN EAGLE was advised by the ENTERPRISE that it was on a collision course with several MODU's anchored in the area.

58. Captain Powers, in response to the information reported by the ENTERPRISE, attempted to change the position and heading of the AMERICAN EAGLE using the ship's engine and rudder. He secured the engine and rudder after realizing it would take more power and speed to get the vessel out of the trough than he thought the damaged bow could sustain. After some discussions concerning liability and contracts, it was agreed that the ENTERPRISE would attempt to tow the AMERICAN EAGLE stern first. A towing cable was passed, however the AMERICAN EAGLE did not have adequate gear available on the stern to secure it to the ship. The cable was eventually secured in a "jury rigged" fashion. The ENTERPRISE let out 2000 feet of towing cable and began to take a strain on the cable. The towing cable pulled free from the AMERICAN EAGLE as soon as a good strain was taken. The towing cable was recovered and passed to the AMERICAN EAGLE a second time. This time the crew of the ENTERPRISE attached two

smaller wire pendants to the towing cable. The pendants were secured aboard the AMERICAN EAGLE, the towing cable was again let out, and a strain taken. The ENTERPRISE towed the AMERICAN EAGLE an estimated 15-45 minutes to maneuver it clear of the drilling rigs. The AMERICAN EAGLE was towed enough to allow it to drift past the SEDCO 702 without incident. In so doing the AMERICAN EAGLE was moved out of the trough, with the stern being towed in a direction where the vessel was riding with the seas on the stern quarter. Shortly after the towing operation began the bow started to work violently and independently of the rest of the hull. Captain Powers immediately asked the ENTERPRISE to stop towing.

59. The hull of the AMERICAN EAGLE, severely weakened as a result of the explosion, began to work as the vessel rode in the seas. The situation continued to get worse as weather conditions deteriorated. The bending movement of the hull was not severe as long as the vessel remained in the trough and rode with the seas. When the ENTERPRISE towed the stern out of the trough into a position where it was quartering the seas, the movement of the hull accelerated. The bow continued to work as the ship rode across the seas stern quarter to. The working progressed to the point where the bow was hinging at the main deck, just forward of the midships house. The bow section would swing up and down, pointing vertically, with the anchor windlass and focs'le deck smashing into the forward section of the midships house. This working action continued until the port side broke free. The bow continued to swing upward and also hinge around to the starboard side with the bow facing aft at times. The ship continued to roll and pitch with the seas. The Captain and the crew hoped the bow would break away clean and leave the stern section afloat. At one point the forward end of the stern section went down with the seas, but did not return to the usual horizontal position it had been returning to. The Captain realized the stern section would probably not remain afloat much longer. He immediately ordered the Chief Engineer and the Second Mate to get everyone up to the lifeboats and prepare to abandon ship. The general alarm was not activated nor was a formal muster or accounting of personnel taken. The AMERICAN EAGLE continued to go down by the head and list to starboard.

The Evacuation and Rescue

60. The entire crew wearing lifejackets, assembled on the after boat deck starboard side. A roll call was not taken, however, from the testimony of several witnesses, it is certain all hands were present and did abandon the ship. The starboard lifeboat was prepared for lowering and was lowered to the embarkation or boat deck. The port lifeboat was not used as the vessel was now listing approximately 25 degrees to starboard. There

was no attempt made to launch either inflatable liferaft. The starboard lifeboat was not secured to the side of the ship with frapping lines, but was allowed to swing with the motion of the ship. The swinging made it difficult for some of the crew to enter the lifeboat and frightened others. Several crewmembers required physical assistance in boarding the lifeboat. All hands got into the boat with the exception of the Master, Second Mate, and three other crewmembers, who were either afraid to jump to the swinging boat or to ride the boat to the water. There was some confusion as to whether the sea painter was led out and secured to the ship. The Second Assistant Engineer, Omar Woldvedt, testified he walked the sea painter aft, decided it was not necessary to secure it, and left it hanging there. When queried further as to where he left the painter, he replied "It was run across the davits and that's where I left it hang. I didn't tie it. It was loose." The Second Mate, John Salsbury, stated he saw Ellis Jones, the First Assistant Engineer, secure the sea painter on the boat deck several feet forward of the davits. An AB, Joseph Foster, testified "The Second Mate was standing there and I threw him the sea painter and he led the painter forward, yes." The Board was unable to determine where or how the sea painter was secured.

61. When the crew was in the boat, the lowering operation began. The Second Mate, John Salsbury, operated the brake release lever, allowing the boat to lower by gravity. The boat, as it was descending slowed and/or stopped lowering several times. When the boat slowed or stopped the Master would spin the brake flywheel of the davit winch assembly, and the boat would continue to lower. The boat continued to lower until it reached a point approximately 4 to 15 feet from the water where it stopped. The Second Mate insured that the brake was free and the Master continued to turn the flywheel. The Master testified that the flywheel, which was coupled directly to the davit's winch drums, turned freely. Despite the efforts of the Master and the Second Mate, the lifeboat failed to continue lowering and remained suspended above the water. No one was able to testify as to why the lifeboat failed to lower completely to the water.

62. When the boat stopped lowering there was much panic and confusion in the lifeboat. Many crewmembers, afraid the ship was going to roll over on them, jumped from the boat into the water. Those that remained in the boat operated the Rottmer releasing gear and the boat dropped into the water.

63. The boat dropped into the sea, rolled, and returned to a floating upright position. The crewmembers remaining in the lifeboat, after some difficulty, released the sea painter toggle. The boat remained alongside the ship with the crew unable to get

it away. Some crewmembers thought the current was holding the boat in position alongside the ship when actually the lifeboat was held in the lee of the wind driven ship. The ship continued to go down by the bow and list to starboard. Afraid the ship was going to roll over on them, those remaining in the lifeboat jumped into the water. All of the people in the water experienced difficulty in getting away from the ship. Some tried to swim away from the ship on the starboard side, but the seas would pick them up and wash them back towards the ship. Eventually the seas swept all of the crewmembers around and under the stern of the ship. The rudder and propeller were completely out of the water at this time. Some hung onto the lifeboat which had also drifted around the stern and clear of the ship. Others hung on to pieces of debris floating in the water. Shortly after people entered the water, heavy black oil appeared, coating everyone and everything. The Chief Engineer testified that the oil probably came out of the vents of the after fuel oil settling tanks.

64. Shortly after the ENTERPRISE arrived on scene and commenced the towing operation, two additional offshore supply vessels, the M/V STARLIGHT and M/V LIBERATOR, arrived on scene to lend whatever assistance they could. When it was evident that the AMERICAN EAGLE was going to sink, the ENTERPRISE cut her towing cable and proceeded back to the AMERICAN EAGLE to rescue survivors. In the meantime the STARLIGHT and LIBERATOR had positioned themselves upwind, off the port quarter of the AMERICAN EAGLE, and prepared to pick up survivors. When the AMERICAN EAGLE started to break up, the toolpusher on the MODU PENROD 76 notified the Coast Guard Rescue Coordination Center (RCC) in New Orleans via telephone (microwave link). The Coast Guard immediately diverted a HH-3F (CGNR 1477) helicopter from another mission to the AMERICAN EAGLE. The Coast Guard helicopter arrived on scene at approximately 1735 and commenced rescue operations. It recovered four crewmen, three from the water, and one from the ENTERPRISE who appeared to have expired before he reached the helicopter. The four airlifted crewmen were flown to the Coast Guard Air Station in Belle Chasse, LA, for further transfer to Jo Ellen Smith Hospital in Algiers, LA.

65. The three supply boats each maneuvered into an upwind position off the port stern quarter of the AMERICAN EAGLE to pick up survivors. The seas at the time were running from 20-30 feet with wind blowing 30 to 40 knots, and gusting up to 50 knots. The heavy sea and wind conditions made it difficult for the rescue vessel personnel to sight the people in the water. In addition, bunker "C" fuel oil from the sinking AMERICAN EAGLE coated the survivors making them yet more difficult to spot. In spite of the heavy weather and boarding seas, the three rescue vessels maneuvered alongside people in the water, and the crews pulled them on board the after cargo decks. To facilitate the rescue operations, ring buoys and PFD's were thrown to people in the

water. Many of the people in the water were unable to help themselves, making it necessary for some of the crewmen on the supply vessels to lie down on the cargo decks and reach down and pull people aboard. The Chief Engineer on board the STARLIGHT jumped into an AMERICAN EAGLE lifeboat to assist people clutching to the far side of the lifeboat. Once on board the survivors were given first aid attention, hot food, hot showers and warm dry clothing.

66. The Steward, Andrew Fotopolous, and Messman/Utility Antone Sylvia, died during the rescue operations. Messman/Utility Earl Evans testified that Sylvia, himself and others were in the water and holding on to the #3 lifeboat after abandoning the AMERICAN EAGLE. Evans added that Sylvia was very panicky while in the water. Evans had to assist him several times. Engineman Gene Ayler testified that during rescue operations, a wave swept Sylvia around the bow of the lifeboat and he was momentarily pinned between the lifeboat and the rescue vessel STARLIGHT. Ayler further testified that Sylvia's head was struck when he was pinned between the two boats. Sylvia then let go of the boat and appeared to be unconscious. The crew of the STARLIGHT pulled him aboard and attempted CPR. They were unable to revive him. An autopsy conducted by the St. Mary Parish, LA coroners office indicated that Sylvia died of drowning. The autopsy also indicated there was no evidence of injury or trauma to Sylvia's head. The body of Antone Sylvia was transported to New Bedford, Massachusetts, where he was interred in St. John Cemetery on 3 March 1984.

67. Andrew Fotopolous, after abandoning the AMERICAN EAGLE and while drifting in the water, was approached by the ENTERPRISE. According to John Draggone, Master of the ENTERPRISE, a ring buoy was thrown to Fotopolous, he held it momentarily then let it slip away. The ENTERPRISE maneuvered so that Fotopolous was near an opening in the bulwarks. Several crewmen were helping him aboard, when Fotopolous appeared to lose his strength and slipped away. A wave brought him close to the opening again, crewmembers grabbed him and brought him aboard. It was apparent to the crew of the ENTERPRISE that Fotopolous was not breathing. CPR was started and the nearby Coast Guard helicopter was notified of his condition. After rescuing three other crewmen the Coast Guard helicopter hoisted Fotopolous from the ENTERPRISE. CPR was continued during the flight to New Orleans. Fotopolous was pronounced dead after arriving at Jo Ellen Smith Hospital in New Orleans. The cause of death listed on the death certificate was unclear to the Board. Therefore the doctor performing the autopsy was contacted. He stated the cause of death was not readily apparent, however his opinion was that Fotopolous died as a result of immersion (hypothermia combined with some aspiration of water). The doctor added, there was insufficient water in the lungs to cause drowning. The remains of Andrew Fotopolous were transported to Missoula, Montana, where he was interred in Sunset Memorial Gardens.

68. Despite the rescue efforts of the the three offshore supply boats and the Coast Guard helicopter two AMERICAN EAGLE crewmen were not recovered. The three offshore supply boats and the ocean going tug SMIT NEW YORK, which arrived on scene at approximately 1900, continued searching the area until approximately 2400. Another Coast Guard HH-3F Helicopter (CGNR-1486) arrived on scene at approximately 1915 and dropped a data marker buoy to aid in computing the drift of survivors. CGNR-1486 continued searching until 2123 with negative results. Coast Guard aircraft searched the area on 28 and 29 February 1984 with negative results.

69. According to witness testimony the two missing crewmen, Able Seaman, Steger Burney and Ordinary Seaman, Earsel Warren, both abandoned the AMERICAN EAGLE and entered the water with the rest of the crew. The Master, Francis Powers, testified he saw Earsel Warren in the lifeboat before it was lowered. Jose Del Rio, an able bodied seaman, testified that Earsel Warren swam to Del Rio and grabbed hold of him for a short time. Shortly thereafter Warren let go of Del Rio and started swimming toward one of the offshore supply vessels standing by. Del Rio stated that Warren was wearing a lifejacket. Warren Evans, a wiper, testified that Steger Burney and himself both clung to the same lifeboat oar while floating in the water after abandoning the ship. Evans added that Burney had on a life preserver and one minute Burney was hanging onto the oar and the next minute he was gone. Evans did not see Burney again. There is no further evidence of Warren or Burney having been seen by anyone after these incidents.

70. The AMERICAN EAGLE continued to sink by the head and list to starboard after the vessel was abandoned. The bow section remained attached to the stern until sometime after the crew abandoned the vessel. The stern section sank at approximately 1735 in position 27-48.93N, 90-44.67S. The bow section was later sighted afloat in a vertical attitude and was kept in sight by the SMIT NEW YORK until 2115 when they lost sight of it in approximate position 27-49N, 90-45.5W. The bow section or any other portion of the hull was not sighted again.

71. The Board received information from various sources that indicated the AMERICAN EAGLE experienced problems while discharging cargo at Roosevelt Roads Naval Station, Puerto Rico, in December of 1983. The Naval Station Fuel Depot was contacted by the Board with regards to the incident. The Navy provided the Board with copies of documentary evidence relevant to the incident. The following is a synopsis of the events that transpired. On 27 December 1983 the AMERICAN EAGLE arrived at Roosevelt Roads Naval Station, Puerto Rico, to discharge a cargo of diesel fuel (marine) and JP-5. The discharge operation was secured several

times by Navy personnel because of operational and mechanical problems with the vessel's cargo handling equipment in the after pumproom. The discharge of diesel fuel was initially secured because of excessive water content in the product. The vessel was examined by several individuals, who determined the water was from leaking valves on sea suction lines tied into the cargo pumps. The problem was minimized by reducing the pump discharge rate to 4,000 barrels per hour. During a later examination, Navy personnel noted that the sea suction line low point drain valve was badly corroded and could not be operated. It was eventually opened and several gallons of water were drained out. The discharge operation was again stopped when excessive product leaks were discovered on the #1 stripping pump (approx 0.5 gallon / minute) and the #4 cargo pump (approx 0.33 gallon / minute). It was estimated that the pumproom bilges contained approximately 15 barrels of product. The stripping pump leaks were repaired and the cargo discharge operation resumed. The crew was unable to repair the #4 cargo pump seals, consequently the Navy inspectors prohibited it's use. Later in the day an oil slick was discovered in the water inboard of the AMERICAN EAGLE. The oil was determined to be coming from the starboard overboard discharge, apparently as a result of a leaking valve. A blind was installed in the line to prevent further discharge of oil into the water. The vessel completed discharge operations during the early morning hours of 29 December 1983 without further incident.

ANALYSIS:

A. Weather

72. The weather information contained herein was taken from a weather synopsis prepared by the National Transportation Safety Board. On 25 February 1984, the day before the explosion, at 1200 the wind was variable Easterly at 10-15 knots, the weather clear and the temperature was 69 degrees Fahrenheit (all temperatures are in Fahrenheit unless otherwise noted). Seas were 3 feet and Easterly.

73. On the day of the explosion at 1200 the wind was 20 knots out of the Southeast, the weather partly cloudy with scattered rain showers and the temperature was 73 degrees. Seas were 4.5 feet and Southeasterly.

74. The weather continued to get worse and by 0000 February 27, the wind was Westerly 25 knots and gusty, the weather cloudy, thunderstorms and rain showers and the temperature was 74 degrees. Seas were Westerly at 3 feet with swells Southeasterly at 4 feet.

75. By 1200 on February 27, the wind was Northeasterly 30-35 knots and gusty, the weather cloudy and the temperature 64 degrees. Seas were Northeasterly at 18 feet. This condition continued until approximately 1200 on February 28.

B. Explosion

76. Prior to the explosion the crew of the AMERICAN EAGLE was in the process of tank cleaning and gas freeing or ventilating the cargo tanks. An air mover was being used to ventilate and gas free the cargo tanks forward of the midships house.

77. The air mover ventilator (figures 12 and 13) used aboard the AMERICAN EAGLE was manufactured by Lamb Air Foil Company and was distributed by Mine Safety Appliances Company (MSA). The 6 inch MSA Lamb air mover ventilator had a base of 14 1/2 inches in diameter, an overall length of 47 5/8 inches and a weight of 31 pounds. It could be powered by compressed air or steam and employed a principal similar to a "jet" or "venturi" effect. The constricted passage in the base of the air mover ventilator lowered the pressure and increased the velocity of the air or steam. A rapid flow of outside air was induced. Compressed air or steam was directed into the air mover ventilator through the connection on the side of the base. The outside air is drawn in through the base and forced out through the horn. The steam was also exhausted through the horn and entered the tank. The 6 inch model could move up to 3,150 cubic feet of air per minute at 70 pounds pressure. A warning label was located near the end of the air mover horn. It stated the following: "Warning --1. This air mover should be properly grounded to prevent static discharge when used in atmospheres containing combustible gases, vapors or

dusts. --2. Noise levels generated by this device as the result of high air pressure flow may exceed OSHA permissible levels.-- Hearing devices should be worn while the air mover is in operation." The air mover ventilator had no grounding connection on it. No operating manual or instructions for use were included with the device.

78. There were two air movers aboard the AMERICAN EAGLE. Prior to this last voyage, one was used to force air into the starboard domestic water tank when it was recemented. It was powered by compressed air. On another occasion both air movers were used to ventilate #4 starboard cargo tank. The devices were powered by compressed air and no ground wires were attached. The Chief Mate had supervised this use of the devices. The Bosun, reportedly had used similar devices previous to this voyage on the tankship AMERICAN HAWK. It is not known whether the Pumpman had ever used the air mover prior to 26 February 1984 or if he was familiar with its operation.

79. A representative of Mine Safety Appliances (MSA) stated that there were not any locations where they would recommend that the air mover ventilator not be used. The MSA data sheets indicate their devices can be used either with steam or air. MSA also indicated that they were not aware of any tests having been conducted on these devices with respect to static discharge. The Lamb air mover ventilator is not shipped with any information other than an attached warning label. However there is a product information brochure available which gives operating parameters.

80. The series of events aboard the AMERICAN EAGLE prior to the casualty make it quite clear that two legs of the fire triangle were present (gasoline vapor as the fuel, and oxygen). The third leg of the triangle (ignition source) was provided by a static electricity discharge from the steam being injected into the tank through the air mover ventilator.

81. The hazards involved with introducing steam into a non-gas free atmosphere are well known and are described in the International Safety Guide for Tankers and Terminals (ISGOTT) in at least five different places (see appendix B). The Master in response to a question "Do you know whether or not steam passing through a confined space can create static charges or potential static charges?" stated "Apparently it can." He further explained he discerned this from reading various publications after the casualty. Mr. Marshall, Vice President in Charge of Operations, for American Foreign Steamship Corporation, indicated he was aware of certain hazards associated with steam. A copy of ISGOTT was aboard the AMERICAN EAGLE.

82. Information gathered from the tanker industry indicated that it is generally known that steam presents a source of very high static charge generation. Recommendations advising against the use of steam in flammable atmospheres were first issued by the International Chamber of Shipping many years ago and were review-

ed in the early 1970s in the course of its investigation into the cause of explosions in very large crude carriers (VLCCs). In their work it was pointed out that charge potentials resulting from the introduction of steam into a tank can be substantially higher than those resulting from other causes. Introduction of steam into a tank can cause very high potentials (48 kv or higher). The charge transfer in the case of a conductive object will be rapid and could take the form of a spark. Certain ungrounded objects suspended in a charge mist may cause an incendive spark by the above mentioned charge transfer.

83. The air mover was placed in the Butterworth opening in such a manner that either a Butterworth opening gasket, the plastic sleeve, paint, or dirt may have prevented sufficent electrical continuity from the air mover to the flange. It was stated that the air mover did not have a ground wire and was not grounded. The air mover if not grounded, would thus be a collector of static charges from the steam when it was turned on and could then reach a sufficient potential to spark to the grounded flange in the vicinity of a flammable mixture.

84. The air mover would collect the static charge from the steam very quickly if the air mover was not grounded either by a bonding cable or by sufficient contact with the deck at the tank opening. The charge would rise to a potential sufficient to produce an incendive spark within the time span described by Mr. Poole. The plastic sleeving could well have provided the insulation necessary for the air mover to become the collector of the static charge which subsequently discharged to the tank opening. This could have taken place at the Butterworth opening where the flammable atmosphere would partly be expelled.

85. Some mention was made during testimony that API 2013, "Cleaning Mobile Tanks in Flammable or Combustible Liquid Service", made specific reference to steaming of tanks. Section 2.10 of API 2013, "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents", states that the ISGOTT Guide should be referenced for safeguards on tank washing on tank ships and barges. In subsequent corespondence, API recommended that the U. S. Coast Guard and the marine industry utilize the ISGOTT Guide as the most authoritative reference, and not attempt to extrapolate any references from API 2013 for application to tank ships.

86. Two reports were submitted to the Board by attorneys for the vessel owners entitled "Investigation of Lamb Air Mover Static Generating Characteristics" and "Estimate of the Occurrance of Incendive Discharge During Gas Freeing Aboard the AMERICAN EAGLE" prepared by Case Consulting Laboratories, Inc. These reports indicate that operation of an ungrounded air mover can produce a charged steam cloud, which in a short time can develop sufficient energy to ignite a flammable mixture.

C. Flares:

87. Shortly after the explosion, a passing ship was sighted at a distance of 5 or 6 miles. Since radio communications had not been established, it was decided to attempt to signal the passing ships using hand held rocket propelled parachute flares. From crew member testimony it was learned that a high percentage of the flares either did not operate or operated improperly. Further testimony revealed that many of the parachute flares had been renewed during the previous Coast Guard inspection conducted in June and July 1983. The Master and Second Mate both testified that it was standard practice aboard the AMERICAN EAGLE to retain on board outdated flares, rather then dispose of them. These outdated flares were stored in a separate location and then used for training. It was not determined if the flares that failed were outdated flares or current ones. However, the Master did testify that some of flares that failed were dated 1982. The failures included the inability of crewmembers to operate them as described in the instructions, failure to fire, and one failed to fire or eject out the top, but instead ejected downward and burned the right hand of the Chief Engineer. The most frequent cause cited was the inability of the operator to execute the steps described in the instructions. Specifically it was reported they could not turn the base section 3/4 of a turn to the left (counter clockwise) before pulling the base or grip down to fire.

88. In a later telephone conversation between Captain Powers and the recorder for the Board, Powers stated that he had taken home the steel box in which the flares were delivered to the ship in July of 1983. He then provided the recorder with the following information, from the steel box, regarding the flares put aboard the vessel in July of 1983:

PROTEUS 2
LOT #101 Code 3803
Date of Manufacture 10-82

The Proteus II is manufactured by the Kilgore Corporation.

89. A review of the Coast Guard approval files for the Proteus II revealed that in 1981 a modification to the firing mechanism was approved. The modification consisted of the addition of a safety pin to the firing mechanism. The safety pin and its bead chain lanyard are covered by a piece of red tape. A warning label was on the tape which read "DO NOT REMOVE TAPE AND SAFETY PIN UNTIL READY TO FIRE." The operating instructions were not modified to reflect the extra step required to operate the device. The Coast Guard, (Commandant, G-MVI-3), contacted the Kilgore Corp. and was informed that the Kilgore Corporation began manufacturing Proteus II flares with the safety pin in March of 1981, lot #79. Witnesses were unable to testify as to whether any of the flares used after the casualty were of the type which employed a safety pin. There was no testimony which indicated a

safety pin was removed, although it is certain some of the flares used after the casualty employed a safety pin in the firing mechanism. These flares are no longer manufactured. Present flares have complete operating instructions describing the necessary steps required to properly operate the flares.

D. Stability and Strength Calculations:

90. Appendix C is the U.S. Coast Guard's Office of Merchant Marine Safety, Marine Technical and Hazardous Materials Division report regarding stability and strength calculations of the AMERICAN EAGLE. Calculations were done for the AMERICAN EAGLE in it's ballasted condition prior to the explosion. These calculations show that the AMERICAN EAGLE met the U. S. Coast Guard and MARPOL 73/78 damage stability requirements in this condition. Damage stability calculations were then done for the ship in the condition it was in after the explosion and after the bow section broke off, showing the effects of progressive flooding. These calculations indicate that because of the large freeboard, after applying damage, significant downflooding through the Butterworth openings and expansion trunks was unlikely to occur until at least the #6 tanks across filled. The ship would become unstable and capsize as the #8 tanks flooded. These calculations, and the fact that the ship sank so rapidly after the bow section broke off, strongly suggests that the transverse bulkheads were also damaged as a result of the explosion and or breaking away of the bow section.

E. Safety Advisory

91. The Board read into the record a suggested safety advisory with respect to the restricted use of the air mover ventilator. The Board made the safety advisory recommendation to the Commandant, U.S. Coast Guard and recommended that Headquarters issue an appropriate safety advisory.

92. On 3 April 1984, the Commandant of the Coast Guard issued a safety advisory (AIG 8994) to appropriate Coast Guard units, to the owners and operators of tankships as well as to the marine industry as a whole. The advisory alerted the marine industry of the potential problem of using portable venturi-type air mover units with steam in a non-gas free atmosphere. Further the safety advisory noted the hazards of injecting steam into a non-gas free atmosphere, and owners/operators were urged to exercise caution when using these devices in the blower mode with steam in a non-gas free atmosphere. The safety advisory also drew attention to the additional potential hazard associated with a plastic sleeve attached to the air mover as this may aggravate the possibility of a static charge release. In addition the advisory indicated that the Coast Guard would be studying this potential problem further.

F. Lifeboat lowering

93. The lifeboat davits used on the AMERICAN EAGLE were manufactured by the Welin Boat and Davit Co. under Coast Guard approval #160.032/158/0. This particular davit is of the gravity type. The regulations required, when the AMERICAN EAGLE and the davits were constructed, that the davit assembly be capable of operating with a 15 degree list. There were no requirements for davit operations with respect to vessel trim. A review of photographs which show the AMERICAN EAGLE sinking, indicates that the AMERICAN EAGLE was experiencing a trim by the bow exceeding 10 degrees while the lifeboat was being lowered. The Second Mate, John Salsbury testified that he estimated the AMERICAN EAGLE was listing approximately 20 degrees to starboard when the lifeboat was being lowered. The amount of list was later determined, by calculation using photographs, to be approximately 25 degrees.

94. The crew abandoned the ship in the #3 lifeboat. The Second Mate operated the davit brake lever as the Master stood by on the boat deck. As the boat was being lowered it's descent would slow down or even stop. When this occurred the Master would spin the flywheel on the davit winch and brake assembly to get the lifeboat moving again. This occurred several times. Before the boat reached the water it stopped lowering and could not be restarted. Shortly thereafter most of the people in the lifeboat jumped into the water. The people remaining in the boat operated the Rottmer releasing gear at the Master's command and the boat dropped into the water.

95. In testimony the Master stated that when the boat stopped he was able to continue to freely turn the flywheel, however the boat would not lower any further. None of the crewmembers were able to testify specifically as to why the boat failed to continue lowering to the water. The Master did say that the boat had been lowered to the water and released without difficulty during the last annual Coast Guard inspection. He said at that time the ship was light and riding high and the boat was lowered without incident. He therefore concluded that the falls were of the proper length. The winch drums on this particular type of lifeboat davit are located approximately 8-10 feet above the deck. Therefore, no one on deck was able to see the drum or the wire on it to make an accurate assessment of the problem.

G. Coast Guard response

96.. The Eighth Coast Guard District Operation Center (Opcen) in New Orleans, Louisiana, received a message on February 26, 1984, at 1355 from the MOBIL VALIANT that the AMERICAN EAGLE had experienced an explosion and was disabled, but not in danger of sinking, approximately 120 miles South of Morgan City, Louisiana. This report indicated that three crewmen were injured and requested their evacuation. The ready helicopter at Coast Guard Air Station New Orleans was determined to be too small for the distance offshore and the anticipated number of people to be evacuated. Therefore, a larger helicopter was prepared and airborne at 1500. Upon arrival on scene at 1649, the pilot was informed that there were three dead in addition to the three injured crewmen. In conditions of adverse weather (thunderstorms, 3 mile visibility in rain, 20 knot wind, 6 foot seas) and impending darkness, the helicopter crew hoisted the three injured crewmen from the stern of the AMERICAN EAGLE. While on scene, the crew of the helicopter was made aware of three persons, other than the three injured, who were killed by the explosion. The Master did not request evacuation of the deceased or the remainder of the crew. Due to darkness, the helicopter crew was unable to make an assessment of the ship's condition. At no time was there any indication from the Master or crew of the AMERICAN EAGLE that the vessel was in danger of sinking. In addition to the evacuation from the AMERICAN EAGLE the helicopter was required to evacuate a man, suffering from symptoms of a heart attack, from an offshore platform on the return trip to shore. The two evacuations were completed at approximately 2100 when all four patients were delivered to Meadowcrest Hospital in stable condition.

97. While the medical evacuation (MEDEVAC) was in progress, Mr. H. W. Marshall of American Foreign Steamship Corporation was contacted and he arranged for a commercial salvage tug, which was scheduled to arrive on scene by noon on 27 February 1984. Arrangements were made to have the FORT EDMONTON standby to provide communications until commercial assistance arrived on scene. The only Coast Guard cutters available in the Gulf of Mexico were the USCGC BUTTONWOOD in Galveston, Texas, and the USCGC DURABLE in Brownsville, Texas. In addition to the time required for these cutters to get underway, the transit time for either cutter was greater than the estimated time of arrival for commercial assistance. With the information that the AMERICAN EAGLE was in no danger of sinking, these cutters were not directed to get underway at that time.

98. Throughout the evening of 26 February 1984 and during the day of the 27th, the Eighth District Operations Center maintained close contact with Mr. Marshall and the FORT EDMONTON, which was on scene with the AMERICAN EAGLE. After the initial medical evacuation, no request for additional Coast Guard assistance was received and there was no indication at any time that the vessel was in danger. On the afternoon of 27 February 1984 the FORT EDMONTON departed the scene without prior notification to the Coast Guard. Since communications with the AMERICAN EAGLE appeared to be lost, an offshore platform which could communicate with the AMERICAN EAGLE was contacted. It was discovered at that time that three offshore supply boats were assisting and the AMERICAN EAGLE was experiencing problems. At that time there was no indication that the AMERICAN EAGLE was in danger of sinking, there was concern as to the actual conditions on scene and a Coast Guard helicopter was dispatched to investigate. When the helicopter arrived the AMERICAN EAGLE had almost completely sunk

and survivors were in the water. The helicopter assisted in the rescue of the crewmen from the water and commenced searching for additional survivors. The search for the two missing crewmen continued through 29 February 1984 utilizing aircraft from Air Station Corpus Christi, Air Station New Orleans, and Aviation Training Center Mobile. A total of 12 aircraft search missions (20.3 on scene flight hours) were flown with 3300 square miles searched. No additional survivors were located.

H. Structural Damage

99. As a result of the explosion on 26 February 1984 the AMERICAN EAGLE suffered extensive hull damage to the forward part of the vessel. The Master made no effort to formally assess any damage to the vessel, however, based on photographs and witness testimony it can be stated that the damage to the AMERICAN EAGLE as a result of the explosion was as follows:

A tear in the main deck on the port side extending from the forward bulkhead of tank #1 through the midships house almost up to tank #5 (figures 2, 3, and 5)

A tear on the starboard side of the vessel below the shear strake extending from tank #1 into tank #5 (figures 2 and 5).

A bulged section on the port side encompassing most of the area above the waterline and forward of the midships house in way of tanks #3 and #4. In addition there were two holes within this set out area (figure 4).

Port wing of the midship house was damaged and sagged down (figures 3 and 4).

The forward mast, located on the main deck immediately aft of the focsle was at a 30 degree angle from the vertical (figure 2).

The bow section was initially hinged and then broke away from the remainder of the vessel. The hinge point appeared to be just forward of the midships house, probably at the bulkhead between #2 and #3 tanks.

100. The extent of internal damage is unknown. However, from the extent of external damage visible, it can be presumed that internal damage existed to transverse tank bulkheads and that contributed to the eventual rapid sinking of the vessel.

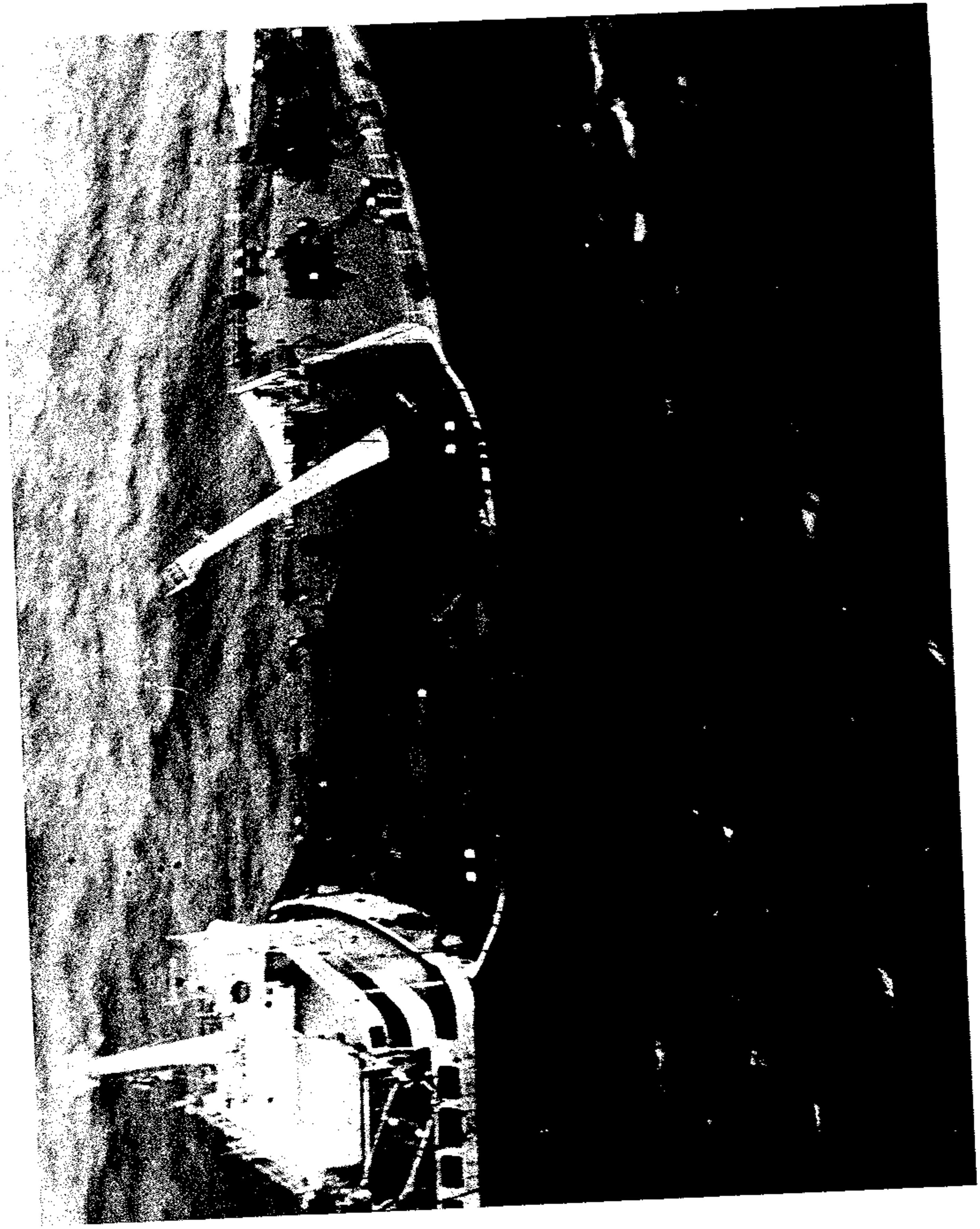
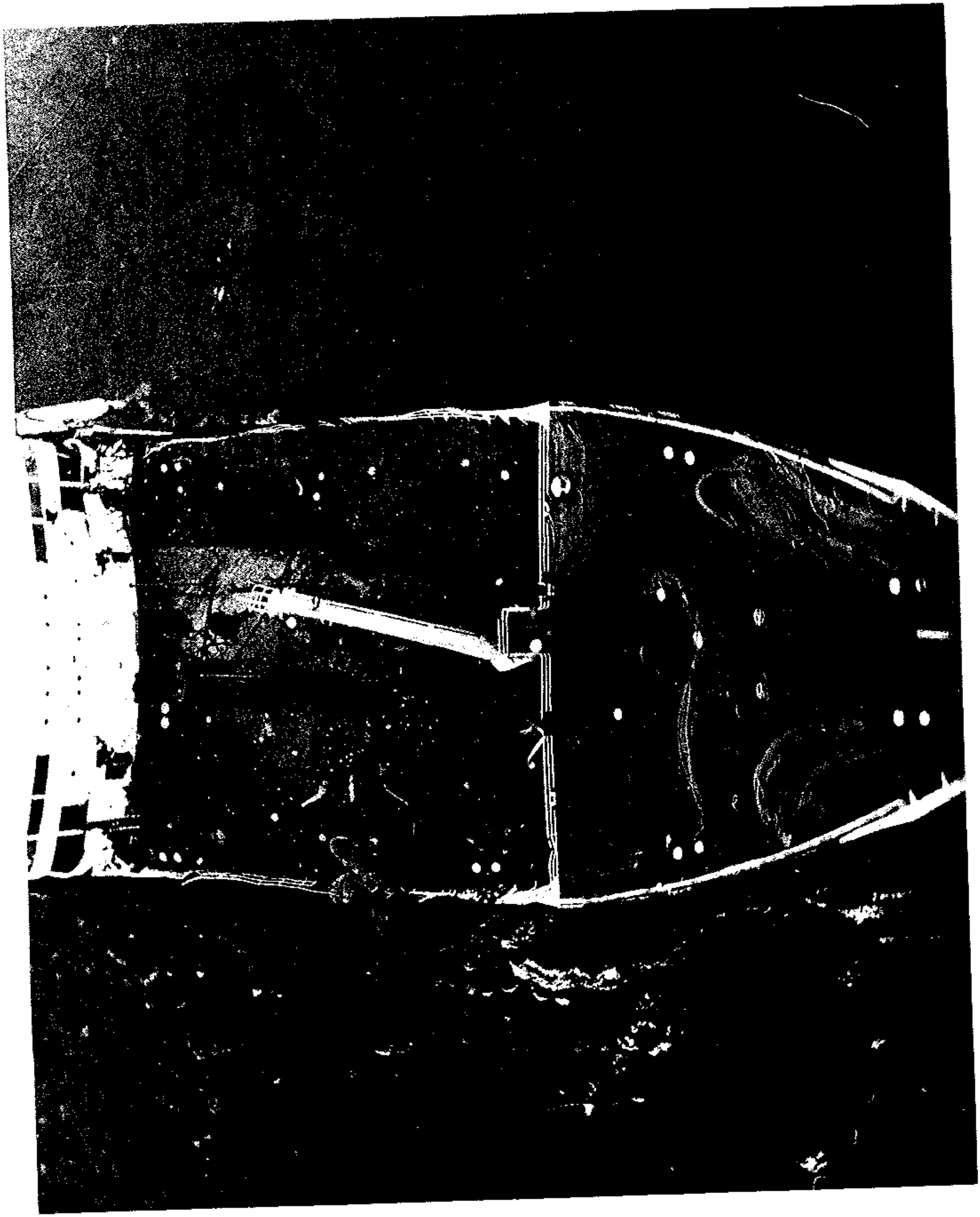


Figure 2



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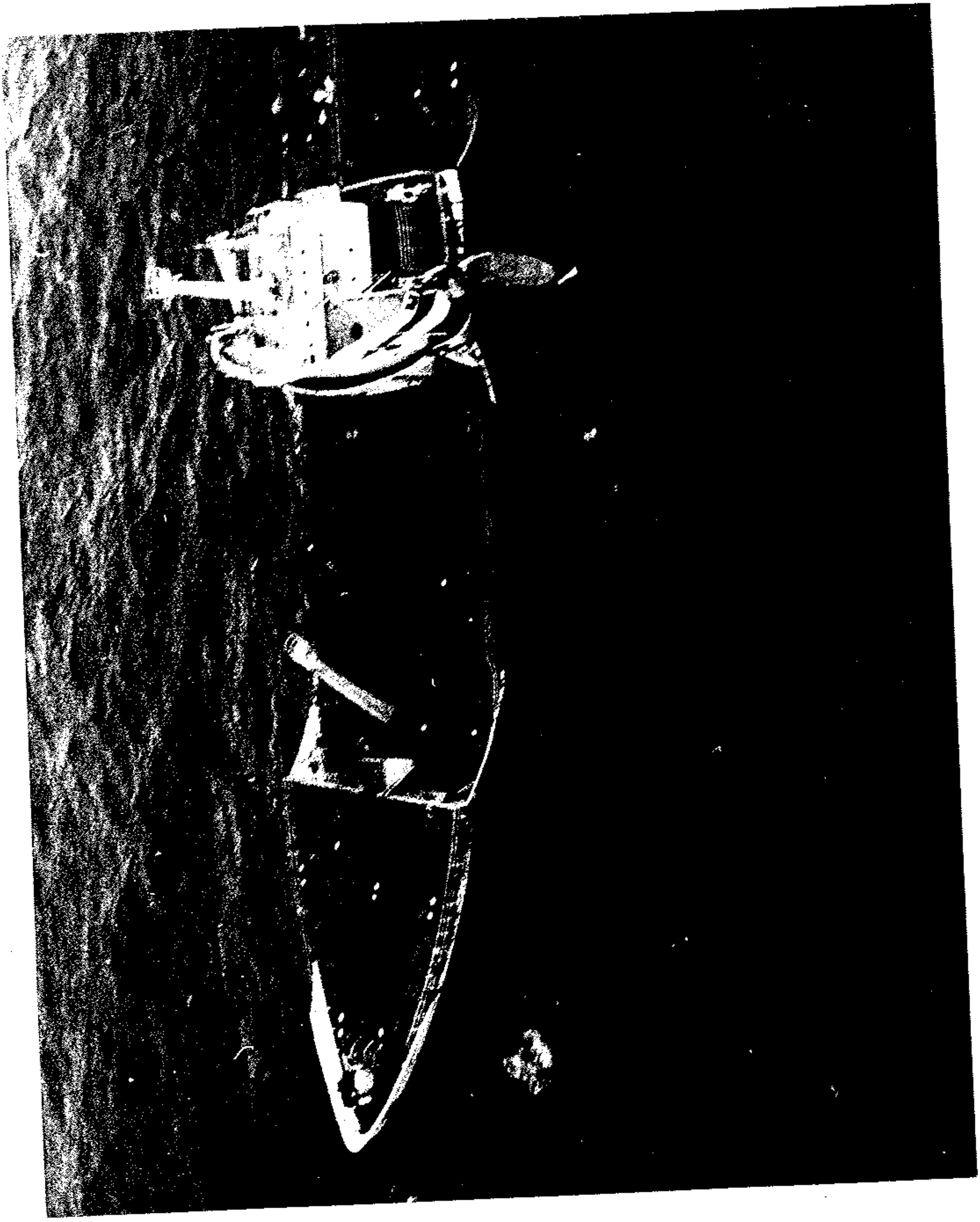


Figure 4

Figure 5

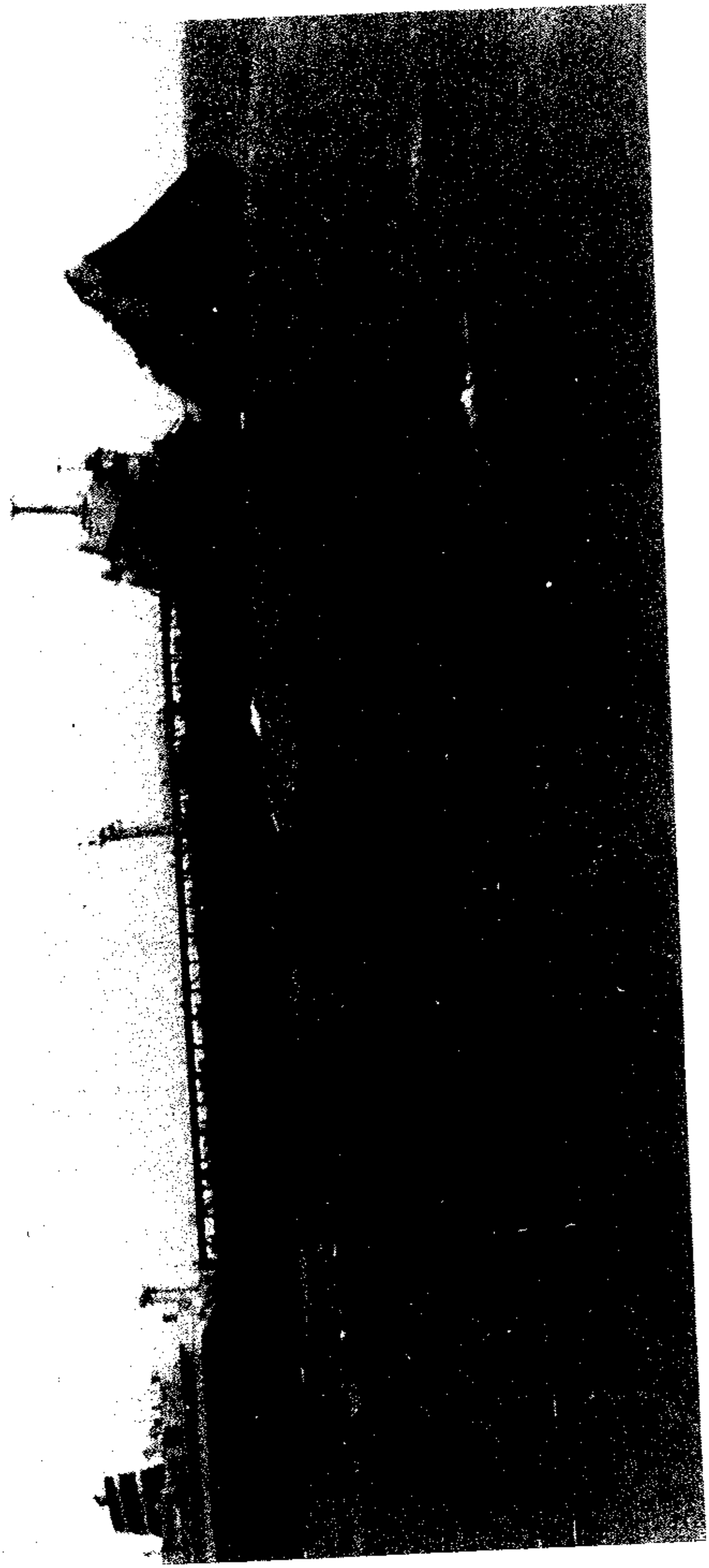


Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

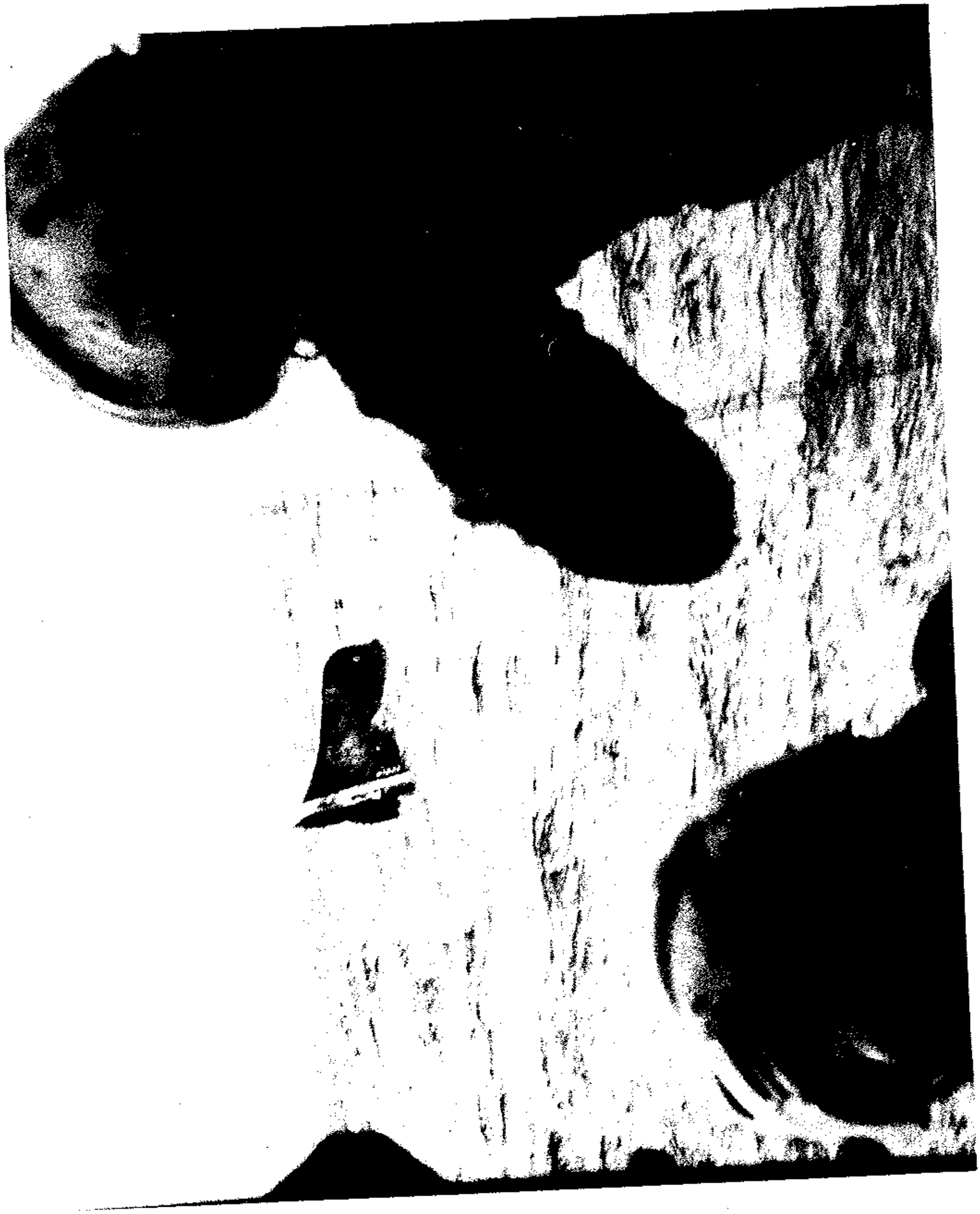


Figure 11

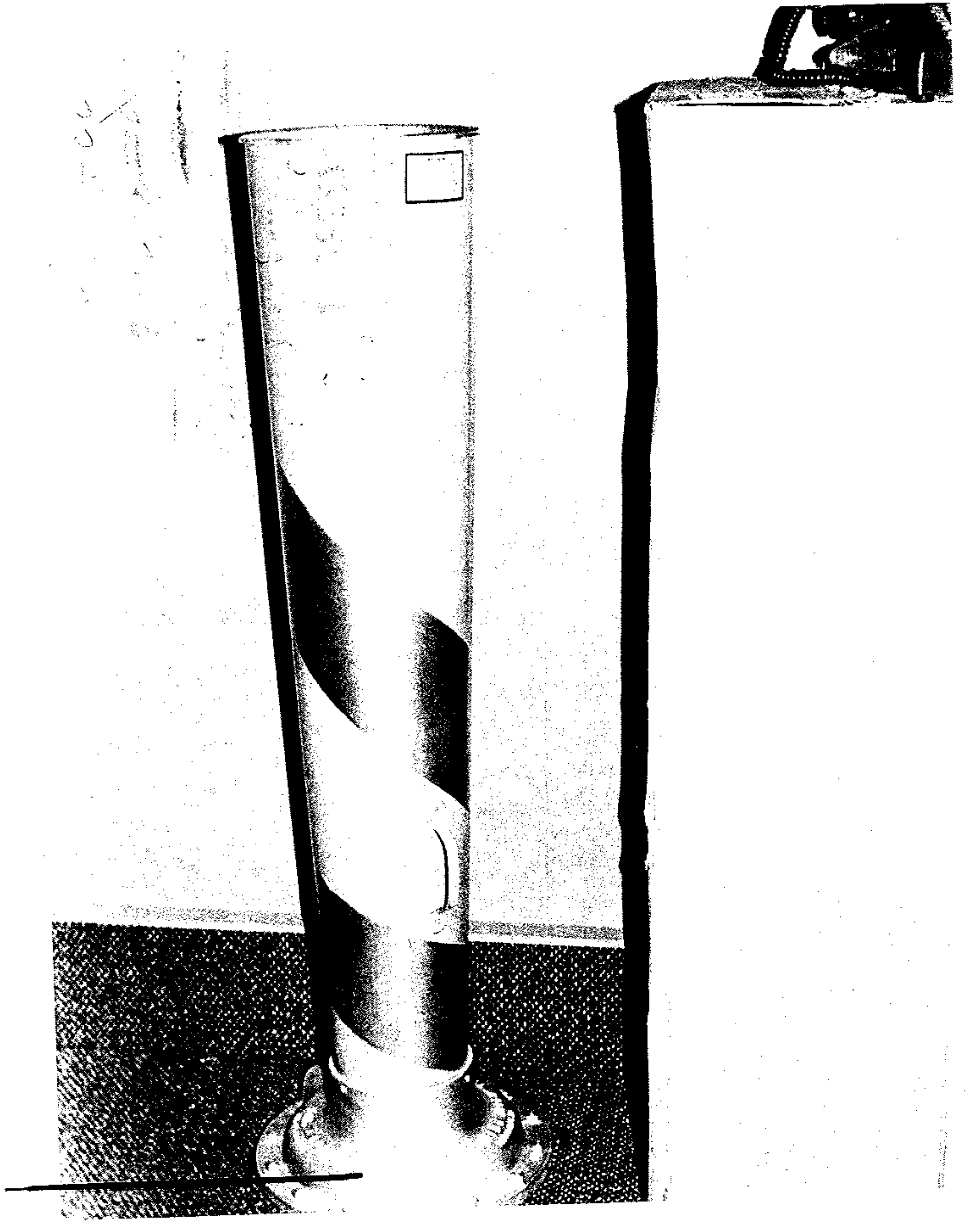


Figure 12

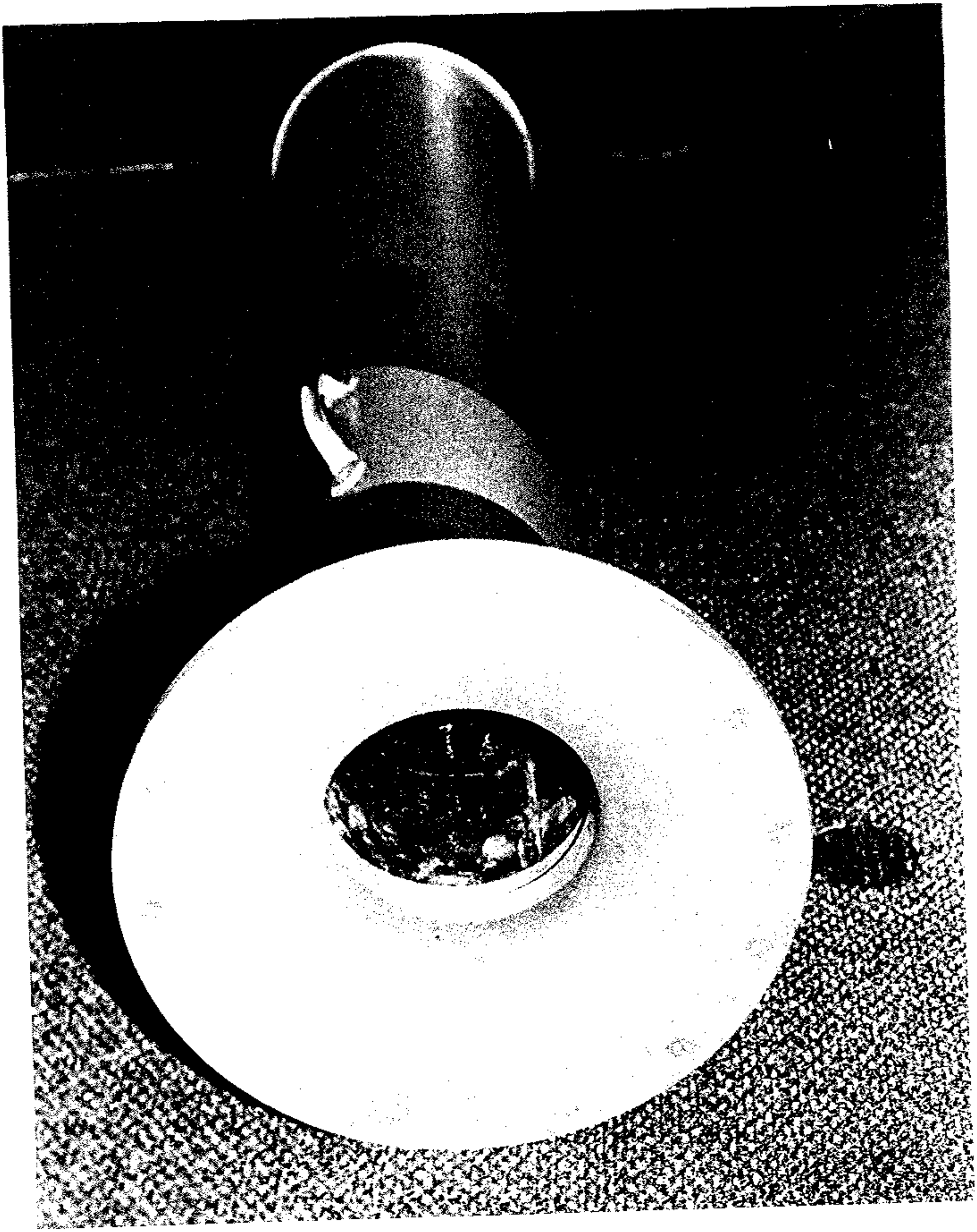


Figure 13

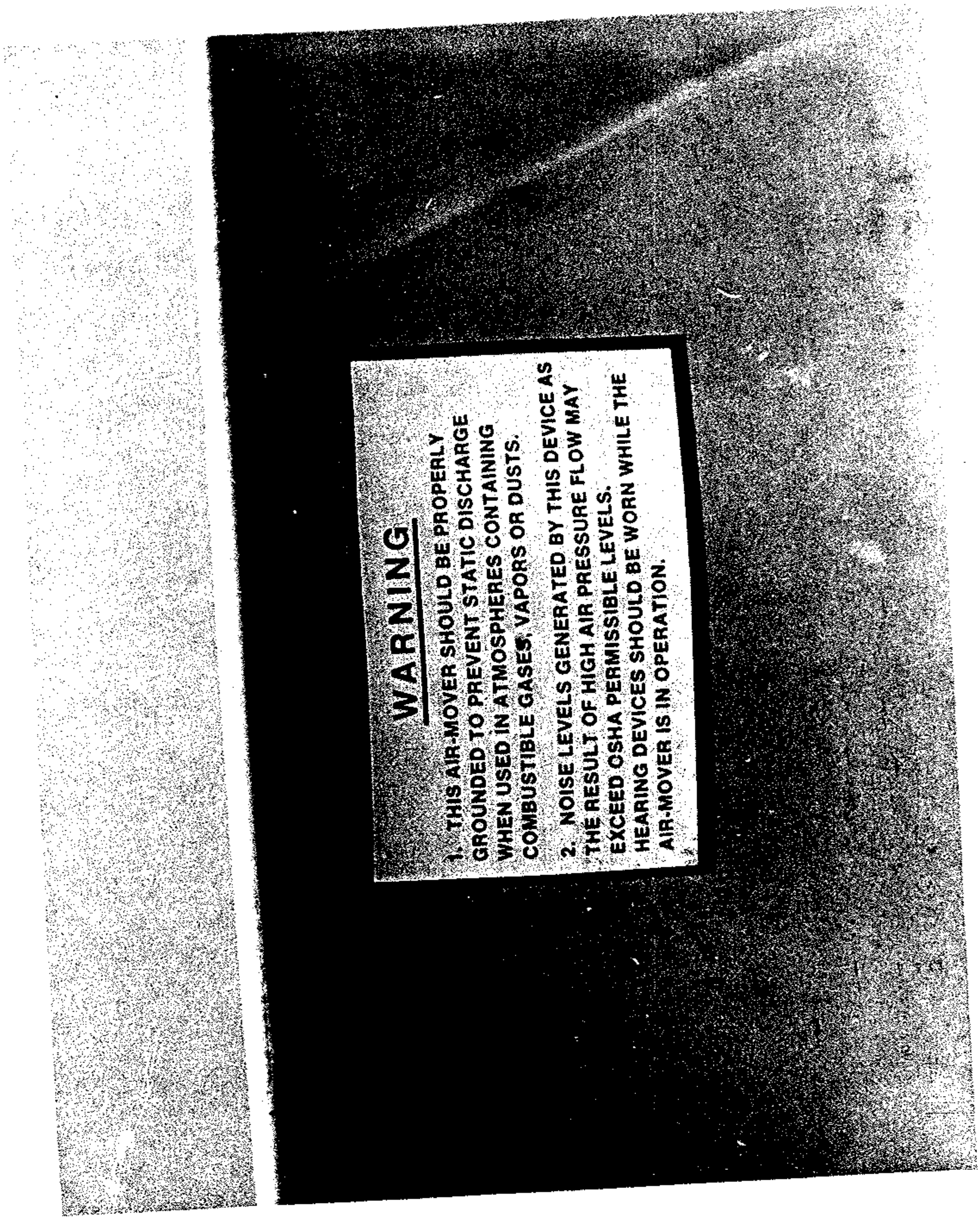

WARNING
1. THIS AIR-MOVER SHOULD BE PROPERLY GROUNDED TO PREVENT STATIC DISCHARGE WHEN USED IN ATMOSPHERES CONTAINING COMBUSTIBLE GASES, VAPORS OR DUSTS.
2. NOISE LEVELS GENERATED BY THIS DEVICE AS THE RESULT OF HIGH AIR PRESSURE FLOW MAY EXCEED OSHA PERMISSIBLE LEVELS. HEARING DEVICES SHOULD BE WORN WHILE THE AIR-MOVER IS IN OPERATION.

Figure 14

CONCLUSIONS

1. That the proximate cause of this casualty was the introduction of steam through a venturi type air mover with attached plastic sleeve into the #3 center cargo tank which was not rendered free of flammable vapors. The ignition of hydrocarbon vapors by a static charge from the ungrounded air mover, in the blower mode, introducing steam into the #3 center cargo tank caused the explosion.

2. That the evidence indicates the AMERICAN EAGLE had some minor maintenance problems with regard to the cargo system while discharging cargo at the Roosevelt Roads Naval Station, Puerto Rico. The major extent of the problems centered around the quality of the product delivered and were not safety oriented. The only safety related item would have been the product in the cargo pumproom bilges as a result of leaking cargo pump seals. Cargo pump seals are a relatively frequent maintenance item on tank vessels. Pumproom bilges are usually pumped or stripped periodically into a slop tank or cargo tank containing a similiar product.

3. That there is no evidence that the problems experienced by the AMERICAN EAGLE at the Roosevelt Roads Naval Station on 27-29 December 1983 were related to or contributed to the explosion on 26 February 1984.

4. That the discrepancies noted by a Coast Guard boarding officer at Port Everglades, FL, on 19 February 1984 did not contribute to the casualty.

5. That the repairs made to deck steam lines by the Chief Engineer and the First Assistant Engineer on the morning of 26 February 1984 were not related to and did not contribute to the casualty.

6. That the Bosun and Chief Mate most likely went forward to the foredeck on the starboard side, after coffee, and were not observed by the Master who was talking to the Pumpman on the port side.

7. That the #3 cargo tank, on the morning of 26 February 1984, was not gas free and contained an explosive mixture of gasoline vapors and oxygen (ambient air).

8. That hydrocarbon vapors remaining in cargo tank #3C provided the source of fuel for the explosion.

9. That there is evidence that the gas freeing procedures followed by the Chief Mate, which included the introduction of steam into non-gas free tanks, was improper and did not follow acceptable procedures as outlined in the International Safety Guide for Oil Tankers and Terminals (ISGOTT), a copy of which was aboard the vessel.

10. That the air mover was placed in the #3 cargo tank and the steam was turned on immediately after Able Bodied Seaman Poole observed the attached plastic sleeve being placed in the #3 Butterworth opening.

11. That there is no evidence of personnel working in any cargo tanks, of anyone doing hotwork or smoking or of other actions that may have been a source of ignition.

12. That there is some question as to whether all precautions associated with the Lamb air mover ventilator were being observed. The warning label states that the device should be grounded; however, testimony verified that the device was not properly grounded.

13. That the air mover was not intentionally grounded when it was placed in the #3 center cargo tank.

14. That the air mover may have been insulated from the ships hull by the plastic sleeve, dirt, gasket material, or paint, when it was placed in the #3 center cargo tank Butterworth opening.

15. That a copy of the International Safety Guide for Oil Tankers and Terminals (ISGOTT), which represents good, well proven international industry practice, was on board but obviously the ship's personnel were not aware of or did not heed the specific warnings on the hazards of using steam in a non-gas free atmosphere.

16. That the Chief Mate and Master should have been aware of the hazards associated with introducing steam into non-gas free tanks as stated in ISGOTT.

17. That the AMERICAN EAGLE did not have sufficient compressed air capacity available on 26 February 1984 to effectively operate an air mover.

18. That the testimony of the radio operator, Fred Conklin, indicating there were three separate explosions was discounted by the Board. All other testimony received indicated there was only one explosion heard or felt. The number of explosions is not considered material to the casualty or this investigation.

19. That the emergency radio transmitter was operating properly as indicated by a signal received in the radio room and heard by the radio operator. The cause for the weak signal could not be determined, however, it may have been due to improper operating procedures or damage to the receiver in the radio room as a result of the explosion.

20. That the cause of the malfunctioning flares could not be determined. However, it is possible that some of the flares used were outdated flares retained onboard for instructional purposes. It is also possible that the crewmembers were unaware of the

safety pin installed on Proteus 2 flares manufactured after April 1981. This is no longer a problem as these particular devices are no longer manufactured.

21. That the problems encountered with the flares did not contribute to the casualty, as radio communications were established and maintained shortly thereafter.

22. That had the Master secured all cargo tank hatches, Butterworth plates, and watertight doors at the time he ordered all valves to be shut, the vessel may not have sunk as rapidly, allowing more time for an orderly evacuation.

23. That had the Master lined up the four cargo pumps to cargo tanks #5, #6 and/or #7 across, rapid dewatering of those tanks using the cargo pumps may have prevented or reduced the rate of sinking allowing more time for an orderly evacuation of the vessel.

24. That the exact cause of the failure of the #3 lifeboat davits to lower the lifeboat to the water could not be determined. However, the most probable cause may have been the severe trim by the head of the AMERICAN EAGLE, in excess of 10 degrees, coupled with the extreme list to starboard causing the lifeboat falls to come out of the sheaves at the davit head as the lifeboat swung freely by the falls, causing the falls to bind at the head of the davit and thereby preventing the boat from lowering.

25. That the lifeboat and it's occupants suffered little harm or damage from the free fall when the releasing gear was activated, was due to the unintentional timing of the sea to crest in way of the lifeboat as it dropped.

26. That had the crew remained in the lifeboat the chances of survival of those missing and presumed dead and of the two that died after abandoning the AMERICAN EAGLE, would have been greatly increased.

27. That Steger R. Burney, Able Seaman, and Earsel Warren, Ordinary Seaman, abandoned the AMERICAN EAGLE with the other crewmembers. After entering the water, they became separated from the main group of survivors and were not located by rescue craft.

28. That Steger R. Burney, Able Seaman and Earsel Warren, Ordinary Seaman, are missing and presumed dead.

29. That Edward J. Mallon, Chief Mate, Jack R. Campbell, Bosun, and Roy D. Carter, Pumpman, were working on deck in the vicinity of #2 and #3 center cargo tanks at the time of the explosion.

30. That Edward J. Mallon, Chief Mate; Jack R. Campbell, Bosun; and Roy D. Carter, Pumpman, were killed almost instantly by the explosion aboard the AMERICAN EAGLE at approximately 1045 on 26 February 1984 while the vessel was in position 27-30N, 91-30W in the Gulf of Mexico. And further that their bodies were lost at sea or went down with the ship when the AMERICAN EAGLE broke up and sank on 27 February 1984.

31. That weather conditions did not contribute to the initial casualty, however the rapid deterioration of weather and sea conditions contributed to the rapid breakup and sinking of the AMERICAN EAGLE.

32. That had the Master evacuated non-essential personnel after the explosion, the loss of life and injury resulting from the evacuation may have been reduced.

33. That the average age of the crew was 56.3 years. This, however, was not a factor in the casualty.

34. That there is evidence of negligence on the part of the Master Francis, Powers, with regard to the following actions or inactions:

(1) failure to assess the extent of structural damage to the vessel after the explosion

(2) failure to secure the ship after the explosion (close hatches and Butterworth plates)

(3) failure to follow-up with the Chief Mate on USCG deficiencies issued at Port Everglades, Florida on 19 February 1984

(4) failure to sound the general alarm and organize a fire party after the explosion

(5) failure to evaluate the vessels condition after the explosion and make plans for a more timely and orderly evacuation

(6) failure to hold a crew muster after the explosion and prior to abandonment

This matter has been forwarded to the Commander, Eighth Coast District for further investigation under the suspension and revocation proceedings.

35. That the voluntary efforts of the M/V MOBIL VALIANT, for serving as a radio relay, and the M/V FORT EDMONTON, for standing by in excess of twenty-four hours and serving as a radio relay, are commendable and recognized.

36. That the commendable assistance and lifesaving efforts of the crews of the M/V LIBERATOR, M/V ENTERPRISE and M/V STARLIGHT was heroic and accounted for the saving of most of the lives of those in the water. Recognition for their actions has been initiated by the Commander, Eighth Coast Guard District.

37. That Coast Guard assistance rendered was both timely and adequate, considering the Master's and owner representative's assurance that no other Coast Guard assistance was necessary or required.

38. That the AMERICAN EAGLE sank in 300 fathoms of water in approximate position Latitude 27 degrees North, Longitude 90.45 degrees West, and does not constitute a menace to navigation.

39. That prior to the casualty and to the extent ascertainable, with the exception of the discrepancies noted in the Port Everglades, FL, Coast Guard boarding, the AMERICAN EAGLE was in all respects seaworthy and in full compliance with the Rules and Regulations for Tank Vessels.

40. That there was no evidence that the casualty was caused by any object or influence outside the vessel, or that any sabotage, willful intent to destroy, or any other form of foul play was involved.

41. That had the Chief Mate and Master been aware of and complied with the recommendations in the International Safety Guide for Oil Tankers and Terminals (ISGOTT) this casualty may have been prevented.

42. That the American Foreign Steamship Corporation did not have a formal safety program.

43. That with the exception of the above, there is no evidence of actionable misconduct, inattention to duty, negligence, or willful violation of law or regulation on the part of licensed or certificated personnel, nor evidence that failure of inspected material or equipment, nor evidence that any personnel of the U.S. Coast Guard, or any other government agency or other person contributed to the casualty.

RECOMMENDATIONS

1. It is recommended that the Coast Guard issue precautions on the use of steam in tanks that are not gas free. Steam should not be injected into non-gas free tanks. All personnel involved in tank cleaning/gas freeing operations should be made aware of the hazards.

2. It is recommended that the Coast Guard publish a safety advisory to alert seamen who serve aboard tank vessels of the need to ground cargo tank ventilating blowers. This is particularly important with respect to portable venturi air mover ventilators as used aboard the AMERICAN EAGLE.

3. It is recommended that ISGOTT be endorsed by the Coast Guard and that a copy be required aboard all U.S. tank vessels and those foreign tank vessels entering U.S. waters.

4. It is recommended that consideration be given to requiring the inerting of cargo tanks containing flammable products such as gasoline. Present regulations only require inerting of cargo tanks containing crude oil on existing vessels of tonnages similar to the AMERICAN EAGLE.

5. It is recommended that the use of portable venturi air mover ventilators, when operated in the blower mode, be prohibited in any spaces which are not gas free.

6. It is recommended that portable venturi air mover ventilators be used in accordance with provided warning labels.

7. It is recommended that manufacturers of portable venturi air mover ventilators provide a practical and positive method of grounding these devices

8. It is recommended that this report be given wide dissemination to the marine industry by means of the Marine Safety Council Proceedings after final action by the Commandant and the National Transportation Safety Board. This Marine Board believes that by publicizing the factors which led to this casualty, many mariners will relate them to their own shipboard operations, perhaps recognizing potential hazardous situations in time to take necessary corrective action.

9. It is recommended that this casualty investigation be closed.

A. E. TANOS, CAPTAIN, U. S. COAST GUARD
Chairman

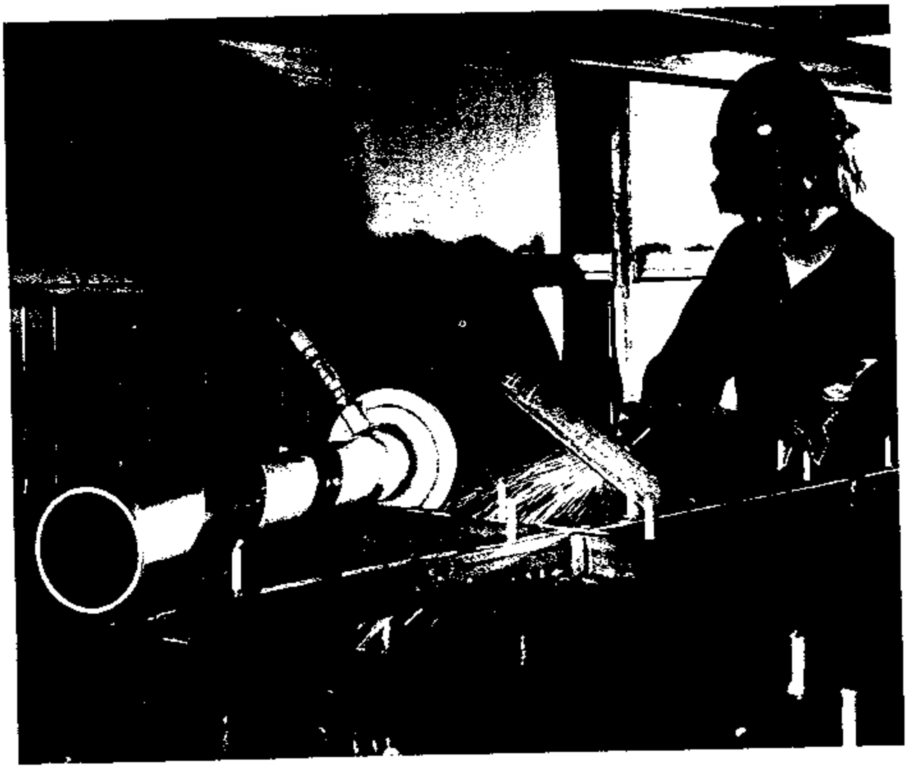
D. J. KERLIN, U. S. COAST GUARD
Member

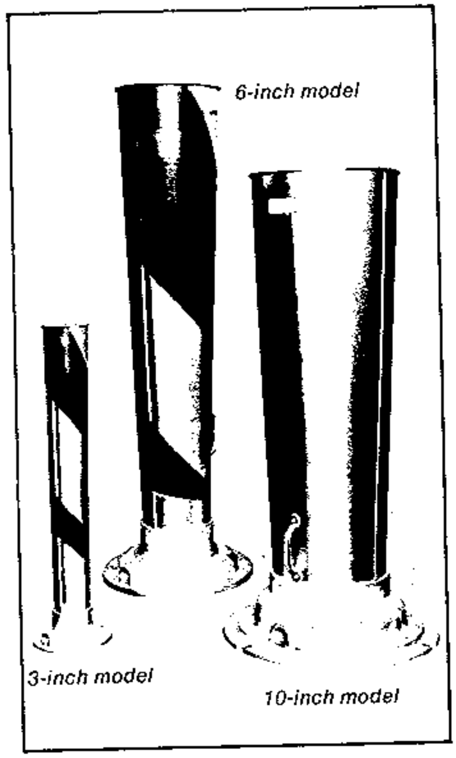
D. W. KUTZ, LIEUTENANT, U. S. COAST GUARD
Member and Recorder

MSA

Data Sheet
26-00-01

Lamb Air-Mover™ Ventilator





Application

The Lamb Air-Mover Ventilator functions as a portable blower or exhaust unit; the device removes hazardous concentrations of gases, dusts, smoke, or toxic vapors from confined areas, or cools atmospheres in hot operations. Because there are no electrical or moving parts, the ventilator is suitable for use in potentially explosive atmospheres, when properly grounded.

Typical applications include purging tanks, boilers, ship holds; cooling furnaces to speed repairs; supplying air to manholes and other confined working spaces.

Description

The lightweight, portable Lamb Air-Mover Ventilator is available in three models, identified by the diameter of their annular orifices—3, 6, and 10 inches. Made of galvanized steel and aluminum alloy, the ventilators use compressed air or steam to induce a rapid flow of outside air equal to 10 times its own volume. Pressure sources of up to 100 psig may be used to power the device.

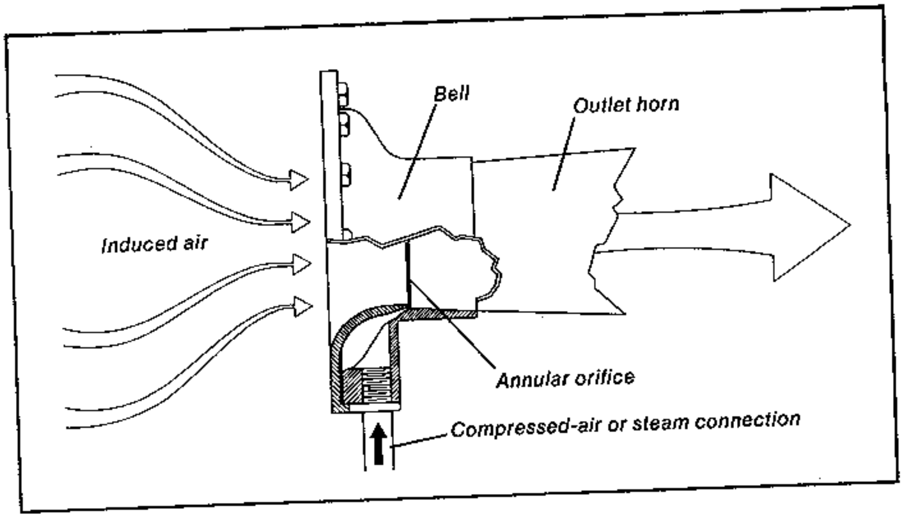
Because the ventilator requires little space, the unit fits into areas too small for motors and blowers. And the cost is much less than conventional explosionproof motors and blowers.

Specifications

	Lamb Air-Mover		
	3″ model	6″ model	10″ model
Overall length, in.	31¼	47⅝	44½
Weight, lb	6½	31	47
Base diameter, in.	7½	14½	20
OD exhaust end, in.	4⅝	10 3/16	14⅛
Compressed-air inlet connection	½″ pipe	1″ pipe	1″ pipe

Operation

No moving parts required. Compressed-air or steam lines can be quickly connected to a fitting on the bell of the unit. As the air or steam enters the annular orifice, decompression and expansion produce a powerful venturi effect which pulls in a large amount of the air around the bell. The air is then forced through the outlet horn at high velocity.



Typical Performance

	Gage pressure (psi)	Compressed air (scfm)	Induced air (scfm)	Discharge air (scfm)
Flow test 3″ model	20	60	740	800
	40	105	900	1005
	60	150	1060	1210
	80	195	1225	1420
	100	240	1400	1640
Flow test 6″ model	20	120	2550	2670
	40	260	3450	3710
	60	390	4400	4790
	80	530	5300	5830
	100	670	6950	7620
Flow test 10″ model	20	330	3800	4130
	40	520	5800	6320
	60	710	7700	8410
	80	910	9100	10200
	100	1100	9700	10800

Note: Flow rates shown above are typical for compressed air. At a given manifold pressure, steam data should be similar. Contact MSA for complete details.

Warning

Noise levels generated by this device, as a result of high airflow, may exceed OSHA permissible levels. Hearing protective devices should be worn when the Lamb Air-Mover Ventilator is in operation.

Ordering information

Catalog numbers

32119 Lamb Air-Mover, 3″ model
32120 Lamb Air-Mover, 6″ model
33552 Lamb Air-Mover, 10″ model

Note: This Data Sheet is a guide, containing only a general description of the uses and performance capabilities of MSA Lamb Air-Mover Ventilators. Before use, refer to and strictly follow all instructions, cautions, and warnings on or with the product. For more complete information, contact MSA, 600 Penn Center Blvd., Pittsburgh, Pa. 15235.

MSA Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, Pennsylvania 15235

At your service: 25 branch offices in the United States; MSA CANADA, Downsview, Ontario (Metro Toronto), Halifax, Montreal, Winnipeg, Saskatoon, Edmonton, Calgary, Vancouver; representatives in principal cities of the world.
Cable address—"MINSAF" Pittsburgh

Data Sheet 26-00-01

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APPENDIX B

Excerpts from second edition of International Safety Guide for Tankers and Terminals (ISGOTT)

International Safety Guide for Oil Tankers & Terminals

Second Edition

International Chamber of Shipping
Oil Companies International Marine Forum
International Association of Ports and Harbors

Witherby
Marine Publishing

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Chapter 8

Tank Cleaning and Gas Freeing

This Chapter deals with the procedures for cleaning and gas freeing cargo tanks and other enclosed spaces after the discharge of volatile petroleum or of non-volatile petroleum carried in a non-gas free tank, or when there is a possibility of flammable gas entering the tank or space. Safety precautions to be taken are set out, including those related to crude oil washing of cargo tanks.

8.1 SUPERVISION AND PREPARATIONS

8.1.1 Supervision

A responsible officer must supervise all tank cleaning and gas freeing operations.

8.1.2 Preparations

Both before and during tank cleaning and gas freeing operations, the responsible officer should be satisfied that all the appropriate precautions set out in Chapters 2 and 6 are being observed. All personnel on board should be notified that tank cleaning or gas freeing is about to begin.

If craft are alongside the tanker, their personnel should also be notified and their compliance with all appropriate safety measures should be checked.

Before starting to gas free or tank clean alongside a terminal, the following additional measures should be taken:

The precautions in Chapter 4 should be observed as appropriate.

The appropriate personnel ashore should be consulted to ascertain that conditions on the jetty do not present a hazard and to obtain agreement that operations can start.

8.1.3 Gas Freeing and Tank Cleaning Concurrently With Cargo Handling

As a general rule tank cleaning and gas freeing should not take place concurrently with cargo handling. If for any reason this is necessary, there should be close consultation with, and agreement by, both the terminal representative and the port authority.

Crude oil washing and cargo discharge may take place concurrently, but the terminal representative should be advised (see Section 8.4).

8.1.4 Testing of Tank Cleaning Hoses

All hoses should be tested for electrical continuity in a dry condition prior to use and in no case should the resistance exceed 6 ohms per metre length.

8.1.5 Entry Into Cargo Tanks

No one should enter any cargo tank unless permission to do so has been received from the responsible officer and all appropriate precautions have been taken, including the issue of an entry permit (see Chapter 10).

8.1.6 Gas Measuring Equipment

In order to maintain a proper control of the tank atmosphere and to check the effectiveness of gas freeing, a number of gas measuring instruments should be available on the ship.

Depending upon the type of atmosphere being measured, at least two of each of the following portable instruments should be available:

With a too lean tank atmosphere

— flammable gas indicator capable of measuring gas to the lower flammable limit (LFL) and with the scale graduated as a percentage of this limit.

With an inerted tank atmosphere

— gas indicator capable of measuring percentage volume of hydrocarbon gas in an inerted atmosphere.

— oxygen analyser.

With an over rich tank atmosphere

— gas indicator capable of measuring hydrocarbon gas concentrations above 15% volume in air.

In order to be able to check the effectiveness of gas freeing for tank entry the following instruments should be provided:

— a flammable gas indicator capable of measuring gas to the lower flammable limit (LFL) and with the scale graduated as a percentage of this limit.

— an oxygen analyser.

— an instrument capable of measuring concentrations in the human toxicity range of toxic gases and calibrated in parts per million.

The instruments to be used for gas measurement should be calibrated and tested in accordance with the manufacturer's instructions before starting to tank clean or gas free.

Tank atmosphere sampling lines should be in all respects suitable for and impervious to the gases present, and should be resistant to the effects of hot wash water.

8.2 CARGO TANK WASHING AND CLEANING

8.2.1 Tank Washing Atmospheres

Tank washing can be carried out in any of the following atmospheres:

Inerted — An atmosphere made incapable of burning by the introduction of inert gas and the resultant reduction of the overall oxygen content. For the purposes of this guide the oxygen content of the tank atmosphere should not exceed 8% by volume.

Too lean — An atmosphere made incapable of burning by the deliberate reduction of the hydrocarbon content to below the lower flammable limit (LFL).

Uncontrolled — An atmosphere which is not controlled and which can thus be above, below, or within the flammable range.

Over rich — An atmosphere made incapable of burning by deliberately maintaining the hydrocarbon content of the tank over the upper flammable limit (UFL). A hydrocarbon content of at least 15% by volume should be attained before starting to wash and maintained throughout washing.

8.2.2 Washing in an Inert Atmosphere

The requirements for the maintenance of an inert atmosphere and precautions to be observed during washing are set out in Section 9.6.8.

8.2.3 Washing in a Too Lean Atmosphere

The following precautions must be observed:

(a) Before washing, the tank bottom should be flushed with water and stripped. The piping system, including cargo pumps, crossovers and discharge lines, should also be flushed with water. The flushing water should be drained to the tank designed or designated to receive slops.

(b) Before washing, the tank should be ventilated to reduce the gas concentration of the atmosphere to 10% or less of the lower flammable limit (LFL). Gas tests must be made at various levels and due consideration given to the possible existence of local pockets of flammable gas. Mechanical ventilation and gas testing should continue during washing. Ventilation should as far as possible provide a free flow of air from one end of the tank to the other.

(c) If the tank has a venting system which is common to other tanks, the tank must be isolated to prevent an ingress of gas from the other tanks.

(d) If portable washing machines are used, all hose connections should be made up and tested for electrical continuity before the washing machine is introduced into the tank. Connections should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then re-tightened before the machine is removed.

(e) During tank washing regular gas tests must be made at various levels. Consideration should be given to the possible effect of water on the efficiency of the gas measuring equipment. Washing should be discontinued if the gas concentration rises to 50% of the LFL. Washing may be resumed when continued ventilation has reduced the gas concentration to 20% of the LFL and maintained it at or below that level for a short period.

(f) The tank should be kept drained during washing. Washing should be stopped to clear any build-up of wash water.

(g) Recirculated wash water should not be used for tank washing.

(h) Steam should not be injected into the tank.

(i) The same precautions relating to sounding and the introduction of other similar equipment should be taken as when washing in an uncontrolled atmosphere (see paragraph 8.2.4(h)).

(j) Chemical additives may be employed provided the temperature of the wash water does not exceed 60°C.

(k) Wash water may be heated. If the wash water temperature is 60°C or less, washing should be discontinued if the gas concentration reaches 50% of the LFL. If the wash water temperature is above 60°C, washing should be discontinued if the gas concentration reaches 35% of the LFL.

8.2.4 **Washing in an Uncontrolled Atmosphere**

When washing in an uncontrolled atmosphere precautions must be taken to avoid all possible ignition sources. It is essential that all the following precautions are observed:

(a) Not more than four washing machines may be used at any one time in any one compartment, each machine having a flow rate not exceeding 35 cubic metres/hour; or, alternatively, not more than 3 machines may be used, each having a flow rate of between 35 and 60 cubic metres/hour. Washing machines having a flow rate greater than 60 cubic metres/hour must not be used in an uncontrolled atmosphere.

For the purpose of this section a compartment is defined as any part of a tank that is sub-divided by a wash plate (swash) bulkhead.

(b) All hose connections must be made up and tested for electrical continuity before the washing machine is introduced into the tank. Connections should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then re-tightened before the machine is removed.

(c) Recirculated wash water must not be used for tank washing.

(d) Chemical additives may not be used. If it is deemed essential to use chemicals for any reason, washing should be done under too lean or inerted atmospheric conditions.

(e) Wash water may be heated provided the temperature does not exceed 60°C; if water above 60°C is required for any reason, for instance in preparation for drydocking, washing should be undertaken under too lean or inerted atmospheric conditions.

(f) Steam must not be injected into the tank.

(g) The tank should be kept drained during washing. Washing should be stopped to clear any build-up of wash water.

(h) Sounding and the introduction of other equipment must be done through a sounding pipe if fitted.

If a sounding pipe is not fitted, it is essential that any metallic components of the sounding or other equipment are bonded and securely earthed to the ship before introduction into the tank and remain so earthed until removed. This precaution should be observed during washing and for 5 hours thereafter. If, however, the tank is continuously mechanically ventilated after washing, this period can be reduced to 1 hour. During this period:

An interface detector of metallic construction may be used if earthed to the ship by means of a clamp or bolted metal lug.

A metal rod may be used on the end of a metal tape which is earthed to the ship.

A metal sounding rod suspended on a fibre rope should not be used even if the end at deck level is fastened to the ship because the rope cannot be completely relied upon as an earthing path.

Equipment made entirely of non-metallic materials may, in general, be used; e.g. a wooden sounding rod may be suspended on a rope without earthing.

Ropes made of synthetic polymers should not be used for lowering equipment into cargo tanks.

Further information on electrostatic precautions during tank washing is given in Chapter 19.

8.2.5 Washing in an Over Rich Atmosphere

The procedures for making a tank atmosphere over rich and thereafter water washing the tank involve special measures intended to prevent the ingress of air. This method of tank washing should only be carried out when authorized by the owner and under the supervision of a person who has received special training in these procedures.

Water washing must not be started, or if in progress must be discontinued and not re-started, if the hydrocarbon content of the tank atmosphere is less than 15% by volume.

8.2.6 Portable Tank Washing Machines and Hoses

The outer casing of portable machines should be of a material which on contact with the internal structure of a cargo tank will not give rise to an incendive spark.

Bonding wires should be incorporated within all water hoses. Couplings should be connected to the hose in such a way that effective bonding is ensured between them.

The coupling arrangement for the hose should be such that effective bonding can be established between the tank washing machine, the hoses and the fixed tank cleaning water supply line.

Hoses should be indelibly marked to allow identification. A record should be kept showing the date and the result of electrical continuity testing.

Washing machines should be electrically bonded to the water hose by means of a suitable connection or external bonding wire.

When suspended within a cargo tank, machines should be supported by means of a rope and not by means of the water supply hose.

8.2.7 **Free Fall**
It is essential to avoid the free fall of water or slops in the receiving tank. The liquid level should always be such that the discharge inlets in the slop tank are covered to a depth of at least one metre to avoid splashing. This is not necessary when the slop and cargo tanks are fully inerted.

8.2.8 **Spraying of Water**
The spraying of water into a tank containing a substantial quantity of static accumulator oil could result in the generation of static electricity at the liquid surface, either by agitation or by water settling. Tanks which contain a static accumulator oil should always be pumped out before they are washed with water unless the tank is kept in an inert condition (see Section 7.4.2 and 7.4.4).

8.2.9 **Steaming of Tanks**
Because of the hazard of static electricity, steaming may only be carried out in tanks which have been water washed and gas freed.

The concentration of flammable gas should not exceed 10% of the LFL prior to steaming.

8.2.10 **Leaded Gasoline**
Whereas shore tanks may contain leaded gasoline for long periods and therefore present a hazard from tetraethyl lead (TEL) and tetramethyl lead (TML), ships' tanks normally alternate between different products and ballast and thus present very little risk. Ships employed in the regular carriage of leaded gasoline should flush the bottom of the tanks after every cargo discharge unless the tank is to be ballasted.

Entry into ships' tanks used regularly for the carriage of leaded gasoline should be limited.

8.2.11 **Removal of Sludge, Scale and Sediment**
Before the removal by hand of sludge, scale and sediment the tank atmosphere must be safe for entry and an entry permit issued. The precautions described in Section 10.5.5 should be maintained throughout the period of work.

Equipment to be used for further tank cleaning operations, such as the removal of solid residues or products, in tanks which have been gas freed should be so designed and constructed, and the construction materials so chosen, that no risk of ignition is introduced.

8.3 GAS FREEING

8.3.1 **General**
It is generally recognised that tank cleaning and gas freeing is the most hazardous period of tanker operations. This is true whether washing for clean ballast, gas freeing for entry, or gas freeing for hot work. The additional risk from the toxic effect of petroleum gas during this period cannot be over-emphasised and must be impressed on all concerned. It is therefore essential that the greatest possible care is exercised in all operations connected with tank cleaning and gas freeing.

8.3.2 **General Procedures**
The following recommendations apply to cargo tank gas freeing generally. Additional considerations which apply when the tank has been inerted are given in Chapter 9.

(a) The covers of all tank openings should be kept closed until actual ventilation of the individual tank is about to commence.

(b) Portable fans or blowers should only be used if they are hydraulically, pneumatically or steam driven. Their construction materials should be such that no hazard of incendiary sparking arises if, for any reason, the impeller touches the inside of the casing.

The capacity and penetration of portable fans should be such that the entire atmosphere of the tank on which the fan is employed can be made non-flammable in the shortest possible time.

(c) The venting of flammable gas during gas freeing should be by the vessel's approved method, and where gas freeing involves the escape of gas at deck level or through tank hatch openings the degree of ventilation and number of openings should be controlled to produce an exit velocity sufficient to carry the gas clear of the deck (see Section 6.8.2).

(d) Intakes of central air conditioning or mechanical ventilating systems should be adjusted to prevent the entry of petroleum gas, if possible by recirculation of air within the enclosed spaces.

If at any time it is suspected that gas is being drawn into the accommodation, central air conditioning and mechanical ventilating systems should be stopped and the intakes covered or closed.

Window type air conditioning units which are not certified as safe for use in the presence of flammable gas or which draw in air from outside the superstructure must be electrically disconnected and any external vents or intakes closed.

(e) Where cargo tanks are gas freed by means of one of more permanently installed blowers, all connections between the cargo tank system and the blowers should be blanked except when the blowers are in use.

Before putting such a system into service, the cargo piping system, including crossovers and discharge lines, should be flushed through with sea water and the tanks stripped. Valves on the system, other than those required for ventilation, should be closed and secured.

(f) Tank openings within enclosed or partially enclosed spaces should not be opened until the tank has been sufficiently ventilated by means of openings in the tank which are outside these spaces. When the gas level within the tank has fallen to 25% of the LFL or less, openings into enclosed or partially enclosed spaces may be opened to complete the ventilation. Such enclosed or partially enclosed spaces should also be tested for gas during this subsequent ventilation.

(g) If the tanks are connected by a common venting system, each tank should be isolated to prevent the transfer of gas to or from other tanks.

(h) Portable fans, where used, should be placed in such positions and the ventilation openings so arranged that all parts of the tank being ventilated are equally and effectively gas freed. Ventilation outlets should generally be as remote as possible from the fans.

(i) Portable fans, where used, should be so connected to the deck that an effective electrical bond exists between the fan and the deck.

(j) Fixed gas freeing equipment may be used to gas free more than one tank simultaneously but must not be used for this purpose if the system is being used to ventilate another tank in which washing is in progress.

(k) On the apparent completion of gas freeing any tank, a period of about 10 minutes should elapse before taking final gas measurements. This allows relatively stable conditions to develop within the tank space. Tests should be made at several levels and, where the tank is sub-divided by a wash bulkhead, in each compartment of the tank. In large compartments such tests should be made at widely separate positions.

If satisfactory gas readings are not obtained ventilation must be resumed.

(l) On completion of gas freeing all openings except the tank hatch should be closed.

(m) On completion of all gas freeing and tank washing the gas venting system should be carefully checked, particular attention being paid to the efficient working of the pressure/vacuum valves and any high velocity vent valves. If the valves or vent risers are fitted with devices designed to prevent the passage of flame these should also be checked and cleaned.

Gas vent riser drains should be cleared of water, rust and sediment, and any steam smothering connections tested and proved satisfactory.

8.3.3 Gas Free for the Reception of Cargo
A tank which is required to be gas free for receiving cargo should be ventilated until tests confirm that the hydrocarbon gas concentration throughout that tank does not exceed 40% of the LFL.

8.3.4 Gas Free for Entry and Cold Work Without Breathing Apparatus
In order to be gas free for entry without breathing apparatus a tank or space must be ventilated until tests confirm that the hydrocarbon gas concentration throughout the compartment is not more than 1% of the LFL and the additional tests have been made to check for oxygen content, the presence of hydrogen sulphide, benzene and other toxic gases as appropriate (see Section 10.2).

8.3.5 Gas Free in Preparation for Hot Work

In addition to meeting the requirements of Section 8.3.4, the requirements of Section 10.5.7 must also be complied with.

8.4 CRUDE OIL WASHING

8.4.1 General

A crude oil tanker fitted with an inert gas system and fixed washing equipment in its cargo tanks can use crude oil from the cargo as the washing medium. This operation may take place either in port or at sea between discharge ports. It is most frequently carried out while the tanker is discharging cargo and permits the removal of oil fractions adhering to or deposited on tank surfaces. These deposits, which would normally remain on board after discharge, are then discharged with the cargo.

As a consequence, the need to water wash the discharged tanks during the ballast voyage for the removal of residues is much reduced and, in some cases, entirely eliminated.

Water rinsing will be necessary if the tank is to be used for clean ballast.

Reference should be made to the IMO publication 'Crude Oil Washing Systems'' and the vessel's approved Operations and Equipment Manual for further detailed guidance on the procedures involved.

8.4.2 Advance Notice

When it is required to carry out crude oil washing during cargo discharge the master should inform the competent authority and the terminal (or vessel when ship to ship transfer is involved) at least 24 hours in advance, or in such time as is required. Crude oil washing should only proceed when their approval is received.

8.4.3 Tank Washing Machines

Only fixed tank washing machines may be used for crude oil washing.

8.4.4 Control of Tank Atmosphere

The oxygen content of the tank must not exceed 8% by volume as described in Section 9.6.8.

8.4.5 Precautions Against Leakage from the Washing System

Before arriving in a port where it is intended to crude oil wash, the tank washing system should be pressure tested to normal working pressure and examined for leaks.

All machines which are to be used should be operated briefly to check for leaks beyond the shut-off valve. Any leaks found should be made good.

During crude oil washing, the system must be kept under constant observation so that any leak can be detected immediately and action taken to deal with it.

8.4.6 Avoidance of Oil/Water Mixtures

Mixtures of crude oil and water can produce an electrically charged mist during washing much in excess of that produced by "dry" crude oil. The use of "dry" crude oil is therefore important, and before washing begins any tank which is to be used as a source of crude oil washing fluid should be partly discharged to remove any water which has settled out during the voyage. The discharge of a layer at least one metre in depth is necessary for this purpose.

For the same reason, if the slop tank is to be used as a source of oil for washing, it should first be completely discharged ashore and refilled with "dry" crude oil.

8.4.7 Exclusion of Cargo Oil from the Engine Room

If any part of the tank washing system extends into the engine room it must be blanked-off to prevent cargo oil from entering the engine-room.

If the tank wash water heater is fitted outside the engine-room, it must be blanked-off during crude oil washing to prevent oil from flowing through it.

8.4.8 Control of Vapour Emissions

During crude oil washing hydrocarbon gas is generated within the cargo tanks beyond normally existing levels. Subsequent ballasting of such cargo tanks could lead to considerable hydrocarbon gas being expelled to the atmosphere. Some port authorities prohibit such discharges.

The emission of hydrocarbon gas from ballasted tanks can be avoided in one of four ways:

(a) By the use of permanent ballast tanks of sufficient capacity to provide the minimum departure draught.

(b) By containing gas in empty cargo tanks by simultaneous ballasting and cargo discharge where the ullage spaces of the tanks being ballasted are directly connected to those of the tanks being discharged.

(c) By the gas compression method which requires that, on completion of the discharge, the tank pressure is at a minimum and all cargo tanks are made common via the inert gas line. While ballasting, the gases from the ballasted cargo tanks are transferred through the inert gas lines into the whole available cargo tank space and, with all vent valves, ullage ports, etc. closed, the gases are compressed within the vessel up to a safe margin below P/V valve and breaker settings. The P/V valves and breaker must be in good operational condition. All non-return devices must be closed to prevent the backflow of inert gas into the inert gas plant.

(d) By a suitable combination of any of these methods.

Generally, the ullage spaces of all cargo tanks are connected by the inert gas main line. If the ballasting of dirty tanks can be commenced while discharge continues from other tanks, judicious adjustments of ballast and discharge rates can prevent the gas pressure rising sufficiently to cause a discharge to atmosphere. Where the ballast rate exceeds the discharge rate it may be necessary to reduce or even temporarily stop the flow of inert gas to the tank system.

8.4.9 **Supervision**
The person in charge of crude oil washing operations must be suitably qualified in accordance with the requirements laid down by the flag administration of the vessel and any port regulations in force locally.

8.4.10 **Cautionary Notice**
A notice should be displayed in the cargo and engine control rooms, on the bridge and on the notice boards of ships which carry out crude oil washing. The following text is suggested:

> THE TANK WASHING LINES ON THIS SHIP MAY CONTAIN CRUDE OIL. VALVES ON THESE LINES MUST NOT BE OPENED BY UNAUTHORISED PERSONNEL.

8.5 SPECIAL TANK CLEANING PROCEDURES

After the carriage of certain products, tanks can only be adequately cleaned by steaming, or by the addition of certain tank cleaning chemicals or additives to the wash water.

Steaming may only be carried out in tanks which have been either inerted or water washed and gas freed. The concentration of flammable gas should not exceed 10% of the LFL prior to steaming. Precautions should be taken to avoid the build-up of steam pressure within the tank.

If tank cleaning chemicals are to be used, it is important to understand that certain products may introduce a toxicity hazard. Personnel should be made aware of the TLV (Threshold Limit Value) of the product. Personnel entering tanks should wear breathing apparatus and appropriate protective clothing. All other tank entry precautions must be observed (see Section 10.4). Chemical absorption detectors are particularly useful for detecting the presence of specific gases and vapours at TLV levels.

Tank cleaning chemicals capable of producing a flammable atmosphere should normally only be used when the tank has been inerted. However, such products may be used to clean tank walls in a localised area (e.g. wiping down) in vessels not fitted with an inert gas system provided the amount of tank cleaning chemical used is small and the personnel entering the tank observe all enclosed space entry requirements.

In addition to the above, any manufacturers' instructions or recommendations for the use of these products should be observed.

Where these operations take place in port, additional requirements may be imposed by local authorities.

Chapter 19

Static Electricity

This Chapter deals with the generation of static electricity during the loading and discharging of cargo and during tank cleaning. In addition the Chapter deals with ship to shore and ship to ship electric currents.

19.1 PRINCIPLES OF ELECTROSTATIC HAZARD

19.1.1 General

Static electricity presents fire and explosion hazards during the handling of petroleum, and tanker operations are no exception. Certain operations can give rise to accumulations of electric charge which may be released suddenly in electrostatic discharges with sufficient energy to ignite flammable hydrocarbon gas/air mixtures; there is, of course, no risk of ignition unless a flammable mixture is present. There are three basic stages leading up to a potential static hazard: charge separation, charge accumulation and electrostatic discharge. All three of these stages are necessary for an electrostatic ignition.

19.1.2 Charge separation

Whenever two dissimiliar materials come into contact charge separation occurs at the interface. The interface may be between two solids, between a solid and a liquid or between two immiscible liquids. At the interface charge of one sign (say positive) moves from material A to material B so that materials A and B become respectively negatively and positively charged. Whilst the materials stay in contact and immobile relative to one another, the charges are extremely close together. The voltage difference between the charges of opposite sign is then very small, and no hazard exists.

The charges can be widely separated by many processes, such as:

The flow of liquids (e.g. petroleum or mixtures of petroleum and water) through pipes or fine filters.

The settling of a solid or an immiscible liquid through a liquid (e.g. rust or water through petroleum).

The ejection of particles or droplets from a nozzle (e.g. steaming operations).

The splashing or agitation of a liquid against a solid surface (e.g. water washing operations or the initial stages of filling a tank with oil).

The vigorous rubbing together and subsequent separation of certain synthetic polymers (e.g. the sliding of a polypropylene rope through PVC gloved hands).

When the charges are separated a large voltage difference develops between them. Also a voltage distribution is set up throughout the neighbouring space and this is known as an electrostatic field. As examples, the charge on a charged petroleum liquid in a tank produces an electrostatic field throughout the tank both in the liquid and in the ullage space, and the charge on a water mist caused by tank washing produces a field throughout the tank.

If an uncharged conductor is present in an electrostatic field it has approximately the same voltage as the region it occupies. Furthermore the field causes a movement of charge within the conductor; charge of one sign is attracted by the field to one end of the conductor and an equal charge of opposite sign is left at the opposite end. Charges separated in this way are known as induced charges and as long as they are kept separate by the presence of the field they are capable of contributing to an electrostatic discharge.

19.1.3 Charge accumulation

Charges which have been separated attempt to recombine and to neutralize each other. This process is known as charge relaxation. If one, or both, of the separated materials carrying charge is a very poor electrical conductor recombination is impeded and the material retains or accumulates the charge upon it. The period of time for which the charge is retained is characterized by the relaxation time of the material, which is related to its conductivity; the lower the conductivity the greater is the relaxation time.

If a material has a comparatively high conductivity the recombination of charges is very rapid and can counteract the separation process, and consequently little or no static electricity accumulates on the material. Such a highly conducting material can only retain or accumulate charge if it is insulated by means of a poor conductor, and the rate of loss of charge is then dependent upon the relaxation time of this less conducting material.

The important factors governing relaxation are therefore the electrical conductivities of the separated materials and of any additional materials which may be interposed between them after their separation.

19.1.4 Electrostatic discharges

Electrical breakdown between any two points, giving rise to a discharge, is dependent upon the strength of the electrostatic field in the space between the points. This field strength, or voltage gradient, is given approximately by dividing the difference in voltage between the points by their distance apart. A field strength of about 3,000 kilovolts per metre is sufficient to cause breakdown of air or petroleum gases.

The field strength near protrusions is greater than the overall field strength in the vicinity and discharges therefore generally occur at protrusions. A discharge may occur between a protrusion and the space in its vicinity without reaching another object. These single electrode discharges are rarely, if ever, incendive in the context of normal tanker operations.

The alternative is a discharge between two electrodes adjacent to each other. Examples are:

Between sampling apparatus lowered into a tank and the surface of a charged petroleum liquid.

Between an unearthed object floating on the surface of a charged liquid and the adjacent tank structure.

Between unearthed equipment suspended in a tank and the adjacent tank structure.

Two-electrode discharges may be incendive if various requirements are met. These include:

A discharge gap short enough to allow the discharge to take place with the voltage difference present, but not so short that any resulting flame is quenched.

Sufficient electrical energy to supply the minimum amount of energy to initiate combustion.

The nearly instantaneous release of this energy into the discharge gap.

Whether the last requirement can be fulfilled depends to a large extent on the conductivity of the electrodes. In order to consider this further it is necessary to classify solids and liquids intro three groups.

The first group is the conductors. In the case of solids these are the metals, and in the case of liquids the whole range of aqueous solutions including sea water. The human body, consisting of about 60% water, is effectively a liquid conductor. The important property of conductors is that not only are they incapable of holding a charge unless insulated, but also that if they are insulated and an opportunity for an electrical discharge occurs all the charge available is almost instantaneously released into the discharge.

Discharges between two conductors very frequently occur as sparks, and are much more energetic and potentially dangerous than those occurring between objects, one of which is not a conductor. In the latter case discharges often take a more diffuse and much less dangerous form, known as corona or brush discharge, rather than a spark.

The second group is the non-conductors, which have such low conductivities that once they have received a charge they retain it for a very long period. Alternatively they can prevent the loss of charge from conductors by acting as insulators. Charged non-conductors are of primary concern because they can transfer charge to, or induce charge on, neighbouring insulated conductors which may then give rise to sparks. Very highly charged non-conductors may themselves contribute directly to incendive sparks.

Liquids are considered to be non-conductors when they have conductivies less than 100 picoSiemens/metre (pS/m) giving relaxation times greater than 0·2 seconds; they are often known as static accumulators. In the case of petroleum, clean oils (distillates) frequently fall into this category. An antistatic additive is a substance which is deliberately added to a petroleum distillate to raise its conductivity above 100 pS/m.

The solid non-conductors are highly insulating materials such as polypropylene, PVC, nylon and many types of rubber. They become more conductive as their surfaces are contaminated with dirt or moisture.

The third group is a range of liquids and solids with conductivities intermediate between those of the first two groups. The liquids have conductivities exceeding 100 pS/m and are often known as static non-accumulators. Examples are black oils (containing residual materials) and crude oils, which typically have conductivities in the range 10,000-100,000 pS/m. Some chemicals, for example alcohols, are also static non-accumulators.

The solids in this intermediate category include such materials as wood, cork, sisal and naturally occurring organic substances generally. They owe their conductivity to their ready absorption of water and they become more conductive as their surfaces are contaminated by moisture and dirt. In some cases thorough cleaning and drying may lower their conductivities sufficiently to bring them into the non-conductive range.

If materials in the intermediate conductivity group are not insulated from earth, their conductivities are normally sufficiently high to prevent accumulation of an electrostatic charge. However, their conductivities are normally low enough to inhibit production of energetic sparks.

The incendivity of a discharge from a material of intermediate conductivity depends upon so many factors in addition to conductivity that generalizations beyond the foregoing are impossible, and it is necessary to rely upon practical experience to indicate when it is acceptable to use them.

Under normal conditions gases are highly insulating; this has important implications with respect to mists and particulate suspensions in air and other gases. Charged mists are formed during the ejection of wet steam from a nozzle, while using tank washing machines and during crude oil washing. Although the liquid, for example water, may have a very high conductivity, the relaxation of the charge on the droplets is hindered by the insulating properties of the surrounding gas. Fine particles present in inert flue gas or created during discharge of pressurized liquid carbon dioxide are frequently charged. The gradual charge relaxation which does occur is the result of the settling of the particles or droplets and, if the field strength is high, of corona discharge at protrusions which supplies a neutralizing charge of the sign opposite to that on the suspension.

In summary, electrostatic discharges can occur as a result of accumulations of charge on:

Liquid or solid non-conductors, for example a static accumulator oil (such as kerosene) pumped into a tank, or a polypropylene rope.

Electrically isolated liquid or solid conductors, for example mists, sprays or particulate suspensions in air, or a metal rod hanging on the end of a synthetic fibre rope.

For materials with intermediate conductivities the risk of electrostatic discharge is small, particularly if current practices are adhered to, and the chance of their being incendive is even smaller.

19.2 GENERAL PRECAUTIONS AGAINST ELECTROSTATIC HAZARDS

The most important countermeasure that must be taken to prevent an electrostatic hazard is to bond all metal objects together; bonding eliminates the risk of discharges between metal objects, which can be very energetic and dangerous. To avoid discharges from conductors to earth, it is normal practice to include bonding to earth (earthing or grounding). On ships, bonding to earth is effectively accomplished by connecting metallic objects to the metal structure of the ship, which is naturally earthed through the sea.

Some examples of objects which might be electrically insulated in hazardous situations and which must therefore be bonded are:

Ship/shore hose couplings and flanges if more than one length of non-conducting hose or pipe is used in a string.

Portable tank cleaning machines.

Conducting manual ullaging and sampling equipment.

The float of a permanently fitted ullage device if it lacks an earthing path through the metal tape.

The most certain method of bonding and earthing is by means of a metallic connection between the conductors. This method should be used whenever possible, although for electrostatic purposes an adequate bond can in principle be made using a material of intermediate conductivity.

Certain objects may be insulated fortuitously during tanker operations, for example:

A metal object such as a can floating in a static accumulating liquid.

A loose metal object while it is falling in a tank during washing operations.

Every effort should be made to ensure that such objects are removed from the tank, since there is evidently no question of deliberately bonding them. This necessitates careful inspection of tanks, particularly after shipyard repairs.

19.3 ELECTROSTATIC HAZARDS WHEN HANDLING STATIC ACCUMULATOR OILS

19.3.1 Pumping oil into tanks

Petroleum distillates often have electrical conductivities less than 100 picoSiemens/metre and thus fall into the category of accumulators.

Since their conductivites are not normally known, all distillates must be treated as static accumulators unless they contain an antistatic additive (see Section 19.3.4). During and for some time after entry into the tank a static accumulator oil may carry sufficient charge to constitute a hazard.

The charge may arise through one or more of several different processes:

Flow of the oil through the pipeline system into the tank. Charge generation is enhanced if water droplets are suspended in the oil as it flows through the pipes.

Flow through a micropore filter of the kind used for aircraft jet fuels. These filters have the ability to charge fuels to a very high level, probably because all the fuel is brought into intimate contact with the filter surface, where cargo separation occurs.

Turbulence and splashing in the early stages of pumping the oil into an empty tank.

The settling of water droplets, rust or other particles entering the tank with the oil or stirred up by it in the tank.

The generally accepted method for controlling electrostatic generation in the initial stages of loading is to restrict the flow rate of the static accumulator oil into the tank until all splashing and surface turbulence in the tank has ceased.

At the commencement of loading an empty tank the linear velocity in the branch line to each individual cargo tank should not exceed 1 metre/second (3 feet/second). The reasons for such a low rate are twofold:

It is at the beginning of filling a tank that there is the greatest likelihood of water being mixed with the oil entering the tank; mixtures of oil and water constitute a most potent source of static electricity.

A low loading rate minimizes the extent of turbulence and splashing as oil enters the tank; this helps to reduce the generation of static electricity and also reduces the dispersal of any water present, so that it more quickly settles out to the bottom of the tank where it can lie relatively undisturbed when the loading rate is subsequently increased.

During subsequent loading the limitations on flow rate imposed by present design of pipeline systems, coupled with precautions in the introduction of dipping, ullaging and sampling equipment (see Section 19.5) and the avoidance of electrically isolated conductors, have proved sufficient to maintain operational safety. If, however, markedly different pipeline or pumping systems were to be introduced enabling higher flow rates or velocities to be achieved then flow rate limitations might have to be imposed throughout loading.

The limitation on the initial loading rate for static accumulator oils applies whenever a flammable gas mixture may be present. These situations are fully described in Section 7.4 and are summarized in Table 7-1.

It is not uncommon during loading to encounter water from such operations as water washing, ballasting or line flushing and care should be taken to prevent excess water and unnecessary mixing. For example, cargo tanks and water flushed lines should be drained before loading and water should not be permitted to accumulate in tanks. Lines should not be displaced with water back into a tank containing a static accumulator oil.

Coarse filters are sometimes used in tanker operations. These generate an insignificant amount of charge provided that they are kept clean. However, if micropore filtration is used on the jetty sufficient time must be allowed for the charge to relax before the liquid reaches the tank. It is desirable for the liquid to spend a minimum of 30 seconds in the piping downstream of the filter.

19.3.2 Fixed equipment in cargo tanks

Equipment permanently mounted from the top of a tank, such as fixed washing machines or high level alarms, may act as isolated probes. A metal probe remote from any other tank structure but near a highly charged liquid surface will have a high voltage gradient at the probe tip. During the loading of static accumulator oils, this high voltage gradient may cause electrostatic discharges to the approaching liquid surface.

An isolated probe configuration can be avoided by installing the device adjacent to a wall or other tank structure to reduce the voltage gradient at the probe tip. Alternatively a support can be added running from the lower end to the tank structure so that the rising liquid meets an edge rather than the isolated tip of a probe. Another solution possible in some cases is to construct the probe-like device entirely of a non-conductive material. These measures are not necessary if the vessel is limited to crude and black oil service.

19.3.3 Air release in the bottom of tanks

If air or inert gas is blown into the bottom of a tank containing a static accumulator oil a strong electrostatic field can be generated, especially in the presence of water or particulate matter. Accordingly precautions should be taken to minimize the amount of air or inert gas entering tanks containing static accumulator oils.

19.3.4 Antistatic additives

If the oil contains an effective antistatic additive it is no longer a static accumulator. Although, strictly, this means that the precautions applicable to an accumulator can be relaxed, it is still advisable to adhere to them in practice unless it is certain that the conductivity is above 100 picoSiemens/metre.

19.4 OTHER SOURCES OF ELECTROSTATIC HAZARDS

19.4.1 Free fall in tanks

Loading or ballasting overall delivers charged liquid to a tank in such a manner that it can break up into small droplets and splash into the tank. This may produce a charged mist as well as increasing the petroleum gas concentration in the tank. Restrictions upon loading or ballasting overall are given in Section 7.6.15.

19.4.2 Water mists

The spraying of water into tanks, for instance during water washing, gives rise to electrostatically charged mist. This mist is uniformly spread throughout the tank being washed. The electrostatic levels vary widely from tank to tank both in magnitude and in sign.

When washing is started in a dirty tank the charge in the mist is initially negative, reaches a maximum negative value, then goes back through zero and finally rises towards a positive equilibrium value. It has been found that, among the many variables affecting the level and polarity of charging, the characteristics of the wash water and the degree of cleanlinesss of the tank have the most significant influence. The electrostatic charging characteristics of the water are altered by recirculation or by the addition of tank cleaning chemicals, either of which may cause very high electrostatic levels in the mist. The size and number of washing machines in a tank affect the rate of change of charge but they have little effect on the final equilibrium value.

The charged mist droplets created in the tank during washing give rise to an electrostatic field which is characterized by a distribution of potential (voltage) throughout the tank space. The walls and structure are at earth (zero) potential; the space potential increases with distance from these surfaces and is highest at points furthest from them. The field strength, or voltage gradient, in the space is greatest near the tank walls and structure, more especially where there are protrusions into the tank. If the field strength is high enough electric breakdown occurs into the space, giving rise to corona. Because protrusions cause concentrations of field strength a corona occurs preferentially from such points. A corona injects a charge of the opposite sign into the mist and is believed to be one of the main processes limiting the amount of charge in the mist to an equilibrium value. The corona discharges produced during tank washing are not strong enough to ignite the hydrocarbon gas/air mixtures that may be present.

Under certain circumstances discharges with sufficient energy to ignite hydrocarbon gas/air mixtures can occur from unearthed conducting objects already within, or introduced into, a tank filled with charged mist. Examples of such unearthed conductors are a metal sounding rod suspended on a non-conducting rope or a piece of metal falling through the tank space. Primarily by induction an unearthed conductor within a tank can acquire a high potential when it comes near an earthed object or structure, particularly if the latter is in the form of a protrusion. The unearthed conductor may then discharge to earth giving rise to a spark capable of igniting a flammable hydocarbon gas/air mixture.

The processes by which unearthed conductors give rise to ignitions in a mist are fairly complex, and a number of conditions must be satisfied simultaneously before an ignition can occur. These conditions include the size of the object, its trajectory, the electrostatic level in the tank and the geometrical configuration where the discharge takes place.

As well as solid unearthed conducting objects, an isolated slug of water produced by the washing process may similarly act as a spark promoter and cause an ignition. Experiments have shown that high capacity, single nozzle fixed washing machines can produce water slugs which, owing to their size, trajectory and duration before breaking up, may satisfy the criteria for producing incendive discharges. On the other hand there is no evidence of such water slugs being produced by portable types of washing machine.

Following extensive experimental investigations and using the results of long-term experience, the tanker industry has drawn up the tank washing guidelines set out in Chapter 8. These guidelines are aimed at preventing excessive charge generation in mists and at controlling the introduction of unearthed conducting objects when there is charged mist in the tank. The guidelines apply to tanks of all sizes.

Charged mists very similar to those produced during tank washing occur from time to time in partly ballasted holds of OBOs. Due to the design of these ships there may be violent mist-generating impacts of the ballast against the sides of the hold when the ship rolls in even a moderate sea. The impacts also give rise to free flying slugs of water in the tank, so that if the atmosphere of the tank is flammable all the elements for an ignition are present. The most effective counter-measure is to have tanks either empty or fully pressed up so that the violent wave motion in the tank cannot take place.

19.4.3 Steam

Steaming can produce mist clouds which may be electrostatically charged. The effects and possible hazards from such clouds are similar to those described for the mists created by water washing, but the introduction of steam can cause very much higher levels of charging than those produced by water washing. The time required to reach maximum charge levels is also very much less. For these reasons steam should not be injected into cargo tanks where there is any risk of the presence of a flammable atmosphere.

19.4.4 Inert gas

Small particulate matter carried in inert gas can be electrostically charged. The charge separation originates in the combustion process and the charged particles are capable of being carried through the scrubber, fan and distribution pipes into the cargo tanks. The electrostatic charge carried by the inert gas is usually small but levels of charge have been observed well above those encountered with water mists formed during washing. Because the tanks are normally in an inert condition, the possibility of an electrostatic ignition has to be considered only if it is necessary to inert a tank which already contains a flammable atmosphere or if a tank already inerted is likely to become flammable because the oxygen content rises as a result of ingress of air. Precautions are then required during dipping, ullaging and sampling (see Section 19.5.5).

19.4.5 Discharge of carbon dioxide

During the discharge of pressurized liquid carbon dioxide the rapid cooling which takes place can result in the formation of particles of solid carbon dioxide which become charged on impact and contact with

APPENDIX C

Report on Stability and Strength Calculations of the AMERICAN EAGLE

U.S. Department of Transportation
United States Coast Guard

Commandant
United States Coast Guard

Washington, DC 20593
Staff Symbol: G-MTH-5
Phone: (202) 426-2188

16732/AMERICAN EAGLE

10 SEP 1984

From: Commandant
To : Chairman, Marine Board of Investigation; S.S. AMERICAN EAGLE

Subj: S.S. AMERICAN EAGLE, O.N. 278327 Marine Board of Investigation
Technical Assistance

Ref : (a) Your letter 16732/S.S. AMERICAN EAGLE of 1 May 1984

1. Enclosure (1) is the final report of the technical analysis which you requested by reference (a).

A. E. HENN
By direction

Encl: (1) "S.S. AMERICAN EAGLE Casualty Investigation
Stability and Strength Calculations"
Report dated 31 August 1984

United States Coast Guard
Office of Merchant Marine Safety
Marine Technical and Hazardous Materials Division

S.S. AMERICAN EAGLE Casualty Investigation
Stability and Strength Calculations

31 August 1984

S.S. AMERICAN EAGLE Casualty Investigation
Stability and Strength Calculations

The Marine Board of Investigation requested Commandant (G-MTH-5) to perform stability and strength analyses to assist in determining the cause of the sinking of the S.S. AMERICAN EAGLE, O.N. 278327 in the Gulf of Mexico on 26 February 1984. The analyses requested consisted of the following tasks:

1. Calculate a loading condition just before the explosion based on the Board's description of loading. Calculate and evaluate the intact stability of this loading condition.

2. Calculate and evaluate the floating characteristics and damage stability of the stern section after the bow broke off using the progressive flooding sequence prescribed the Board.

3. Perform a longitudinal strength analysis in still water. Determine the shear force between the bow and the stern section prior to the breaking away of the bow.

4. Perform a bulkhead strength analysis to determine the hydrostatic pressure necessary to rupture a tank bulkhead.

This report contains a summary of results, assumptions and a brief description of the analytical methods used.

1. Intact Stability of the Ship Before the Explosion

The Marine Board of Investigation supplied a description of how the ship was loaded just before the explosion. Using this description, ship's drawings and technical reports supplied by the Board, the loading condition shown below was developed:

ITEM DESCRIPTION	WEIGHT (L.T.)	VCG (FT)	LCG FROM ⊕ FT (+) FWD
Light Ship	9984	29.8	-30.5
Tank #10 Center 75% Full-Ballast	1747	17.0	-145.0
Tank #1 Port 100% Full-Ballast	972	24.6	+203.7
Tank #2 Starboard 100% Full-Ballast	1138	23.6	+164.5
Tank #6 Port 3' of Ballast	68	1.8	+15.0
Tank #6 Center 3' of Ballast	148	1.5	+15.0
Tank #6 Starboard 3' of Ballast	68	1.8	+15.0
TOTAL	14,125	26.8	-11.9

The intact stability for this condition was analyzed using the SHCP Computer program. The results are as follows:

Total Displacement	=	14,125 LT
Longitudinal Center of Gravity from ⌘ (+ Fwd.)	=	-11.9 FT
Mean Midship Draft	=	12.4 FT
Trim	=	8.8 FT By the Stern
Draft at Forward Perpendicular	=	8.2 FT
Draft at after Perpendicular	=	17.0 FT
Free Surface Correction (Virtual Rise in VCG)	=	1.3 FT
Vertical Center of Gravity From Base Line (VCG)	=	26.8 FT
Vertical Center of Gravity From Base Line Corrected for Free Surface (VCG')	=	28.1 FT
Metacentric Height (G'M) Corrected for Free Surface	=	28.4 FT

The intact statical stability righting arm curve is shown in Figure 1. The analysis indicates that the ship as loaded just before the explosion met U.S. Coast Guard and Marpol 73/78 stability requirements.

2. Damage Stability and Progressive Flooding of the Stern Section

The separation of the stern section from the bow section was assumed just forward of FR. 87, as directed by the Board. The main transverse bulkhead at FR. 87 was assumed to remain watertight. Figure 2 illustrates the bow and the stern sections. The stern section weight and LCG were calculated from the weight distribution curve which was constructed according to the intact loading condition just before the explosion (see section 3).

The stern section VCG is calculated as follows:

	Weight (L.T.)	VCG (FT. ABOVE BASELINE)
Original Ship (from Loading Condition before Explosion)	14,125	26.82
Deduct Bow Section (from Weight Distribution curve)	- 4,152	24.00 (Estimated)
Stern Section After Separation	9,973	27.99

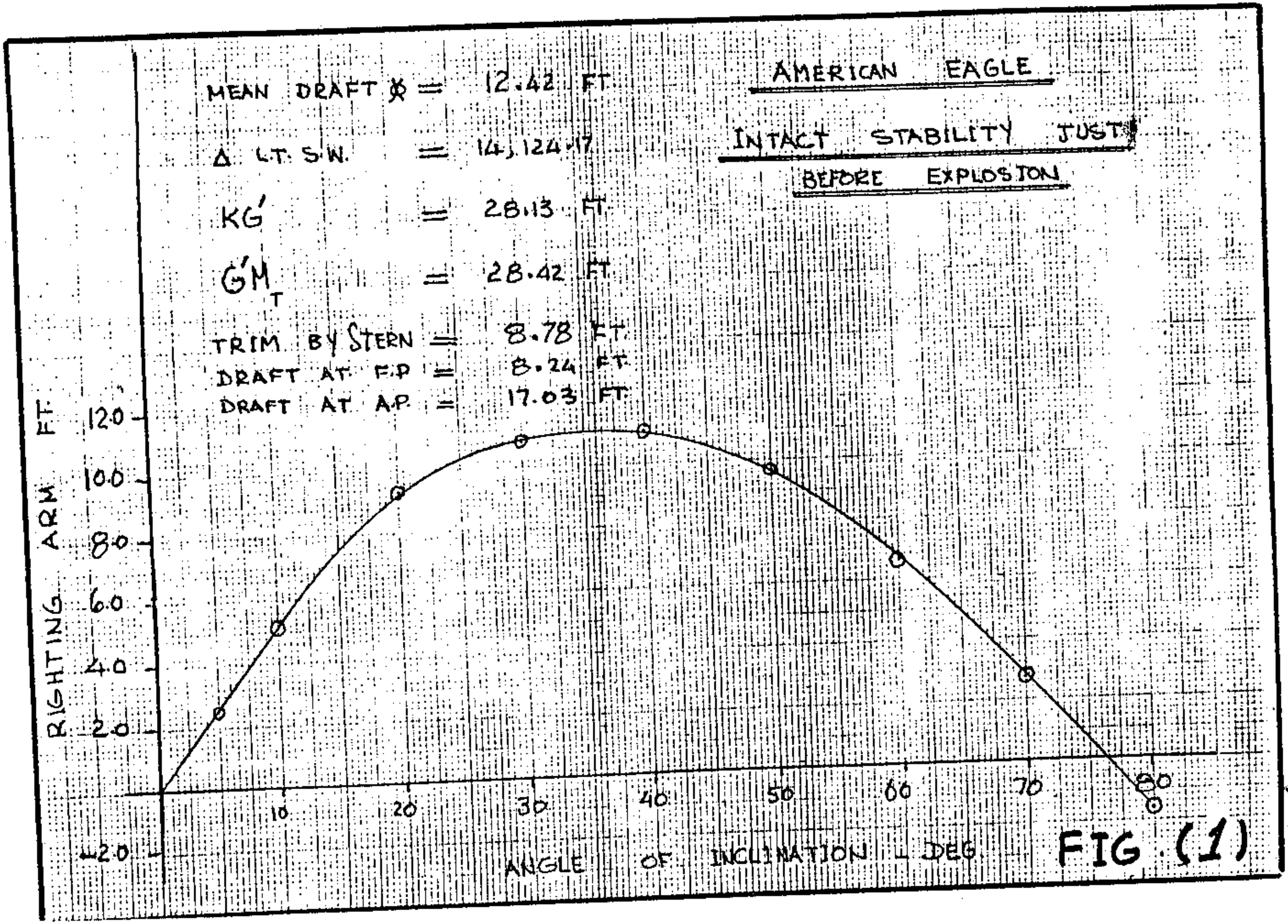

AMERICAN EAGLE
INTACT STABILITY JUST BEFORE EXPLOSION
MEAN DRAFT ⊗ = 12.42 FT
Δ LT. S.W. = 14,124.17
KG' = 28.13 FT
G'M_T = 28.42 FT
TRIM BY STERN = 8.78 FT
DRAFT AT F.P = 8.24 FT
DRAFT AT A.P = 17.03 FT
RIGHTING ARM FT
12.0
10.0
8.0
6.0
4.0
2.0
-2.0
10
20
30
40
50
60
70
80
ANGLE OF INCLINATION ∟ DEG

FIG (1)

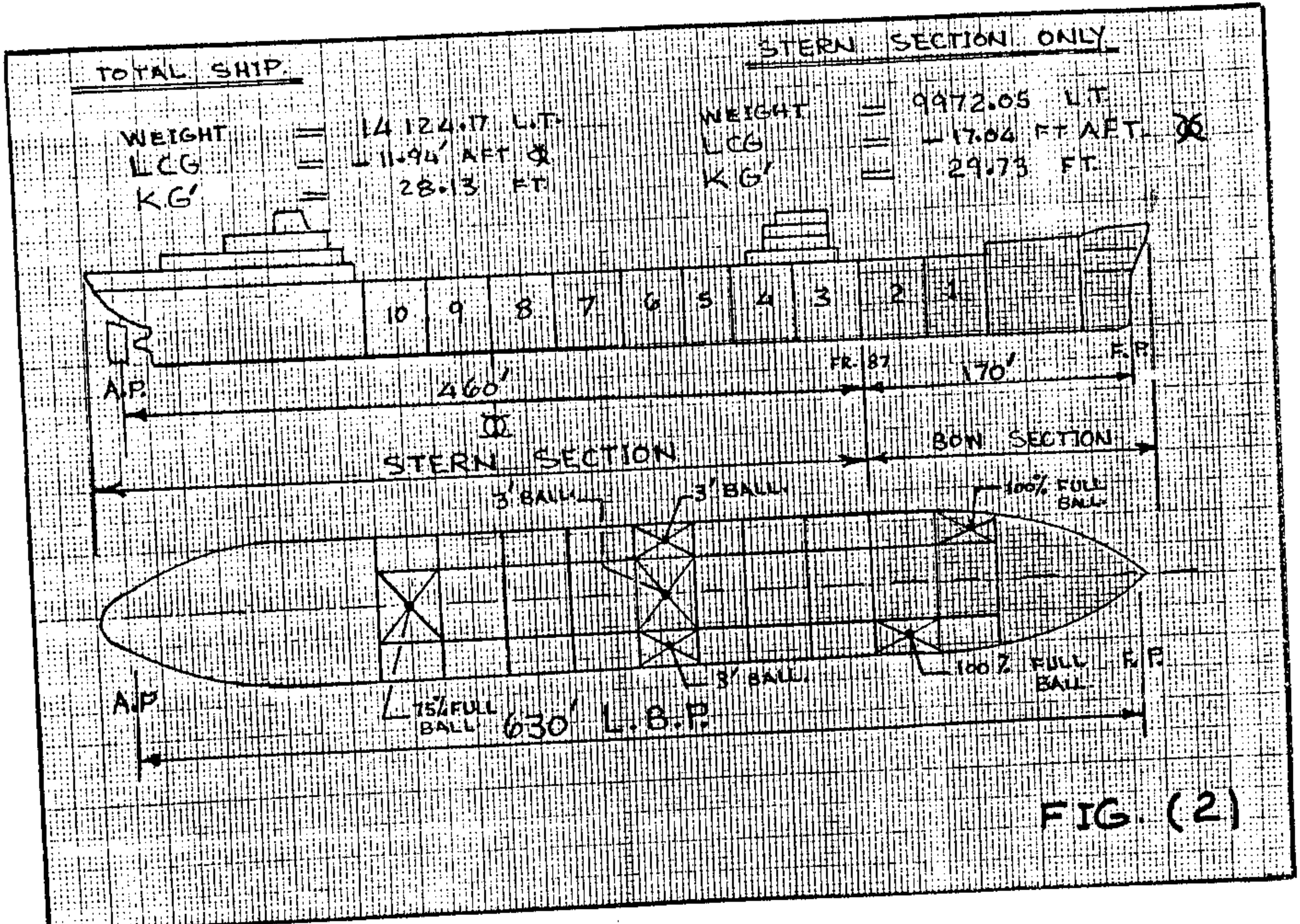

TOTAL SHIP.
WEIGHT = 14 124.17 L.T.
LCG = 11.94' AFT ℄
KG' = 28.13 FT.
STERN SECTION ONLY
WEIGHT = 9972.05 L.T.
LCG = 17.04 FT AFT ℄
KG' = 29.73 FT.
10
9
8
7
6
5
4
3
2
1
A.P.
F.P.
FR. 87
460'
170'
℄
STERN SECTION
BOW SECTION
3' BALL.
3' BALL.
100% FULL BALL.
3' BALL.
100% FULL BALL.
75% FULL BALL
A.P.
F.P.
630' L.B.P.

FIG. (2)

Using the SHCP computer program, the intact stability characteristics of the stern section alone were then calculated. The results are as follows:

Displacement	=	9973 LT
Longitudinal Center of Gravity from ℄ of stern section (+ FWD)	=	- 17.0 FT
Mean Draft Amidship	=	13.2 FT
Trim	=	23.5 FT By the Stern
Draft at FR. 87	=	1.5 FT
Draft at After Perpendicular	=	24.9 FT
Free Surface Correction (Virtual Rise in VCG)	=	1.7 FT
Vertical Center of Gravity from Base Line (VCG)	=	28.0 FT
Vertical Center of Gravity from Base Line Corrected for Free Surface (VCG')	=	29.7 FT
Metacentric Height (G'M) Corrected for Free Surface	=	35.2 FT

Treating the stern section as a separate vessel, a damage stability analysis was performed using the progressive flooding sequence outlined by the Board. Figures (3) through (16) graphically depict the results of this analysis.

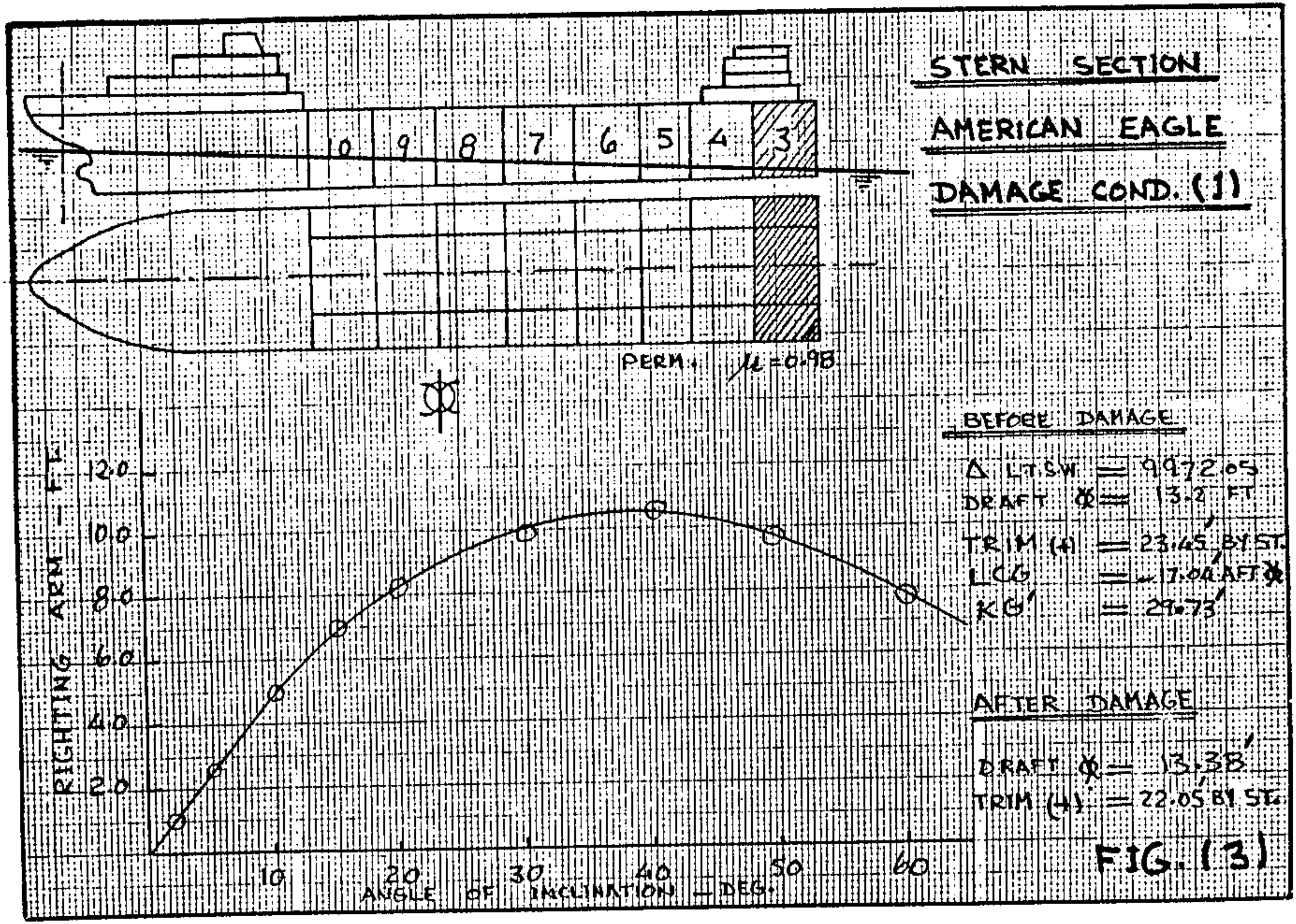
After separation from the bow section, the stern section has a trim by the stern of 23.5 ft. As progressive flooding continues, the trim by the stern decreases gradually until the stern section becomes nearly on an even keel. Heel during this stage of flooding is 4 degrees. These conditions are shown in Figure 10.

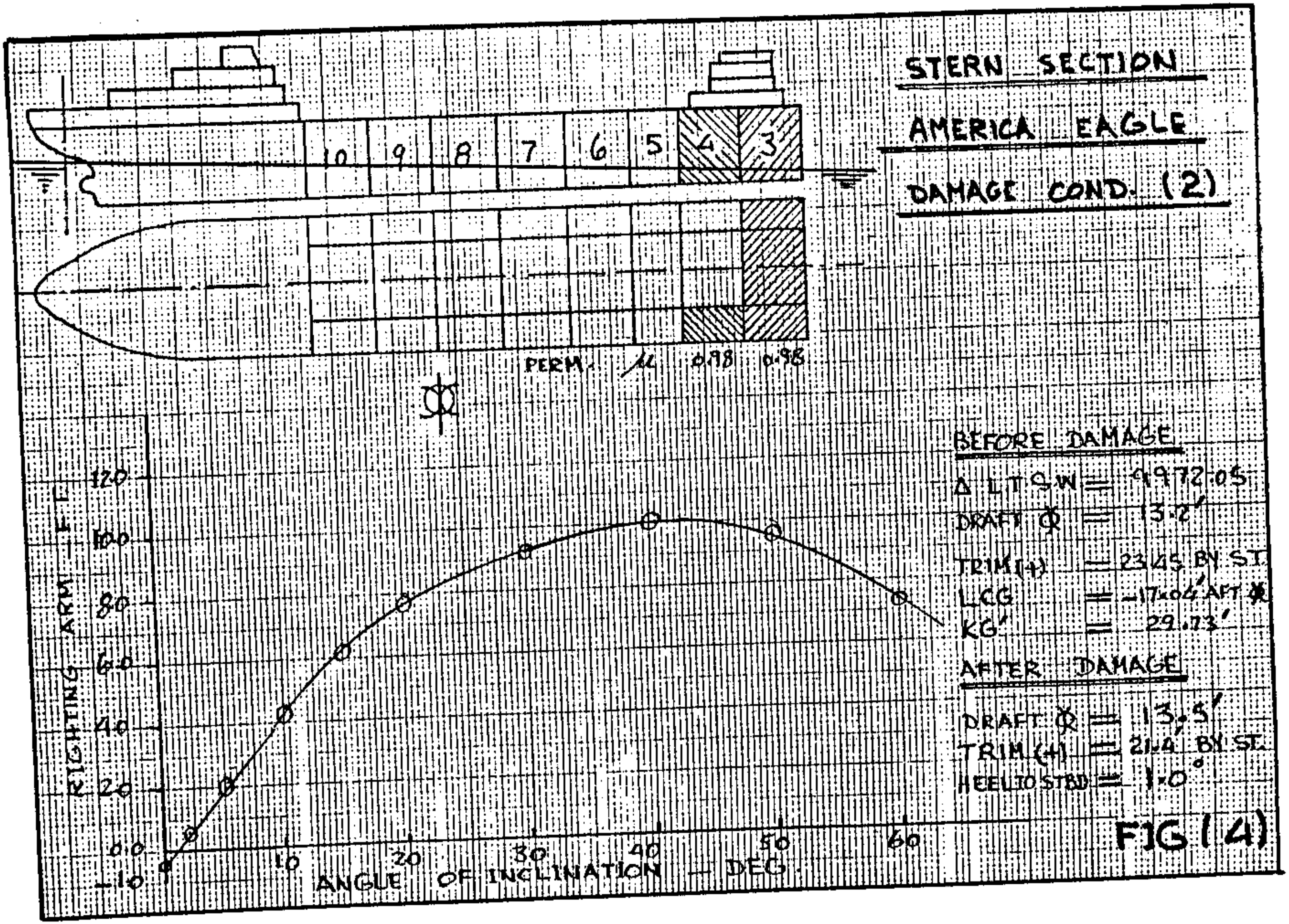
Up to this point, tanks No. 3 P/S/C, 4 P/S/C, 5 P/S/C and 6 S are flooded (Figure 10). Additional flooding causes trim by the bow. Figure 11 shows trim by the bow of 12.0 ft. Trim by the bow increases gradually as progressive flooding continues, until it reaches 81.1 ft. At this point, the deck house is submerged to the first level and the stern is out of the water. Starboard heel during this stage reaches a maximum value of 13 degrees (Figure 14).

Figure 15 shows tanks No. 3 P/S/C, 4 P/S/C, 5 P/S/C, 6 P/S/C, and 7 P/S/C flooded. The transverse stability up to this point is indicated in the righting arm curves, Figures 3 through 15. Additional flooding beyond this point causes the stern section to become statically unstable (no positive area under the righting arm curve). In this condition, the stern section will capsize in still water (See Figure 16).

The following table indicates the drafts of the stern section at FR. 87 and at the af perpendicular and the starboard heel for the different stages of progressive floodin

Condition No. and Description	Total Trim (+) by Stern (FT)	Draft at FR. 87 on C.L. (FT)	Draft at A.P. on C.L. (FT)	Starboar Heel (Deg)
Intact Stern Section	+ 23.5	1.5	24.9	0
(1) Tanks Flooded 3 P/S/C	+ 22.1	2.4	24.4	0
(2) Tanks Flooded as (1) above plus 4S	+ 21.4	2.8	24.2	1
(3) Tanks Flooded as (2) above plus 4C	+ 17.9	4.9	22.7	1
(4) Tanks Flooded as (3) above plus 4P	+ 16.1	6.0	22.1	0
(5) Tanks Flooded as (4) above plus 5S	+ 14.0	7.3	21.3	2
(6) Tanks Flooded as (5) above plus 5C	+ 9.0	10.4	19.4	2
(7) Tanks Flooded as (6) above plus 5P	+ 6.1	12.3	18.3	0
(8) Tanks Flooded as (7) above plus 6S	+ 0.9	16.5	15.6	4
(9) Tanks Flooded as (8) above plus 6C	- 12.0	24.0	12.0	6
(10) Tanks Flooded as (9) above plus 6P	- 19.6	29.1	9.5	0
(11) Tanks Flooded as (10) above plus 7S	-31.0	36.9	5.9	11
(12) Tanks Flooded as (11) above plus 7C	-60.0	56.6	-3.4	13
(13) Tanks Flooded as (12) above plus 7P	-81.1	71.0	-10.2	0
(14) Tanks Flooded as (13) above plus 8S		CAPSIZE		


STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (1)
10 9 8 7 6 5 4 3
PERM. μ = 0.98
BEFORE DAMAGE
Δ LTSW = 9972.05
DRAFT ⊕ = 13.2 FT
TRIM (+) = 23.45' BY ST.
LCG = -17.04' AFT ⊕
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊕ = 13.38'
TRIM (+) = 22.05' BY ST.
RIGHTING ARM - FT.
12.0
10.0
8.0
6.0
4.0
2.0
10 20 30 40 50 60
ANGLE OF INCLINATION - DEG.
FIG. (3)


STERN SECTION
AMERICA EAGLE
DAMAGE COND. (2)
10 9 8 7 6 5 4 3
PERM. μ 0.98 0.98
BEFORE DAMAGE
Δ LT S.W. = 9972.05
DRAFT ℄ = 13.2'
TRIM(+) = 23.45 BY ST.
LCG = -17.04' AFT ℄
KG' = 29.73'
AFTER DAMAGE
DRAFT ℄ = 13.5'
TRIM (+) = 21.4 BY ST.
HEEL TO STBD = 1.0°
RIGHTING ARM — FT
120
100
80
60
40
20
0.0
-10
10 20 30 40 50 60
ANGLE OF INCLINATION — DEG.
FIG (4)

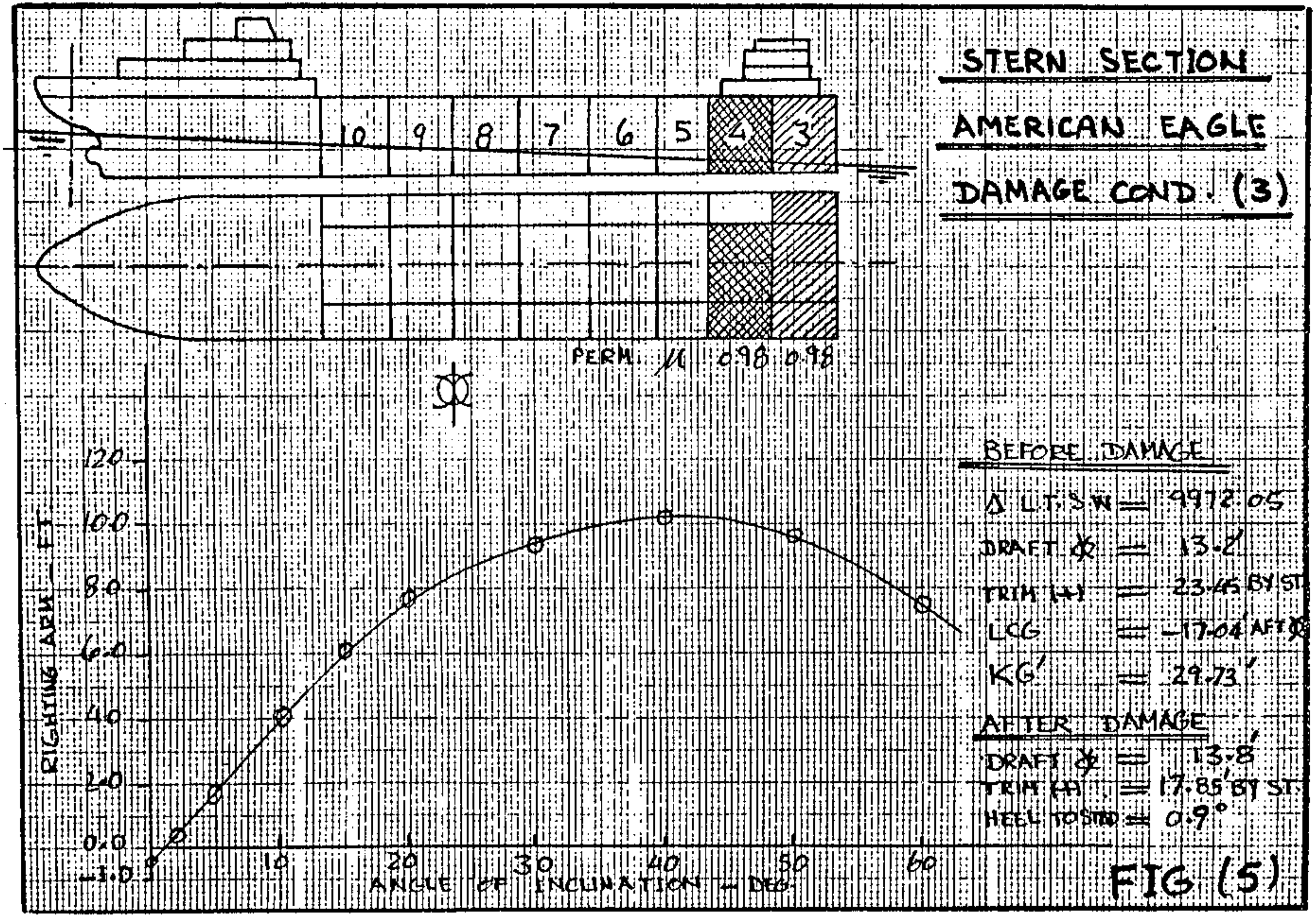

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (3)
10 9 8 7 6 5 4 3
PERM. μ 0.98 0.98
BEFORE DAMAGE
Δ L.T.S.W = 9912.05
DRAFT ⊗ = 13.2'
TRIM (+) = 23.45 BY ST.
LCG = -17.04 AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊗ = 13.8'
TRIM (+) = 17.85' BY ST.
HEEL TO STBD = 0.9°
RIGHTING ARM - FT
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-1.0
10 20 30 40 50 60
ANGLE OF INCLINATION - DEG.

FIG (5)

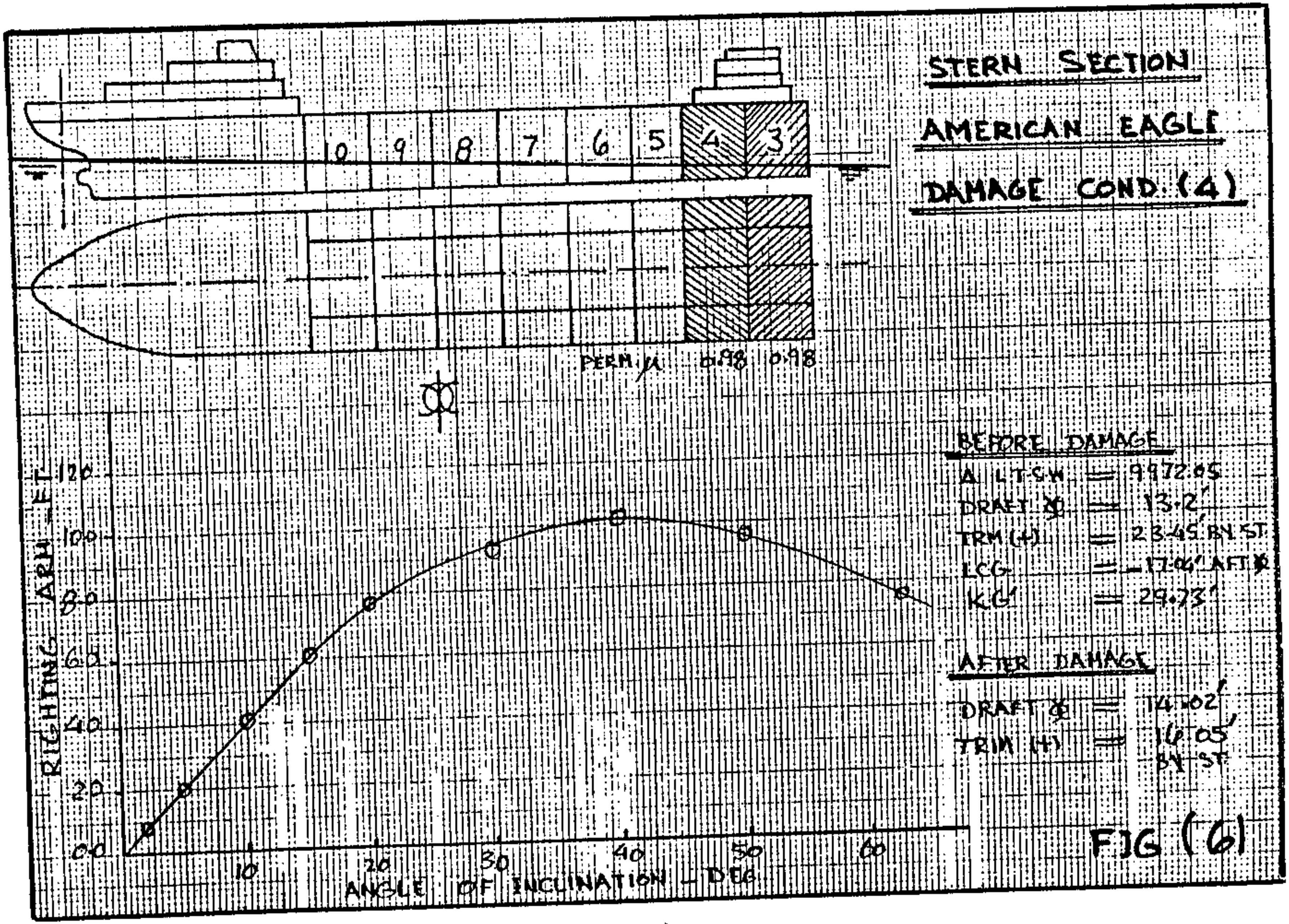

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (4)
10 9 8 7 6 5 4 3
PERM. μ 0.98 0.98
BEFORE DAMAGE
Δ LT SW = 9972.05
DRAFT ⊗ = 13.2'
TRM (+) = 23.45' BY ST
LCG = -17.06' AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊗ = 14.02'
TRIM (+) = 16.05' BY ST
RIGHTING ARM – FT
120
100
8.0
6.0
4.0
2.0
0.0
10
20
30
40
50
60
ANGLE OF INCLINATION – DEG

FIG (6)

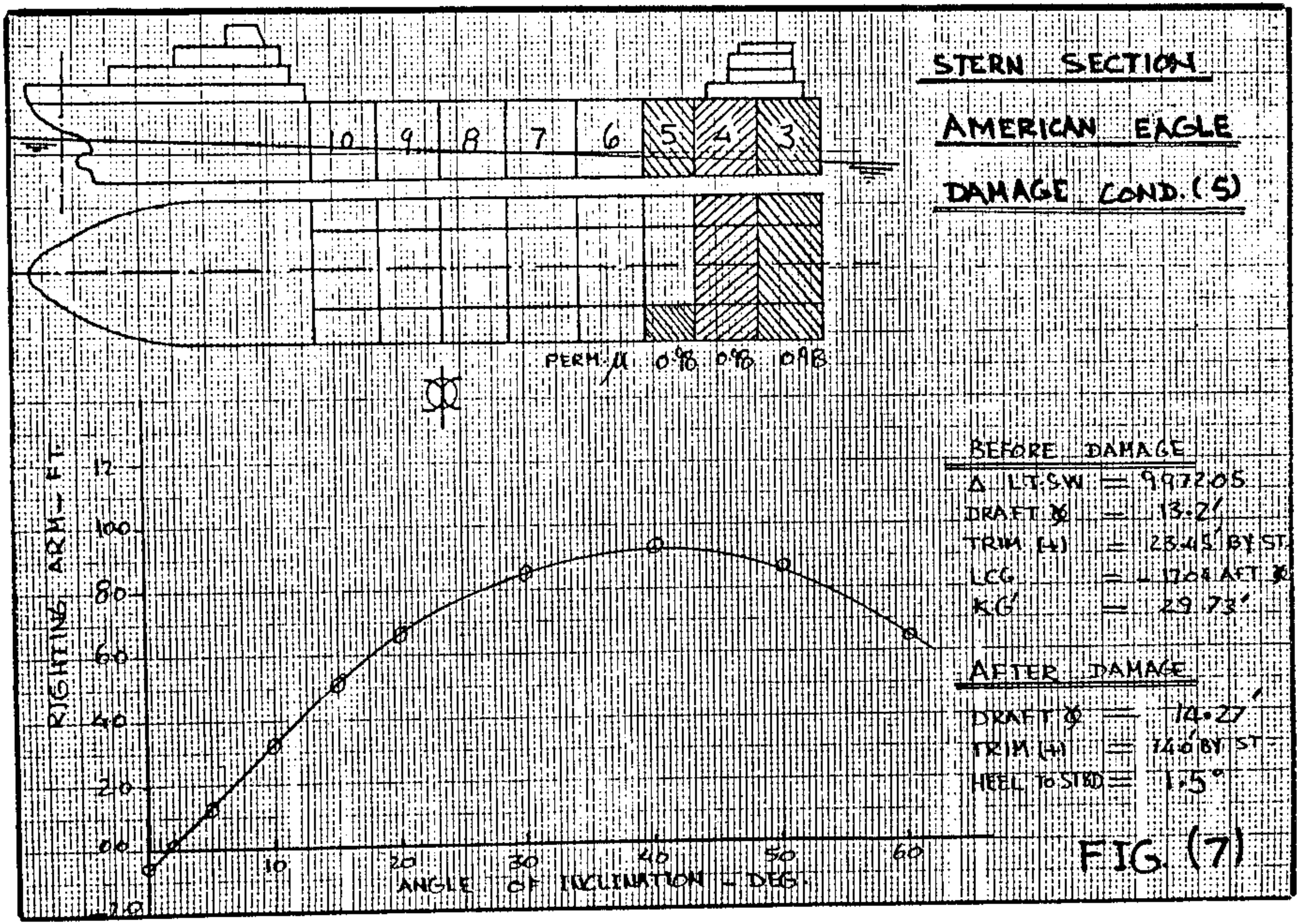

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (5)
10 9 8 7 6 5 4 3
PERM. μ 0.96 0.96 0.98
BEFORE DAMAGE
Δ LT.SW = 9972.05
DRAFT ⊗ = 13.2'
TRIM (+) = 23.45' BY ST.
LCG = 17.04 AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊗ = 14.27'
TRIM (+) = 7.40' BY ST.
HEEL TO STBD = 1.5°
RIGHTING ARM - FT.
ANGLE OF INCLINATION - DEG.

FIG. (7)

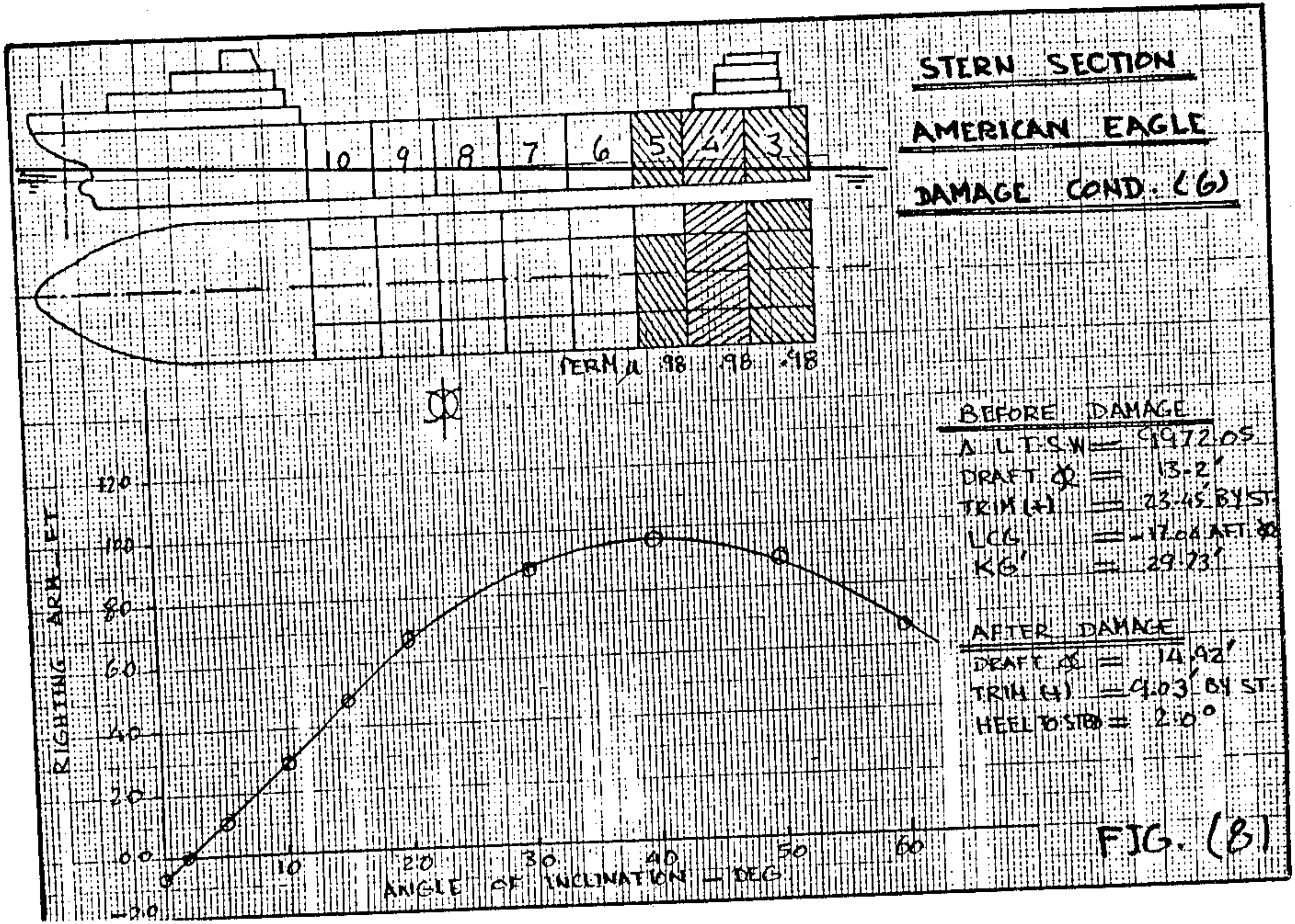

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (6)
10 9 8 7 6 5 4 3
TERM µ .98 .98 .98
BEFORE DAMAGE
Δ L.T.S.W. = 9972.05
DRAFT ℄ = 13.2'
TRIM (+) = 23.45' BY ST.
LCG = -17.04 AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ℄ = 14.92'
TRIM (+) = 9.03' BY ST.
HEEL TO STBD = 2.0°
RIGHTING ARM - FT
120
100
80
60
40
20
0.0
-2.0
10
20
30
40
50
60
ANGLE OF INCLINATION - DEG

FIG. (8)

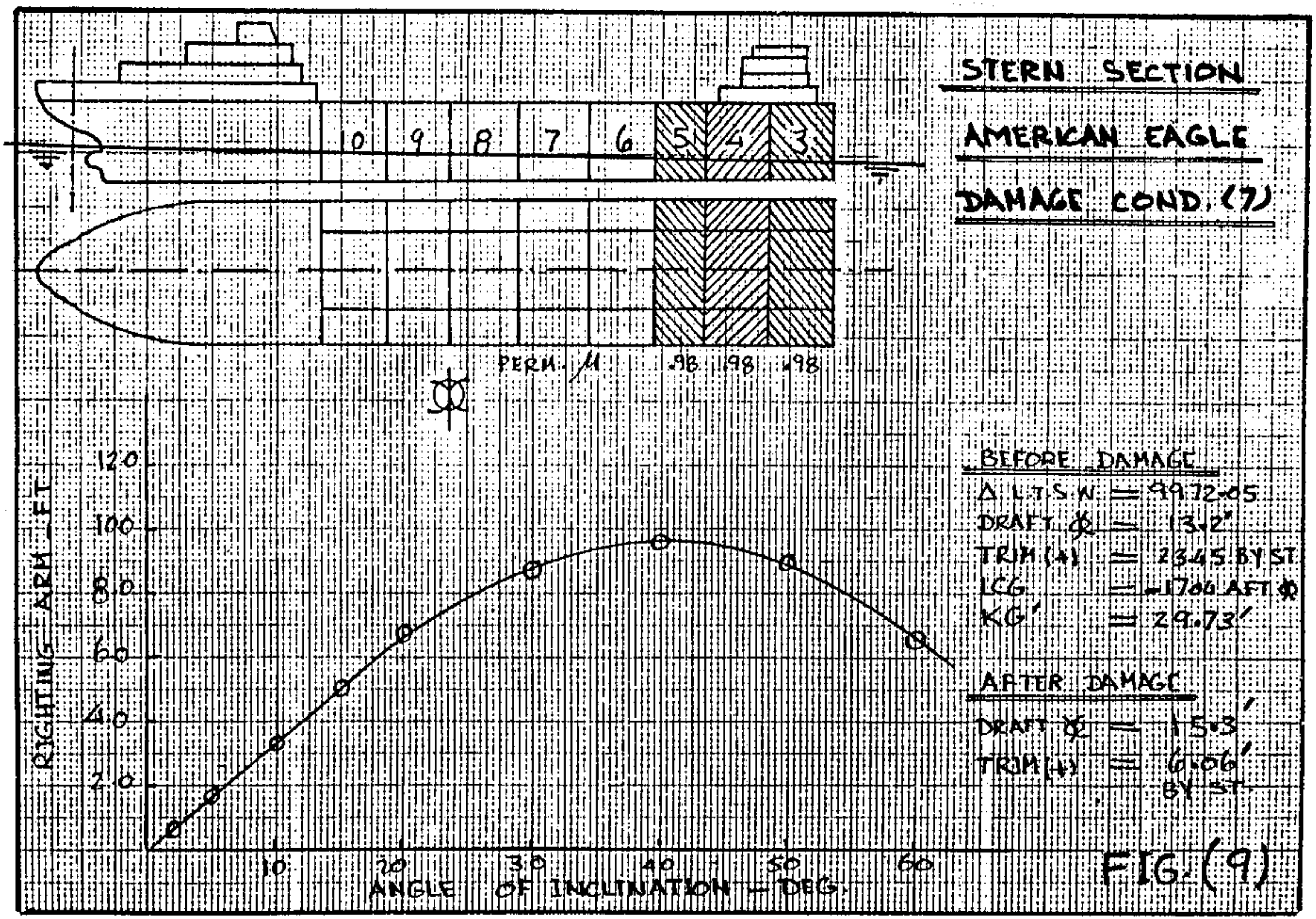
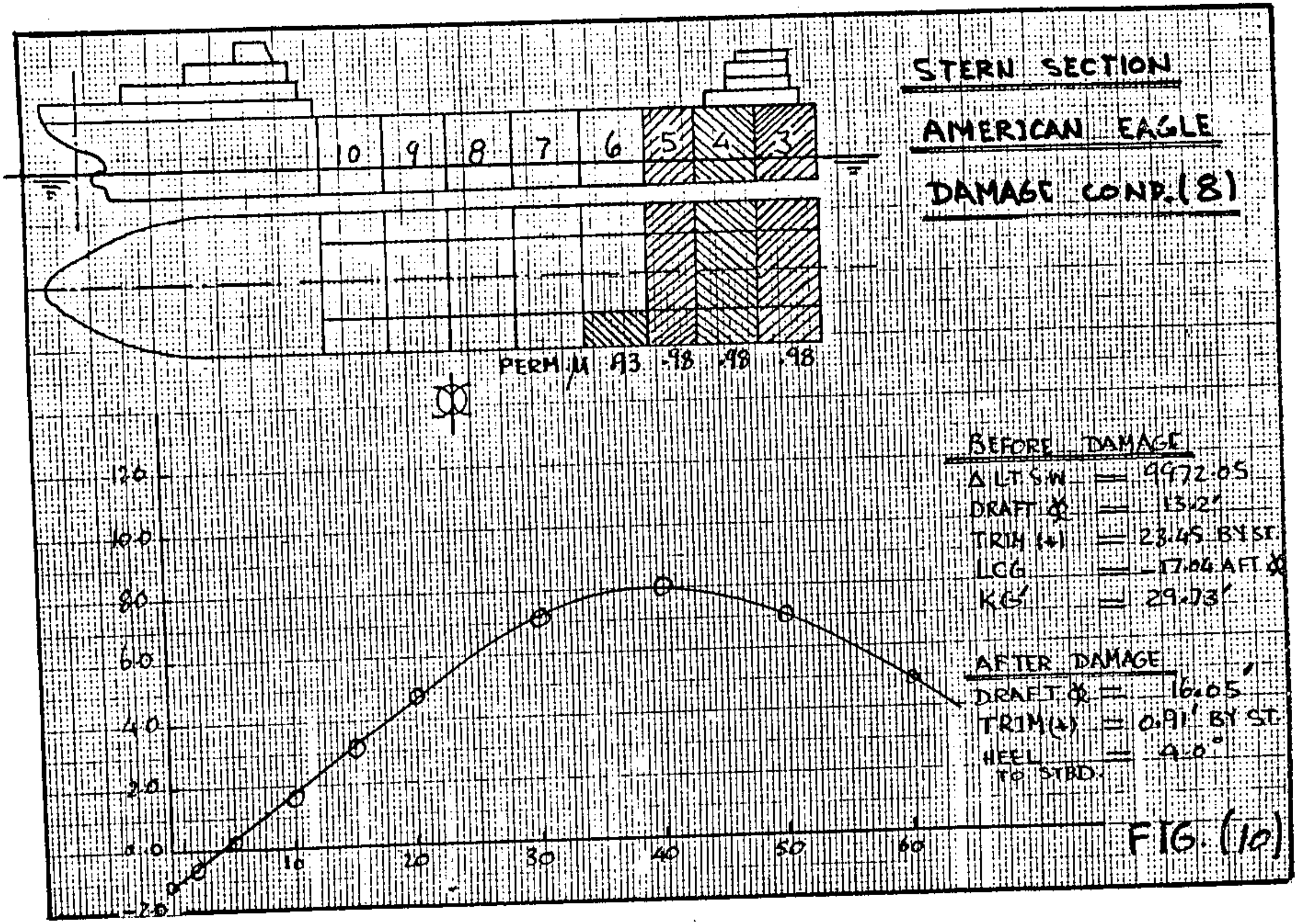

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (7)
10
9
8
7
6
5
4
3
PERM. μ
.98
.98
.98
BEFORE DAMAGE
Δ L.T.S.W. = 9972.05
DRAFT ⊗ = 13.2'
TRIM (4) = 2345 BY ST
LCG = 1766 AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊗ = 15.3'
TRIM (+) = 6.06' BY ST.
RIGHTING ARM – FT
12.0
10.0
8.0
6.0
4.0
2.0
10
20
30
40
50
60
ANGLE OF INCLINATION – DEG.

FIG. (9)


STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (8)
10
9
8
7
6
5
4
3
PERM. μ .93 .98 .98 .98
φ
BEFORE DAMAGE
Δ LT. S.W. = 9972.05
DRAFT ℄ = 13.2'
TRIM (+) = 23.45 BY ST.
LCG = 17.04 AFT ℄
KG' = 29.73'
AFTER DAMAGE
DRAFT ℄ = 16.05'
TRIM (+) = 0.91' BY ST.
HEEL TO STBD. = 4.0°
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
10
20
30
40
50
60
FIG. (10)

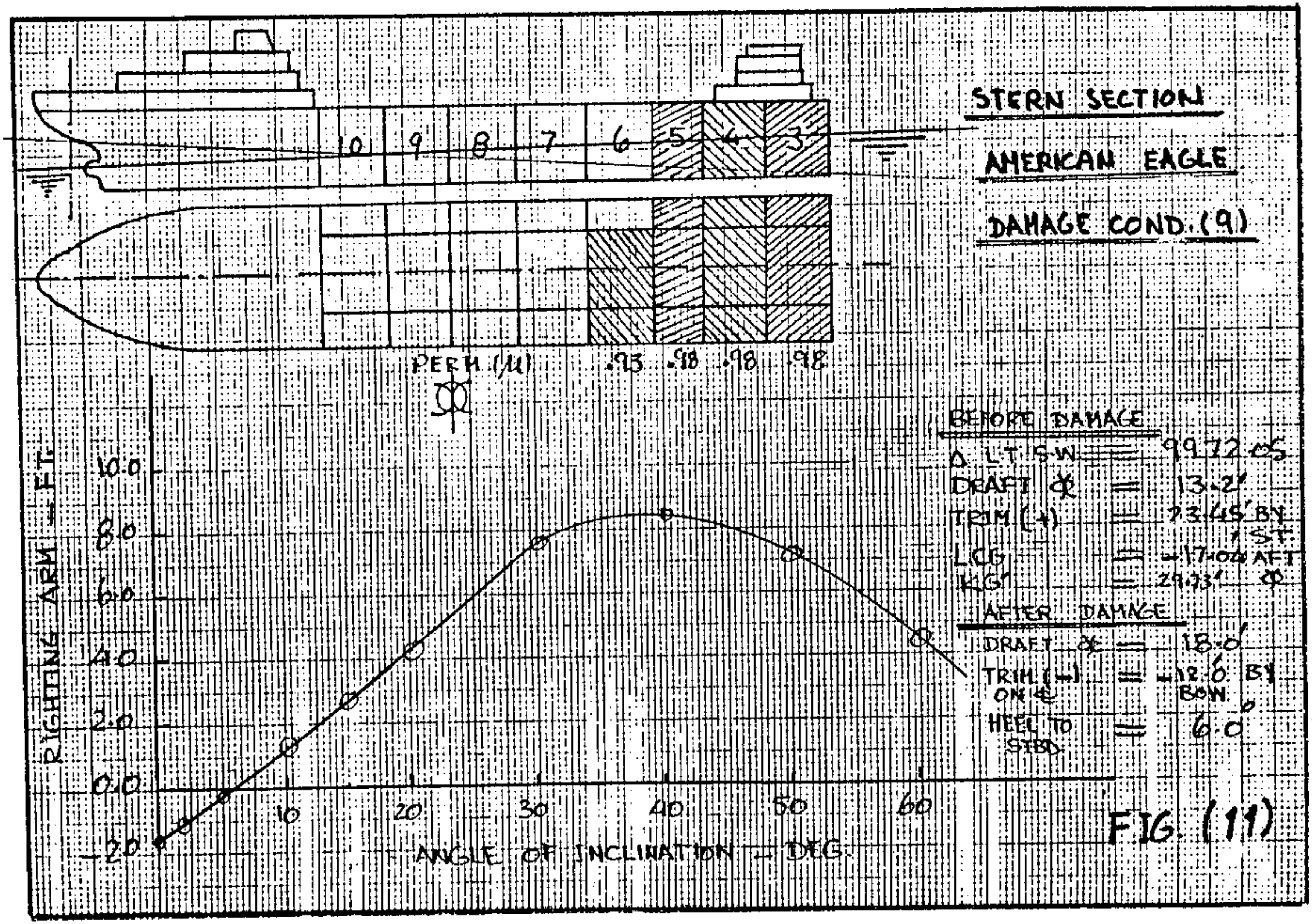

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (9)
10 9 8 7 6 5 4 3
PERM (μ) .93 .98 .98 .98
BEFORE DAMAGE
Δ LT S.W = 9972.05
DRAFT ℄ = 13.2'
TRIM (+) = 23.45' BY ST.
LCG = -17.04' AFT
KG' = 29.73' ℄
AFTER DAMAGE
DRAFT ℄ = 18.0'
TRIM (-) ON ℄ = -12.6' BY BOW
HEEL TO STBD = 6.0°
RIGHTING ARM - FT.
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
10 20 30 40 50 60
ANGLE OF INCLINATION - DEG

FIG. (11)

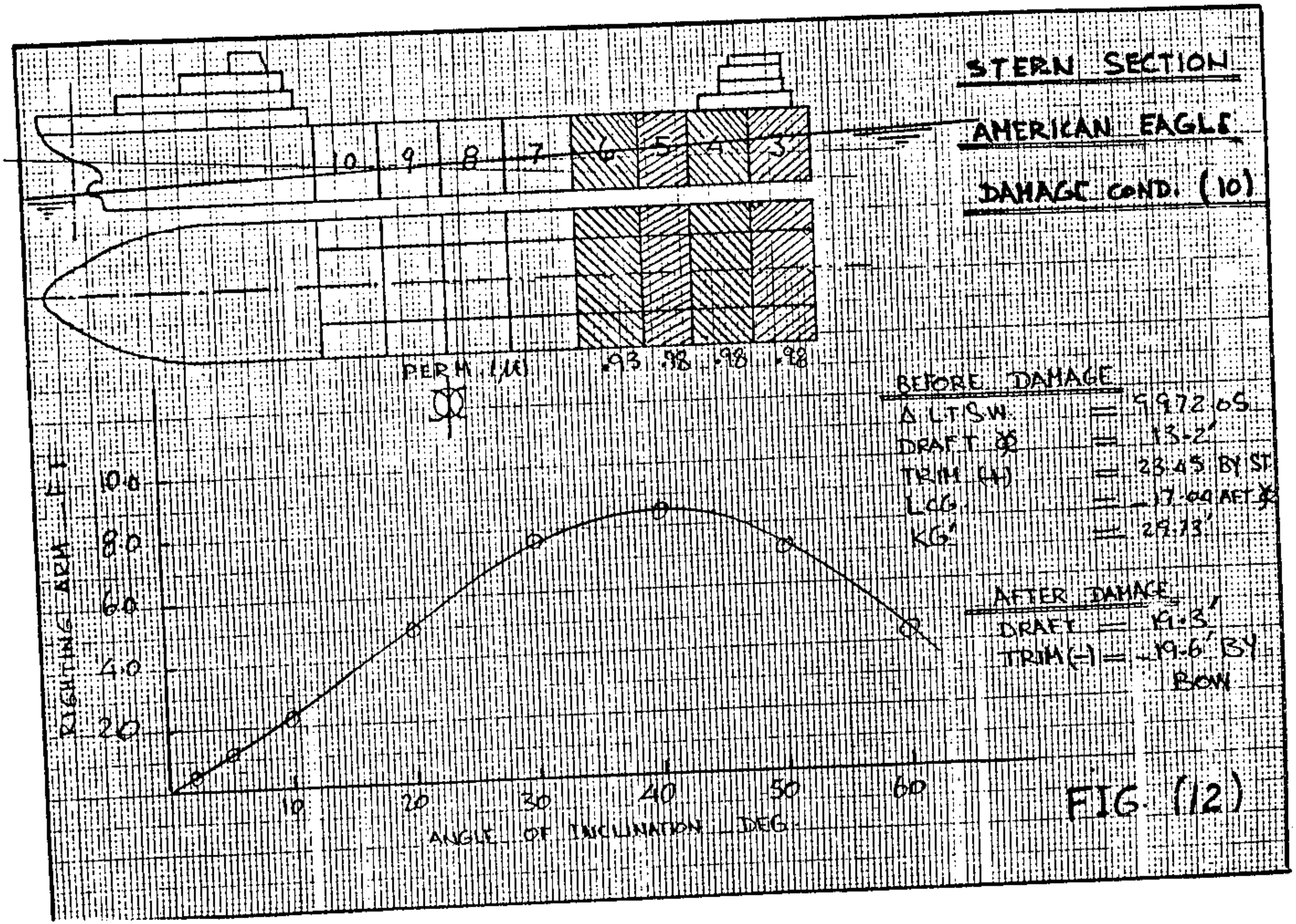

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (10)
10 9 8 7 6 5 4 3
PERM. (μ) .93 .98 .98 .98
BEFORE DAMAGE
Δ LT S.W. = 9972.05
DRAFT ⊗ = 13-2'
TRIM (+) = 23.45' BY ST.
LCG. = 17.09 AFT ⊗
KG' = 29.13'
AFTER DAMAGE
DRAFT = 19-3'
TRIM (-) = -19.6' BY BOW
RIGHTING ARM FT
10.0
8.0
6.0
4.0
2.0
10 20 30 40 50 60
ANGLE OF INCLINATION DEG

FIG. (12)

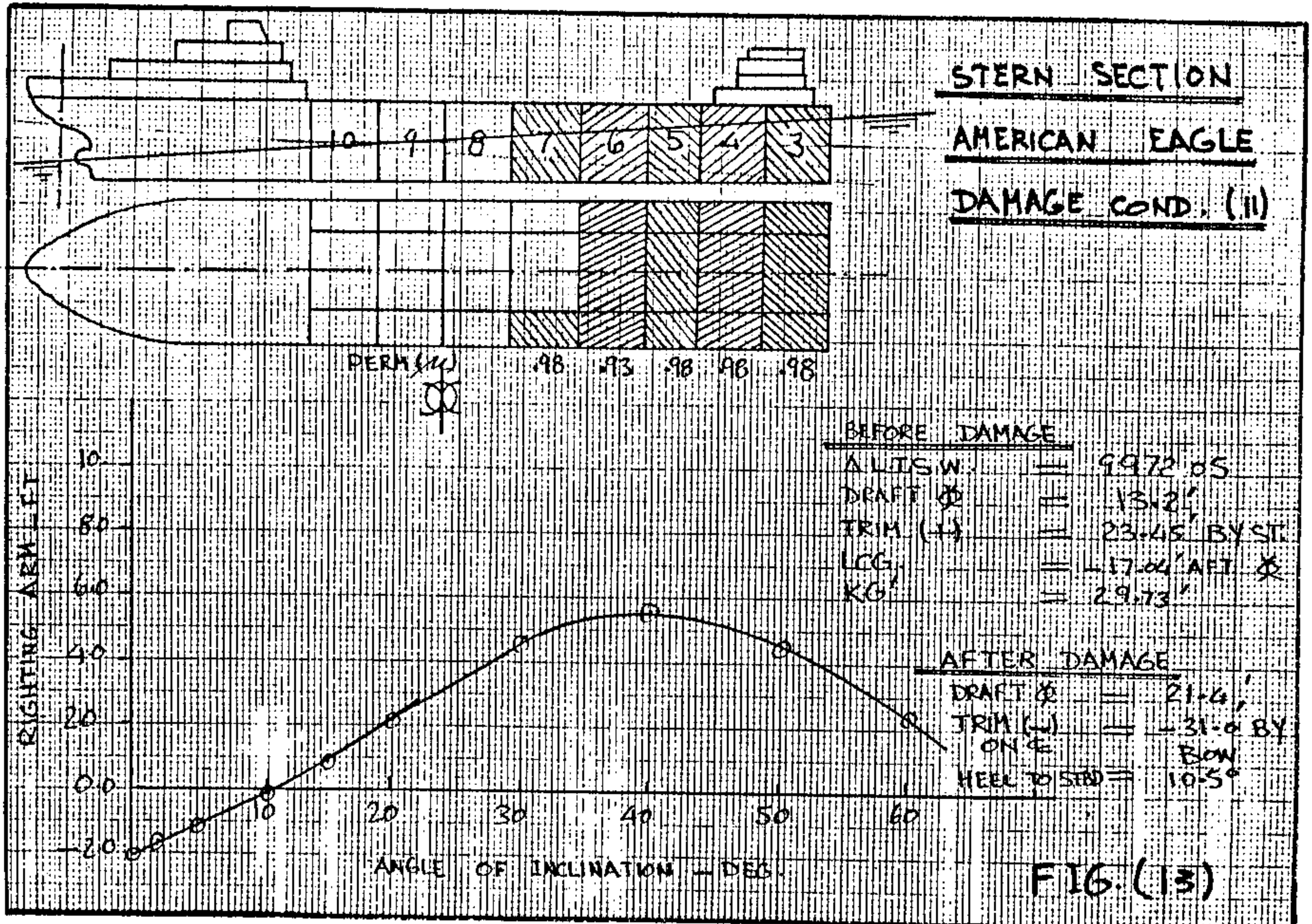

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (11)
10
9
8
7
6
5
4
3
PERM (μ)
.98
.93
.98
.98
.98
BEFORE DAMAGE
Δ LT.S.W. = 9972.05
DRAFT ⊗ = 13.24'
TRIM (+) = 23.45' BY ST.
LCG = -17.04' AFT ⊗
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊗ = 21.4'
TRIM (-) ON ℄ = -31.0 BY BOW
HEEL TO STBD = 10.5°
RIGHTING ARM - FT
10
80
60
40
20
0.0
-20
10
20
30
40
50
60
ANGLE OF INCLINATION - DEG.

FIG. (13)

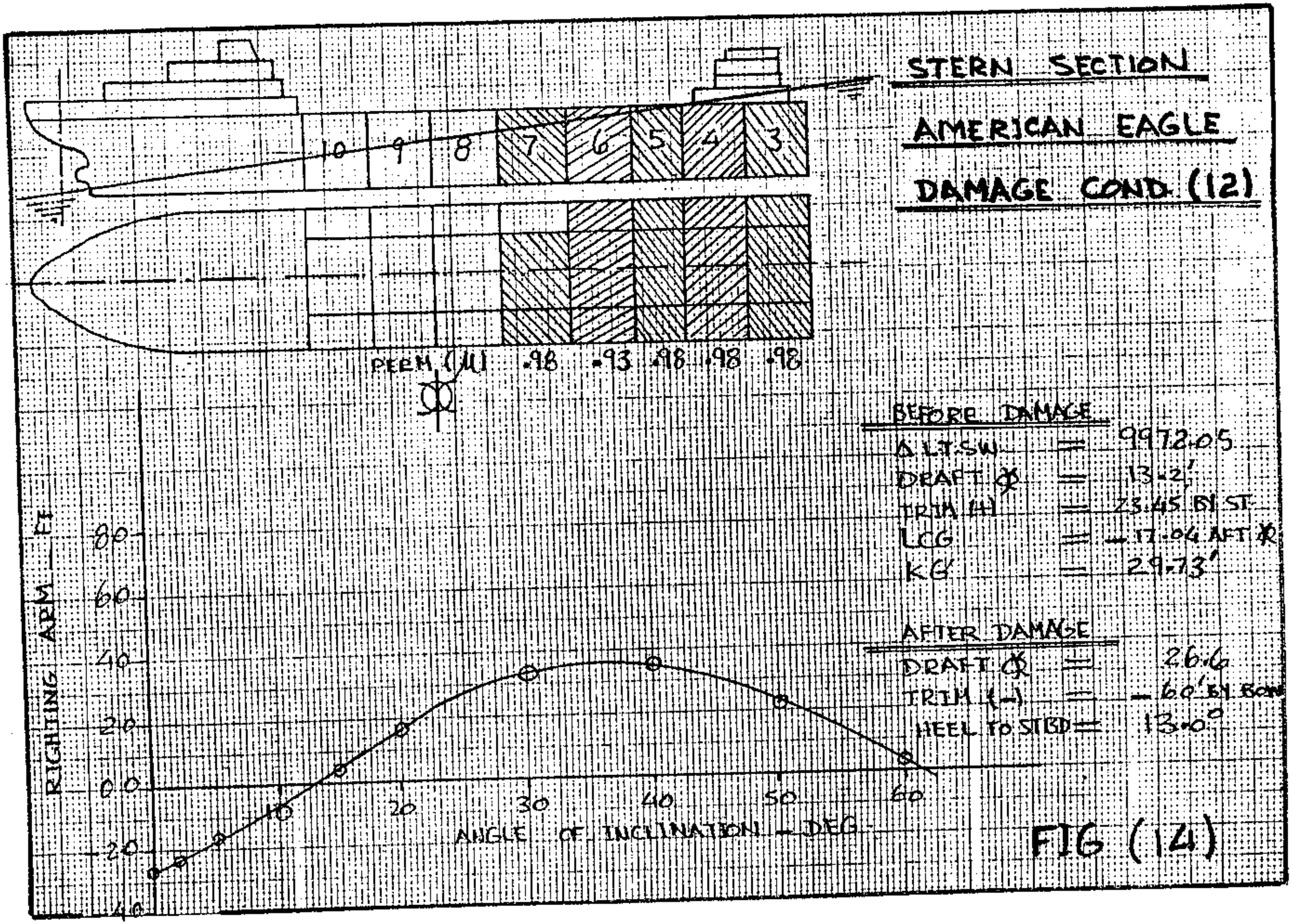
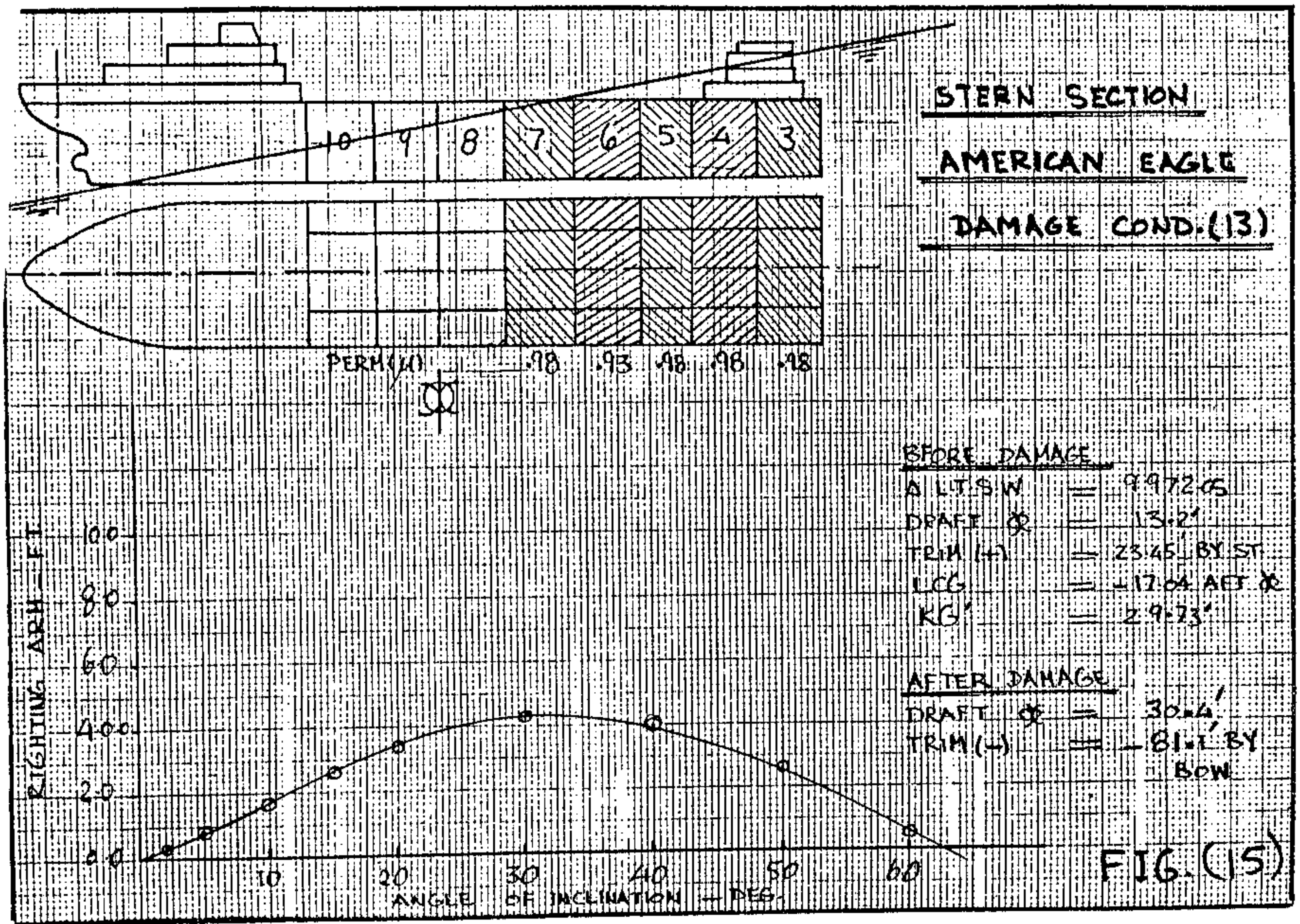
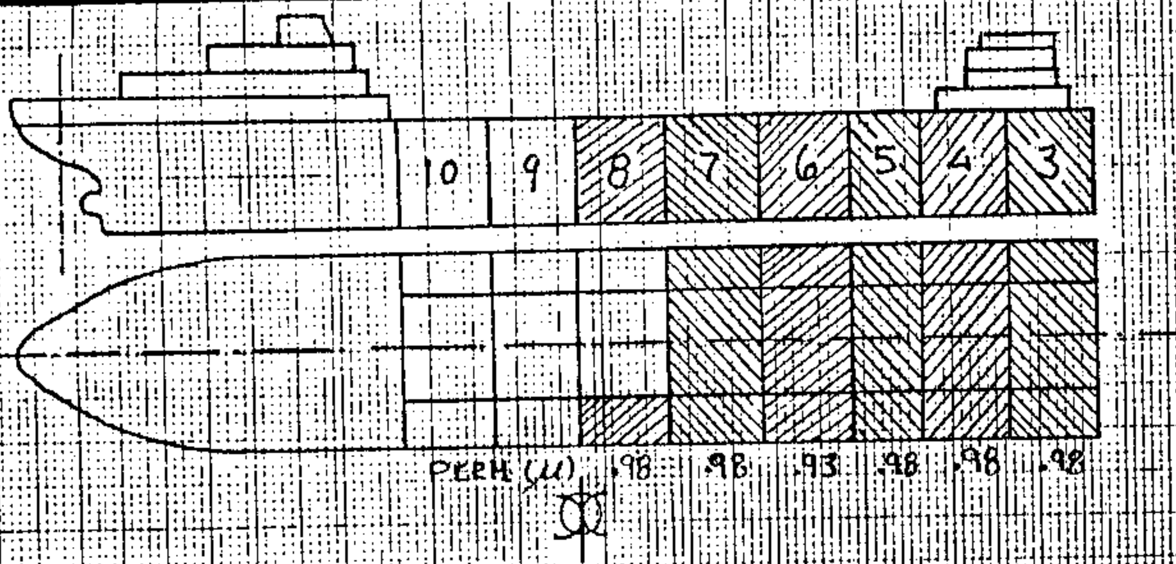

STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (12)
10 9 8 7 6 5 4 3
PERM. (μ) .98 .93 .98 .98 .98
BEFORE DAMAGE
Δ LT.SW. = 9972.05
DRAFT ℄ = 13.2'
TRIM (+) = 23.45 BY ST.
LCG = -17.04 AFT ℄
KG' = 29.73'
AFTER DAMAGE
DRAFT ℄ = 26.6
TRIM (-) = -60' BY BOW
HEEL TO STBD = 13.0°
RIGHTING ARM – FT
80
60
40
20
0.0
-20
-40
10 20 30 40 50 60
ANGLE OF INCLINATION – DEG

FIG (14)



STERN SECTION
AMERICAN EAGLE
DAMAGE COND. (13)
10
9
8
7
6
5
4
3
PERM(μ)
.98
.93
.98
.98
.98
BFORE DAMAGE
Δ LT.S.W = 9972.05
DRAFT ⊄ = 13.2'
TRIM (+) = 23.45 BY ST
LCG = -17.04 AFT ⊄
KG' = 29.73'
AFTER DAMAGE
DRAFT ⊄ = 30.4'
TRIM (-) = -81.1' BY BOW
RIGHTING ARM - FT
10.0
8.0
6.0
4.0
2.0
0.0
10
20
30
40
50
60
ANGLE OF INCLINATION - DEG.

FIG. (15)



STERN SECTION

AMERICAN EAGLE

DAMAGE COND. (14)

BEFORE DAMAGE

Δ L.T.S.W	=	9972.05
DRAFT ⊄	=	13.2'
TRIM (+)	=	23.45 BY ST.
LCG	=	17.04' AFT ⊄
KG'	=	29.73'

THE SHIP IS STATICALLY UNSTABLE.
NO POSITIVE AREA UNDER THE RIGHTING
ARM CURVE EXISTS. IN STILL WATER
AND UNDER THIS DAMAGED CONDITION,
THE SHIP WILL CAPSIZE

FIG. (16)

3. Longitudinal Strength in Still Water just before Explosion

The light ship weight distribution curve was supplied by the Marine Board of Investigation. Using this curve and the loading condition of the ship before the explosion, the weight distribution curve was constructed. The longitudinal strength analysis was performed using the SHCP computer program. Weight, buoyancy and shear force diagrams are shown in Figure 17. The maximum shear force occurs at 170 ft aft of the forward perpendicular (FP). The shear force at this location is 1821 long tons.

4. Bulkhead Strength

Ref: (a) Roark, R.J., "Formulas for Stress and Strain," McGraw-Hill Book Company, Fourth Edition, 1965.
(b) "A Guide for the Analysis of Ship Structures," Thein Wah, Editor, U.S. Department of Commerce, 1960.
(c) Jones, Norman, "Plastic Behavior of Ship Structures," Transactions, The Society of Naval Architects and Marine Engineers, 1976.

Various calculations were performed to determine the strength of the transverse cargo tank bulkheads, based on the original design scantlings provided by the bulkhead drawing. An estimate of the strength was also made with reduced plating thickness due to corrosion. An exact determination of the hydrostatic pressure necessary to cause rupture of a stiffened panel bulkhead can be an extremely cumbersome, if not impossible task. However, a reasonable estimate of the pressure at which the bulkhead will begin to plastically yield is possible. Further estimates can be made for the pressure at which ultimate failure or plastic collapse occurs. Several portions of the bulkhead must be considered in this analysis, i.e. panels with attached bulkhead stiffeners, unsupported panels between stiffeners, and bulkhead headers. This bulkhead consists of six panels, arranged in decreasing thickness from the baseline, with the upper two panels of increased thickness for corrosion considerations. Vertical stiffeners are spaced at 33-inch intervals (12" x 3.5" x 3/4" inverted angles). Four horizontal webs are located transversely across the bulkhead (54" x 6" x 0.5").

A check was made to see if the bulkhead met the design rules of the American Bureau of Shipping. The oldest set of rules readily available, the 1965 Steel Vessel Rules, was used. The bulkhead plating met the ABS bulkhead thickness requirements if it were considered "protected plating" as defined in the Rules. The sizes of the stiffeners exceeded the ABS requirements by a small amount. The actual sizes of the headers exceeded the tabulated values in the rules of the ABS, and they would not fail under full head conditions.

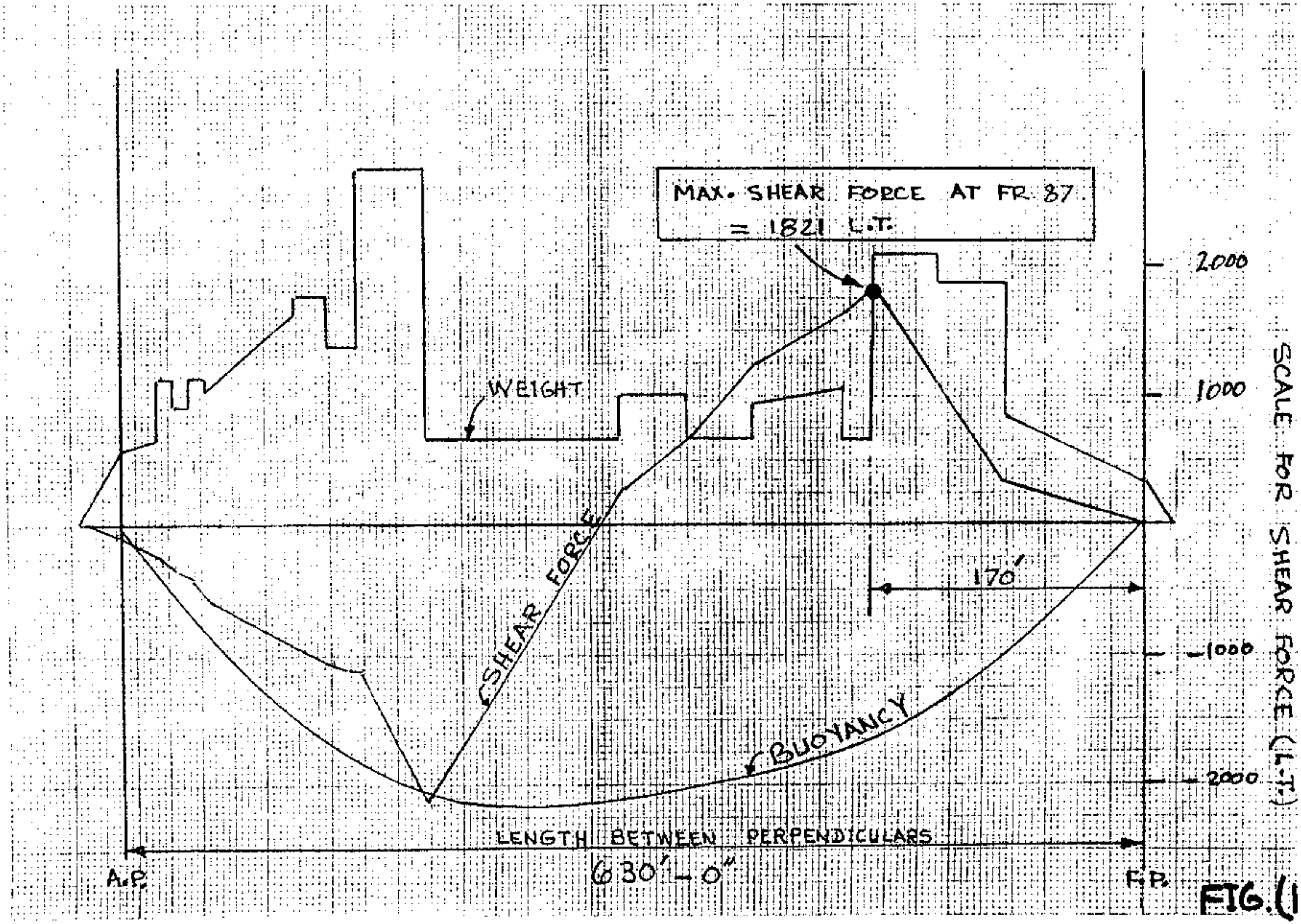

MAX. SHEAR FORCE AT FR. 87
= 1821 L.T.
WEIGHT
SHEAR FORCE
BUOYANCY
170'
2000
1000
-1000
-2000
SCALE FOR SHEAR FORCE (L.T.)
LENGTH BETWEEN PERPENDICULARS
630'-0"
A.P.
F.P.

FIG. (17

The first analysis was to rule out failure of the stiffened panels under normal hydrostatic load. A simple beam analysis of a stiffened panel with an effective breadth of 60 x the plate thickness was made. Spans were taken between the headers. The lowest hydrostatic head to cause yielding of a stiffened panel is 64 feet above the deck at side. This is the lower panel with 5/8 inch plating.

Analysis was done on the unsupported panels between the stiffeners. Three methods were used to determine yielding and collapse pressures on the bulkheads. The first was a simple beam analysis of the unsupported panel to determine pressure required to yield the material. Second, an analysis of the membrane stress produced during large deflection loading was used to estimate ultimate strength of the plating. Third, the pressure necessary to cause plastic collapse of the bulkhead panels was calculated. The yield and ultimate stresses of the bulkhead material were assumed to be 32000 and 58000 psi, respectively. Calculations were initially done for the original design thicknesses.

Using equation 'X.41' from reference (a), which is a simple beam analysis of a plate panel, the pressure needed to cause yielding of the unsupported panels was determined. In each case, the unsupported panels act as infinite plates due to their large aspect ratio. Table (1) shows that yielding occurs on panel #2 with a head of 9.7 feet above the deck at side.

When a laterally loaded plate deflects an amount greater than one-half its thickness, in-plane tensile loads are generated. At large deflections the entire depth of the plating is subjected to tensile load and responds as a membrane. The assumption is made here that failure will occur due primarily to tensile failure of the bulkhead panel. Using a method developed by Greenman and Levy, discussed in reference (b) on page 203, the pressure required to cause membrane failure of the bulkhead panels was determined. As can be seen in Table (1), the least hydrostatic head to cause tensile failure is 43 feet above the deck at side.

Each of the above two analyses were also conducted using a 15 percent reduction in plating thickness. The Board requested that a determination of the condition of the bulkhead be made based upon the information in the ABS gauging report. The report did not contain gaugings for the bulkheads. An estimatation by the Board of the deterioration of the vessel in general was about 15 percent, which was used in this study. With this estimate, it is noted that the bulkhead has yielded with a full head of water in the tank (See Table (1)). Ultimate membrane failure occurs at a head of 22 feet above the deck at side.

Finally, the static plastic collapse loads on the rectangular panel were calculated. For the case when the boundary around a rectangular plate is fully clamped, the upper and lower bounds to the exact uniformly distributed collapse pressure are calculated according to equations (3) and (4) of reference (c). These values are summarized in Table (1). These calculations were only done for the original design plate thicknesses.

TABLE (1)

STATIC PRESSURE TO YIELD AND FAIL CARGO TANK BULKHEADS

Heads Given in Feet Above Deck at Side

	Panel Size	Beam Theory Yield Occurs Original/Corroded	Membrane Theory Ultimate Failure Original/Corroded	Plastic Collapse	Midpoint Below Deck
Panel #1	33" x 119" x 5/8"	10.6' / -3.8'	52.6' / 26.5'	70'	5.5'
Panel #2	33" x 95" x 9/16"	9.7' / -1.9'	43.8' / 22.6'	62'	15.9'
Panel #3	33" x 95" x 17/32"	12.6' / 2.3'	43.1' / 24.3'	58'	24.7'
Panel #4	33" x 111" x 15/32"	13.2' / 5.1'	36.8' / 22.1'	47'	32.1'
Panel #5	33" x 132" x 9/16"	36.3' / 24.7'	70.4' / 49.3'	83'	41.0'

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