U.S. Department
of Transportation
**United States
Coast Guard**

MARINE CASUALTY REPORT

TANKSHIP PUERTO RICAN
O.N. 535000,
EXPLOSION AND FIRE
IN THE PACIFIC OCEAN,
ON 31 OCTOBER 1984
WITH LOSS OF LIFE

U.S. COAST GUARD

MARINE BOARD OF INVESTIGATION REPORT

AND

COMMANDANT'S ACTION

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16. Abstract

At approximately 0324, October 31, 1984, the tankship PUERTO RICAN suffered explosions and fire in number 6 center void space and the adjacent wing cargo tanks. The explosions and fire damaged the hull of the vessel to the extent that it broke in two and the stern section sank three days later. The pilot and one crew member were thrown overboard by the explosions and injured; one crew member was thrown overboard by the explosions and is missing and presumed dead.

The Commandant has concurred with the board that the actual cause of the casualty cannot be established with certainty but the most probable cause was the failure to repair a gouge, later to become an opening, in the stainless steel cladding in the bulkhead separating 5 center port cargo tank and 6 center void space allowing caustic soda cargo to enter the void. The caustic soda reacted with the zinc coatings in the 6 center void space producing hydrogen gas which ignited. This led to a sequence of explosions and fire which led to the loss of the vessel. Contributing to the casualty was the failure of the master to locate the missing caustic soda cargo which leaked from 5 center port tank into 6 center void space.

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.

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16732/PUERTO RICAN

SEP 19 1985

Commandant's Action

on

The Marine Board of Investigation convened to investigate the circumstances surrounding the explosion and fire aboard the SS PUERTO RICAN, O.N. 535000, in the Pacific Ocean on 31 October 1984 with loss of life

The report of the Marine Board of Investigation convened to inquire into the circumstances surrounding this casualty has been reviewed. The record, including the Findings of Fact, Conclusions, and Recommendations, is approved subject to the following comments.

CAUSE OF CASUALTY

The actual cause of the casualty cannot be established with certainty. However, the most probable cause was the failure to repair a gouge, later to become an opening, in the stainless steel cladding on the bulkhead separating 5 center port cargo tank and 6 center void space allowing caustic soda cargo to enter the void. The caustic soda reacted with the zinc coatings in 6 center void space producing hydrogen gas which ignited. This led to a sequence of explosions and fire resulting in the loss of the vessel.

A contributing cause was failure of the Master, K. Z. Wodka, to locate the missing caustic soda cargo which leaked from 5 center port tank into 6 center void.

COMMENTS ON THE FINDINGS OF FACT

Finding of Fact 231. This Finding of Fact is concurred with in general. The term "vapor pressure" is used somewhat imprecisely since liquids rather than atmospheres have vapor pressure. What is obviously meant is that the generation of gas and liquid inflow would increase the pressure in an enclosed space. As previously established in Finding of Fact 22, the void had several safety relief valves the lowest of which was set at a pressure of 2 psig. The assumption that the space was tight is correct only until the safety relief valves open. Therefore, the pressure in 6 center void space prior to ignition of the vapors should not have exceeded 2 psig.

COMMENTS ON CONCLUSIONS

Conclusion 1.c. This conclusion is concurred with in part. The statement that there were no other flammable gases present in 6 center void cannot be supported by the Findings of Fact.

Conclusion 5. This conclusion is concurred with. Although the board found insufficient evidence to support a finding that sabotage or foul play had a role in this casualty, the circumstances preceding the casualty preclude the total elimination of this theory.

Conclusion 11. This conclusion is concurred with. The Coast Guard must conduct its activities including rescue and salvage attempts consistent with congressional intent as set forth in the National Environmental Policy Act, 42 U.S.C. 4321, et. seq. and in the Federal Water Pollution Control Act, 33 U.S.C. 1321(b)(1). Under the circumstances, the delay in towing was prudent. Although the loss of the stern section of the vessel with its ultimate environmental consequences was regrettable, the impact on the environment would have been much worse had the vessel broken up in a confined harbor rather than in open water.

Conclusion 21. This conclusion is concurred with. While examination of 3 and 6 center void spaces was not required by regulation, the Coast Guard policy as described in the Marine Safety Manual, paragraph 30-8-10D(2), is to inspect all spaces except ship's fuel and fresh water tanks during drydock or certification inspections. Since there was no indication that the voids were examined at the inspection prior to the drydocking every effort should have been made to inspect the spaces including issuing a requirement to make the spaces available for inspection if necessary. If these spaces had been entered, it would have permitted the examination of the external boundaries on eight adjacent cargo tanks in addition to the independent cargo tank. However, the facts as developed by the board indicate that the inspection of 6 center void space would not have revealed the hole because it had not yet penetrated the bulkhead between 5 center port tank and 6 center void space.

Conclusion 35. This conclusion is concurred with in part. The Findings of Fact do not support the conclusion that the PUERTO RICAN met the applicable regulations for the carriage of "oil other than crude oil." There is no evidence that the vessel was inspected to ensure compliance with the requirements of a Form B Supplement. There are many requirements other than the slop tank that must be satisfied before a Form B can be issued. The restriction on the Certificate of Inspection to limit the cargoes to "other than oil" was consistent with the Form A Certificate issued and was correct.

Conclusion 54. This conclusion is concurred with. This casualty points out the need for realistic drills to train the crew. All crew members need to be familiar with the station bills as well as the lifesaving and firefighting equipment on the vessel before getting underway. The excuses of "quick turnaround" and interference with cargo handling operations are not justified. The time for drills immediately prior to getting the vessel underway can be scheduled that will neither create a significant delay nor interfere with cargo operations.

Conclusion 56. This conclusion is not concurred with. Prior to the move to the shipyard, the vessel was not in commission and was in lay-up status within the meaning of 46 U.S.C. 3302(e) thus needing no Certificate of Inspection. It remained in the same condition (no power, no crew) as it was moved by tugs to the shipyard; thus it was not in commission during the move and needed no Certificate of Inspection or Permit to Proceed to Another Port for Repairs.

Conclusion 59. This conclusion is concurred with in part. Even if the vessel had met the requirements for the carriage of oil, there is evidence that the vessel was operated in violation of 46 U.S.C. 3313, which requires that during the term of the vessel's Certificate of Inspection the vessel must be operated in accordance with the conditions of the certificate. In this case, the certificate prohibited the carriage of oil. See comments on conclusion 35 for discussion of authorized cargos.

Conclusion 66. This conclusion is not concurred with. Permitting Able Seaman John Peng to engage in duties other than those of lookout does not in itself constitute a violation of International Regulations For Preventing Collisions At Sea, 1972, Rule 5, failure to maintain a proper lookout. What must be shown is that no one else was performing the duties of lookout at the time. A licensed officer can act as lookout under certain circumstances. It appears that only having the master and helmsman on the bridge was sufficient in this situation. However, there is evidence of negligence on the part of Captain James C. Spillane in that he ordered Able Seaman Charles R. Palmer to leave the helm and go to the main deck while the vessel was underway in congested waters with a pilot boat coming alongside without providing a relief and leaving only himself to perform all the duties on the bridge. This matter is hereby referred to Commander, Twelfth Coast Guard District for further investigation.

Conclusion 69. This conclusion is concurred with in part. Certain administrative and procedural errors on the part of Coast Guard personnel in the inspection and certification of the PUERTO RICAN were committed, however, there is no evidence to indicate that these errors contributed in any manner to this casualty. See my comments on Conclusions 21 and 35.

COMMENTS ON RECOMMENDATIONS

Recommendation 1. This recommendation is concurred with. A regulatory project has been initiated to completely revise the lifesaving regulations for most inspected vessels. This revision is based, in part, on the 1983

Amendments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS). An Advance Notice was published in the Federal Register on 31 December 1984 (49 FR 50745). As part of this regulatory project, the Coast Guard will propose a requirement that a gate or other suitable opening be provided in the rail or bulwark adjacent to the stowage location of each liferaft.

Recommendation 2. This recommendation is concurred with. A copy of this report will be forwarded to the Federal Communications Commission.

Recommendation 3. This recommendation is concurred with. An article will be prepared for publication in the Proceedings of the Marine Safety Council.

Recommendation 4. This recommendation is concurred with. As noted in my comments on Recommendation 1, a regulatory project has been initiated to completely revise the lifesaving regulations for most inspected vessels. The Coast Guard will propose detailed requirements for station bills that will include the items identified in NVIC 7-82.

Recommendation 5. This recommendation is concurred with. The Coast Guard has initiated a regulatory project which will clarify the intent of the regulations at 33 CFR 157.11(a) regarding fixed piping systems for transferring cargo residues.

Recommendation 6. This recommendation is concurred with. The Chief of the Survival Systems Branch has written the San Francisco Bar Pilots Association requesting information on their man overboard recovery system. Upon receipt of this information, the Coast Guard will evaluate its application.

Recommendation 7. This recommendation is concurred with. However, a Permit to Proceed to Another Port for Repairs was not required. See my comments on conclusion 56.

Recommendation 8. This recommendation is concurred with.

Recommendation 9. This recommendation is concurred with. Information on the application of this law and regulation will be forwarded to the Coast Guard Marine Safety School for inclusion in the appropriate curriculum.

Recommendation 10. This recommendation is concurred with. A copy of this report will be forwarded to the International Maritime Organization.

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

MARINE CASUALTY REPORT

S.S. PUERTO RICAN
O.N. 535000

EXPLOSION AND FIRE IN THE PACIFIC OCEAN
ON 31 OCTOBER 1984 WITH LOSS OF LIFE

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U.S. Department of Transportation
United States Coast Guard

Commander (m)
Twelfth CG District

Government Island
Alameda, CA 94501
Phone: 415-437-3465

16732/PUERTO RICAN
15 June 85

From: Marine Board of Investigation
To: Commandant (G-MMI)

Subj: S.S. PUERTO RICAN, O.N. 535000; EXPLOSION AND FIRE WITH LOSS OF LIFE ON OCTOBER 31, 1984 AND SUBSEQUENT BREAKUP ON NOVEMBER 3, 1984 IN THE PACIFIC OCEAN WEST OF SAN FRANCISCO, CALIFORNIA.

SUMMARY

1. At approximately 0324 (all times are local time) on October 31, 1984 the S.S. PUERTO RICAN suffered fires and explosions in number 6 center void (6CV) and the adjacent wing tanks. The ship was outbound on voyage 238A on a "Dead Slow" bell approximately 8.5 miles west of the Golden Gate Bridge, San Francisco, California. At the time of the explosion, the Pilot, a Third Mate, and an Able Seaman were standing on the port side of the main deck over the number 4 port forward wing tank (4PF), which was adjacent to number 6CV. They were waiting for the pilot boat, which was approximately one-hundred yards off the port quarter, to come alongside. As a result of the explosion, the three men were thrown over the side. The deck area over number 6CV and adjacent wing tanks were lifted and blown directly forward, landing inverted on the deck immediately forward of its original location. The Pilot and the Third Mate were seriously injured but were recovered alive from the water; the Able Seaman was not found. The remaining twenty-six people on board abandoned ship safely at various times following the casualty. The explosion severed the firemain piping and the water/foam fireline approximately forty-feet forward of the deckhouse. Isolating the breaks caused a delay in bringing primary firefighting equipment to bear on the fire. The vessel's two lifeboats and a liferaft were launched without equipment complications. The starboard lifeboat drifted approximately 300 yards away from the vessel. The majority of the persons on board left the PUERTO RICAN by boarding commercial towing vessels from the stern of the vessel. The Master was the last person to leave the vessel. He boarded a tug from the stern of the vessel at 0526, approximately two hours after the explosion. At 0631 on October 31, 1984, the Operator and crew of a towing vessel secured a towline to the stern of the PUERTO RICAN, which had now drifted to within 3.8 miles of Point Bonita, and started towing it seaward. The fire on board the vessel was not extinguished until the early evening of November 1, 1984. Approximately ninety-two and a half hours after the casualty, at approximately 0000 on November 3, 1984, the stern section separated from the forebody roughly in the middle of number 6CV. The stern section sank in approximately 1,500 feet of water 37 miles southwest of Point Bonita. Number 6CV contained a large independent cargo tank. The independent tank floated free and was towed to a ship

repair yard in Oakland, California on November 4, 1984. The forebody was towed to a graving dock in San Francisco on November 18, 1984. The remaining cargo was removed from the forebody and the tanks were cleaned and gas freed. The forebody was ultimately sold for scrap.

FINDINGS OF FACT

PERSONNEL

2. The following persons aboard the ship at the time of the casualty are missing and presumed dead or incurred injuries reportable under Title 46 Code of Federal Regulations section 4.05.

a. MISSING AND PRESUMED DEAD:

Name:	JOHN PENG
Age	24
Position	Able Seaman
MMD Number	167 56 1529
Next of Kin	Sau Chu Ho Darling (Mother) Philadelphia, Pennsylvania

b. INJURED:

Name:	JAMES S. NOLAN
Age	47
Position	San Francisco Pilot
MMD Number	030 28 2106

Name:	PHILIP R. LEMPRIERE
Age	23
Position	Third Mate
MMD Number	625 41 0476

DESCRIPTION OF THE VESSEL

VESSEL DATA

3. Photograph 1 is a picture of the PUERTO RICAN taken in September 1984.

Name:	S.S. PUERTO RICAN
Official Number	535000
Country of Registry	United States
Home Port	New York, N.Y.
Call Sign	WDJU
Service	Chemical Tankship
Gross Tons	20,295
Net Tons	15,922
Deadweight Tons	35,240
Registered Length	632.3 feet
Overall Length	660.2 feet
Breadth	90.0 feet
Depth	48.75 feet
Frames	119; numbered from stern to bow.
Propulsion	Steam Turbine
Shaft Horsepower	15,000
Built:	
Date	December 15, 1971
Location	Sparrows Point, Maryland
Trustee Owner	Bankers Trust Company 16 Wall Street New York, New York

Chartered Owner	PPG Industries, Inc. 1 PPG Place Pittsburg, Pennsylvania
Operators	Keystone Shipping Co. 313 Chestnut Street Philadelphia, Pennsylvania
Agent	Thornley Pitt, Inc. 48 Gold Street San Francisco, California
Master	JAMES C. SPILLANE
License	Master of steam and motor vessels of any gross tons on Oceans. Radar Observer. Number 8901, issue 2-5. Issued at USCG Marine Safety Office, Seattle, Washington on August 30, 1984.
MMD Number	115 40 9128

CERTIFICATES

4. The PUERTO RICAN's Coast Guard issued Certificate of Inspection specifics were:

Last Inspection	Drydock and Inspection for Certification
Date	June 22, 1984
Port	Philadelphia, Pennsylvania

Cargo Authorization: Grade "B" and lower other than oil; also specified dangerous cargoes (46 CFR Subchapter O Authority Part 153) including caustic soda solution, butadiene inhibited, vinyl chloride, ethylene dichloride, styrene, vinyl acetate, and perchloroethylene.

5. The PUERTO RICAN was issued an International Oil Pollution Prevention (IOPP) Certificate on June 22, 1984 by the U.S. Coast Guard Officer in Charge Marine Inspection (OCMI) Philadelphia, Pennsylvania. This IOPP Certificate indicated the ship was a type other than: "Oil Tanker" or "Ship other than oil tanker with cargo tanks coming under Regulation 2(2) of Annex I of the Convention". Supplement Form A which is for ships other than oil tankers was issued and attached to the IOPP Certificate.

6. The PUERTO RICAN was issued all other United States and international certificates as required by her route and trade.

GENERAL ARRANGEMENT

7. The PUERTO RICAN was a steel tank vessel with special tanks and tank linings for the carriage of specified chemicals and liquefied gases. The deckhouse was located aft and above the machinery space. It contained the navigation bridge, radio room, and quarters for the entire complement of officers and crew. An eductor room, located below the main deck on the centerline of the vessel between the engine space and the aftermost cargo tanks, serviced the double bottom sea water ballast tanks. The cargo control room was located on the port side of the main deck centerline next to the foam room and immediately forward of the deckhouse. The forebody was divided into 27 cargo tanks. The cargo tank arrangement and numbering system is shown in figure 1.

TANK CONSTRUCTION

8. All the cargo wing tanks were integral tanks of typical steel construction. Port and starboard center tanks numbers 1, 2, 4, 5, and 7 were normally used to carry caustic soda and, therefore, were internally lined with a 0.08-inch stainless steel cladding. The centerline bulkheads, webs, stiffeners, and brackets in these tanks were solid 7/16-inch thick stainless steel. All stainless steel was AISI Type 316. Numbers 3C and 6C tanks contained independent, self supporting, non-pressure vessel type cargo tanks for the carriage of liquefied gases.

3C and 6C INDEPENDENT TANKS

9. Numbers 3C and 6C independent tanks were thermally insulated, independent, self supporting, non-pressure vessel type tanks. They were supported by a system that allowed each tank to expand and contract. The insulation was approximately 3-1/2-inch thick polyurethane foam sprayed onto the outside of these tanks. The tanks were designed to carry refrigerated vinyl chloride monomer (VCM) and butadiene. These tanks had not carried cargo for approximately five years. They were normally kept inerted with nitrogen gas for corrosion protection. Each cargo tank was approximately 102 feet long, 60 feet wide, and 39.5 feet high at the center. The height tapered downward slightly toward the sides. An expansion trunk penetrated the main deck just aft of the center of each tank. Each tank was subdivided into port and starboard tanks by a longitudinal watertight centerline bulkhead. Each tank was contained within a void space approximately 112.5 feet long, 65 feet wide, and 46.5 feet high. The space between the insulation of the independent tanks and the void space bulkheads was empty except for the support and positioning structure for the independent tank.

10. The structure designed to support and limit movement of the independent tanks had non-metallic materials (sugar maple or Marinite 65) on all bearing or potential bearing surfaces. If any of these non-metallic materials were missing, metal-to-metal contact could result from movement of the independent tanks.

11. The void space had perforated nitrogen gas fill piping at the top and a purge piping system at the bottom. Three-inch, Schedule 40, galvanized pipe was used for these systems. Each run of bottom purge piping ended in a galvanized bell-mouth.

OTHER TANKS

12. The vessel had double bottom tanks (D/B), separated into port and starboard tanks by a centerline longitudinal bulkhead, beneath all cargo tanks. The double bottom tanks were segregated seawater ballast tanks and they extended to the sides of the ship.

13. The numbers 2 and 4 port and starboard wing tanks were fitted with steam heating coils.

COATINGS

14. At construction the following surface protective coatings were applied:

a. All wing tanks: one coat of inorganic zinc primer and one coat of PPG Metalhide Inorganic Zinc;

b. Double bottom ballast tanks, external surface of 3C and 6C, and the internal surfaces of the 3C and 6C void spaces (3CV and 6CV): one coat of inorganic zinc primer and one coat of PPG Aquapon Zinc Rich Epoxy.

c. The coatings in wing tanks 1P/S, 2P/S F/A, 4P/S F/A and all double bottom tanks were renewed with various inorganic zinc materials during the 1979, 1981, and 1984 yard periods.

CARGO AND BALLAST TRANSFER SYSTEMS

15. Each bulk liquid cargo tank was served by its own deepwell pump. The cargo piping, which included both 6-inch and 8-inch cargo lines running above the main deck, was configured in separate systems serving the following tanks or tank combinations: 1C; 1P/S; 2C P/S; 2P F/A; 2S F/A; 4C P/S; 3P; 3S; 3C P/S; 4P F/A; 4S F/A; 5CP; 5CS; 5 P/S; 6C P/S; 7C P/S. The vessel's "Stowage Plan Pumping Facilities" indicated that the liquefied gas lines serving 3C P/S and 6C P/S were not in service.

16. All cargo piping met at a header system located between frames 60 and 64. Cargo could be transferred between tanks within each system but a "jumper cargo hose" was needed to join any two separate systems.

17. The double bottom ballast piping system, an eductor system, was separate and isolated from the cargo system. The ballast lines ran through the double bottom tanks; they did not enter the cargo tanks. An independent line from the eductor room serviced each double bottom tank. Stop or isolation valves for each line were located at a manifold in the eductor room. There were no valves on these lines in the double bottom tanks.

CARGO VENTING SYSTEMS

18. All cargo tanks except 2C P/S, 3P, 3C P/S, 4C P/S, and 6C P/S were fitted with an independent vent consisting of a 6-inch, pressure-vacuum (PV) relief valve mounted on top of a 7-foot high, 4-inch diameter vent riser located on the tank's expansion trunk.

19. Cargo tanks 2CP, 2CS, 4CP and 4CS were each fitted with an independent vent consisting of a 8-inch, PV relief valve mounted at deck level on the cargo tank's expansion trunk. The exhaust from these 8-inch valves was 6-inch diameter piping, which extended to a height of 13.1 feet above the deck. A 6-inch, Shand and Jurs model 94305 flame arrester was installed at the exhaust end of the vent piping.

20. Cargo tank 3P was fitted with a 4-inch, Waukesha Prec-Vac, Hs-M High Speed PV Valve mounted atop a 10-foot high, 4-inch diameter vent riser from the tank's expansion trunk. The set pressure for all PV valves, including the High Speed PV valve, were 2 psig pressure and 1 psig vacuum.

21. Independent cargo tanks 3CP and 3CS were each fitted with two 6-inch, Shand and Jurs model 94610 Magna-Valve safety relief valves with set pressures of 3.8 psig and 4 psig. The safety relief valves were located at deck level and discharged into a 20-inch diameter vent riser 17.5 feet high which was fitted with a 12-inch diameter, Shand and Jurs model 9431 flame arrester. The pilots for the safety relief valves discharged into a 6-inch diameter vent riser, 17.5 feet high, which was fitted with a 6-inch diameter, Shand and Jurs model 9431 flame arrester. The vent risers are located near the vessel's centerline approximately 10 to 15 feet aft of the cargo tank domes for 3C P/S and 6C P/S. The venting arrangement for 6C P/S was identical to that for 3C P/S.

22. 3CV and 6CV were each fitted with one 2-inch, Shand and Jurs Magna-Valve safety relief valve with a set pressure of 2.0 psig and three 6-inch, Shand and Jurs Magna-Valve safety relief

valves, with a set pressure of 2.6, 2.8, and 3.0 psig respectively. All safety relief valves were located at deck level and discharged into a 12-inch vent riser, 17.5 feet high, which was fitted with a 12-inch diameter, Shand and Jurs model 9431 flame arrester. The pilots for these safety relief valves discharged into a 6-inch diameter vent riser, 17.5 feet high, that was fitted with a 6-inch diameter, Shand and Jurs model 9431 flame arrester.

23. Both 3CV and 6CV were also fitted with a 2-1/2-inch vacuum breaker riser approximately 7-feet high with a set pressure of 0.7 psig. The vent risers and vacuum breaker riser were located near the vessel's centerline approximately 10 to 15 feet aft of the cargo tank domes for 3CV and 6CV.

CARGO CHARACTERISTICS

24. Table 1 lists the cargoes carried on the PUERTO RICAN on Voyages 237A, 238 and 238A. These cargoes are representative of those carried since the May-June 1984 shipyard period. Although the ship was approved to carry several chemicals under 46 CFR Subchapter O, it carried only caustic soda and perchloroethylene during this period; both are non-flammable. Except for 1,1,1 trichloroethane, which is unregulated, the remainder of the cargoes were Grade D or E combustibles regulated under 46 CFR Subchapter D.

25. Since the May-June, 1984 shipyard period, only the simultaneous carriage of ethylene glycol and 50% caustic soda solution on voyage 236 posed a potential incompatibility problem. These cargoes were separated in accordance with 46 CFR 150.130.

26. The cargoes immediately adjacent to 6CV on October 31, 1984 are shown in figure 2.

27. Regarding the characteristics of PUERTO RICAN's cargo, one officer testified that as part of her orientation she was told that "We were carrying Grade E stuff. That's one of the first things I was told about .... the flammable points are so high that it was a totally safe vessel."

LIFESAVING AND FIREFIGHTING SYSTEMS

PRIMARY LIFESAVING EQUIPMENT

28. The vessel's two 26 foot, 48 person, aluminum, open-type, motor lifeboats were manufactured in 1970 by Marine Safety

Equipment Company. Their serial numbers were 2087 and 2088. These lifeboats were stowed in gravity-type davits which were mounted on the Boat Deck, two decks above the main deck. Normal abandon ship procedure was for each boat to be lowered to the edge of the Boat Deck for embarkation. Photograph 7 shows the davit location for the lifeboat on the port side. The boats would then be lowered to the water and released. Each boat was equipped with a sea painter. This line was normally rigged prior to launching in order to keep a waterborne boat from drifting away from the ship.

29. The vessel's two inflatable liferafts were manufactured in 1982 by Switlik Corporation. A 10-person raft, number SPC-MM-21, was located forward on the main deck just aft of the Forecastle Deck. A 20-person raft, number SPC-MM-10, was stowed in a standard cradle on the starboard side of the Boat Deck approximately twelve feet aft of the lifeboat davits. The approximate weight of a 20 person raft and its container is 400 pounds.

30. The Certificate of Inspection requires 41 adult life preservers. The Tankship Hull Inspection Book (CG-840S) dated as completed June 22, 1984 lists forty-one life preservers as passing inspection.

31. Title 46 Code of Federal Regulations section 33.37, effective August 6, 1984, requires one exposure suit for each person onboard vessels with a route such as the PUERTO RICAN's. There was evidence that exposure suits were onboard and used by some, but they were not listed on the Certificate of Inspection since the Bienniel Inspection was conducted prior to the effective date of the regulation.

GENERAL FIREFIGHTING SYSTEMS

32. The PUERTO RICAN was equipped with two firefighting systems: a firemain system that delivered water to various parts of the vessel and a foam system which provided a water/foam mixture to the main deck, the engine spaces, and the eductor room.

FIREFIGHTING PUMPS AND PIPING

33. There were two pumps that fed these systems. The primary pump was a steam turbine fire and butterworth pump located on the port side of the engine space lower level. Its discharge relief valve was set at 190 pounds. An electric emergency pump, located in the shaft alley, was fed from the emergency switchboard. Its relief valve was set at 125 pounds. There was a manifold at each pump which allowed the water flow to be individually or jointly directed to either the firemain system or the foam system or to both simultaneously. An 8-inch

firemain served the main deck in way of the cargo tanks and a 6-inch line served the deckhouse. The stations on the 6-inch line could be segregated from the forward stations, which were on the 8-inch line by valves in the engine spaces or in the fidley. Normal operation was to leave these valves in the "open" position. The foam system was supplied with water from a separate 8-inch line that entered the foam room from the engine spaces. This line could be supplied by either or both the firepump or the emergency pump.

FIREMAIN SYSTEM

34. The firemain system consisted of twenty-four hose stations. Eight were fitted with 75 foot, 2-1/2-inch hoses and associated equipment; sixteen were fitted with 50 foot, 1-1/2-inch hoses and associated equipment. Each station was equipped with one length of hose. The foreward 8-inch firemain line was raised approximately 2 feet off the deck on metal supports. This forward line was located 24 feet inboard of the gunwale between frames 52 and 62 and ran over the top of 7CP and 6CP tanks. It ran forward on the port side of the main deck and fed seven of the eight 2-1/2-inch hose stations; the eighth station was on the main deck on the external, aft bulkhead of the deckhouse. It was serviced by a 4-inch water line off the 8-inch line in the engine spaces.

FOAM SYSTEMS

35. An 8-inch, water supply line served the foam room and six foam monitor stations on the main deck forward of the deckhouse. There was a gate valve in the line where it entered the foam room. Downstream from this valve was a ratio flow proportioner fed by two foam storage tanks. Each tank had a pump to inject the concentrate or the catalyst into the water line. A 4,200-gallon capacity tank was used for foam concentrate. Its pump was rated at 280 gallons per minute at 175 psi. A 600-gallon capacity tank held a foam catalyst solution and was fitted with a pump rated at 45 gallons per minute at 175 psi. There was another gate valve in the 8-inch water/foam line before it passed through the foam room's forward bulkhead. There were two other gate valves that controlled the lines serving the engine room and the eductor room. Foam stations 5 and 6 were located between frames 50 and 51 atop the foam room and the adjacent cargo control room; the remaining four stations were single stations located above center tanks 6, 5 and the forward and after ends of 3. Stations 5 and 6 were designed to provide a water/foam stream forward at the centerline measurement to frame 62. Station 5 was fed off the 8-inch water/foam line; this line was reduced to 4-inches to supply station 6. The system was rated to discharge foam for 15 minutes with only monitors 5 and 6 on the line. There were shut-off valves in the 8-inch water/foam line forward of each station except at the foreward-

most station, station number 1. The valve that isolated all stations forward of numbers 5 and 6 was located in the water/foam line as it passed up the port side just forward of the forward port corner of the cargo control room.

VESSEL HISTORY

GENERAL

36. Keystone Shipping Company began operating the PUERTO RICAN on April 6, 1982. Prior to that time, the vessel was operated by West Coast Shipping Company. The last Certificate of Inspection issued to West Coast Shipping Company for the PUERTO RICAN was issued by the U.S. Coast Guard Officer in Charge, Marine Inspection (OCMI), Mobile, Alabama on October 31, 1981 to expire on October 31, 1983.

37. Cargo was never carried in the 3C or 6C cargo tanks while Keystone operated the vessel. Keystone's normal practice was to inert these tanks and the surrounding void spaces with nitrogen. This was done for the purpose of inhibiting metallic corrosion, not for the purpose of preventing a flammable mixture.

38. The vessel's Certificate of Inspection was surrendered when the vessel was placed in lay-up status in Philadelphia in early September 1983. Title 46 United States Code section 3302(e) provides that a laid-up vessel is exempt from inspection and, therefore, the requirement to maintain a current Certificate of Inspection. The PUERTO RICAN was taken out of lay-up in the middle of May 1984 and towed unmanned as a "dead ship" from Girard Point, Philadelphia, Pennsylvania to the Pennsylvania Shipbuilding Co., Chester, Pennsylvania, a distance of approximately 6 miles, for drydocking and re-certification.

39. There is no evidence that a Permit To Proceed was requested or issued for this move. Title 46 United States Code section 3311 states that "A vessel subject to inspection under this part may not be operated without having on board a valid certificate of inspection....". 46 United States Code 3301 identifies tank vessels as a category of vessels subject to inspection. 46 United States Code 2101 defines "tank vessel" as "... a vessel that is constructed or adapted to carry, or that carries, oil or hazardous material in bulk..."

MAY-JUNE 1984 SHIPYARD

40. During this period the Coast Guard conducted a drydock examination and a Biennial Inspection for Certification. The American Bureau of Shipping (ABS) conducted the following inspections and surveys: Drydocking; Annual Survey of Hull and

Machinery; Annual Load Line Inspection; Port and Starboard Boiler Survey; Continuous Hull Survey items; Continuous Machinery Survey items; Reactivation Survey.

41. The Coast Guard vessel file from OCMI Philadelphia did not contain a Form CG-3752, "Application for Inspection of U.S. Vessel", for the PUERTO RICAN inspection conducted during May-June 1984. A letter to the Marine Board of Investigation from Keystone Shipping Company's counsel dated February 14, 1985 states that Keystone Shipping Company records do not contain a copy of an Application for Inspection because the person representing the vessel requested this inspection verbally and did not submit a written application. One of the Coast Guard Inspectors testified he recalled an application being submitted, and he believed it was signed by the person representing Keystone during the inspection. A May 15, 1984 letter on Keystone Shipping Company letterhead stationary to "Inspector SS PUERTO RICAN" indicates that the liquedfied gas endorsements for butadiene (inhibited) and vinyl chloride were to be retained on the vessel's Certificate. This letter also stated that the vessel was being modified to carry perchloroethylene in tank 3P. Dispite questions by the Board, it could not be determined if this letter was addressed to the Coast Guard or to the Keystone Shipyard representative.

42. An entry dated March 31, 1984 in the Coast Guard Marine Safety Information System Indicates that the PUERTO RICAN is one of the Bethlehem Steel 32,650 deadweight ton (DWT) tankers with a class problem involving center vertical keel (CVK) fractures and that advanced notice should be given to Coast Guard Headquarters when it is scheduled for a drydock inspection.

43. The ABS "STELEX PORT" is a computer printout on a specific vessel. It provides guidance to ABS Surveyors on the scope of their surveys and inspections. An ABS "STELEX PORT" dated May 10, 1984 for the PUERTO RICAN inspection alerts ABS Surveyors to the class problem of center vertical keel fractures and notes that special attention is to be paid to important structural areas and repairs to those areas.

44. The exterior hull plating, all double bottoms, and all cargo tanks except tanks 3C and 6C and voids 3CV and 6CV were inspected by either the Coast Guard Inspectors or the ABS Surveyor during the May-June 1984 inspection period. No indications of CVK fractures or other significant structural defects were noted.

45. Page 85 of the USCG Tankship Hull Inspection Book for the PUERTO RICAN inspection completed June 23, 1984 contains an entry that all tanks and voids were entered and found satisfactory. The Coast Guard Inspector completing this book testified that tanks 3C and 6C and voids 3CV and 6CV were not entered. He testified that the tanks and associated equipment were not inspected because: they were inerted; they were not due

for a periodic 8 year internal exam; and the cargo pumps had been removed and the tanks were no longer used to carry cargo. He testified that VCM was kept on the Certificate of Inspection because he understood that these tanks still contained some cargo residue. He testified that 3CV and 6CV were not inspected because he thought they were inerted and he was told that the void bulkheads were externally stiffened.

46. Title 46 CFR 31.10-15(b) indicates the Inspection for Certification shall be such as to insure the vessel's structure is in satisfactory condition and fit for the service for which it is intended.

47. American Bureau of Shipping inspection records indicate that independent tanks 3C and 6C and voids 3CV and 6CV were not inspected during surveys conducted on the PUERTO RICAN in May-June 1984. The ABS Surveyor testified that those areas were not inspected because liquefied gases were not being carried and ABS had issued a requirement for these tanks to be inspected at the first liquefied gas loading port. He testified that these spaces required inspection by November 1984 to complete the vessel's special survey and that he conveyed this fact to Keystone's shipyard representative.

48. Coast Guard Drydock Examination Book, CG-840H, dated November 1, 1979 indicates that 6CV, 6CP, 6CS and 3CV were inspected on October 31, 1979 and that 3CP and 3CS were inspected on October 5, 1979. The Drydock Examination Book dated October 31, 1981 indicates that all internal tanks except bunker tanks (full of fuel) and the VCM tanks (3C P/S and 6C P/S) were examined. The Tankship Hull Inspection Book, CG-840S, dated October 31, 1981 indicates that independent tanks were examined externally and internally in October 1979.

49. Title 46 CFR 38.25-1(a)(1) requires an internal examination of liquefied flammable gas tanks at least once in each 8 calendar years. Title 46 CFR 38.25-1(a)(2) requires an external examination of the visible parts of lagged liquefied flammable gas tanks at each Inspection for Certification.

50. The American Bureau of Shipping "STELEX PORT" dated May 10, 1984 for the PUERTO RICAN includes the following additional information:

a. Independent cargo tanks 3 and 6 and the void spaces around these tanks are due for Continuous Survey in November 1984.

b. "M 13589 Dated 2 NOV 79 Vessel not currently carrying liquefied gases. AHS requirements for LG to be carrierd out at first LG loading port."

51. PUERTO RICAN Form 558 (5m-79 JCO), which is an outline of the cargo and double-bottom tanks of the vessel, was used by the

ABS Surveyor to keep a record of spaces that were inspected internally during May-June 1984. This form did not contain entries in the following spaces: 1P D/B, 1S D/B, 2P F/A, 2S F/A, 3C P/S, 5CP. American Bureau of Shipping reports of inspections completed during May-June 1984 indicate all double-bottom tanks and all cargo tanks, except numbers 3C and 6C and their void spaces, were entered and inspected during this yard period. The ABS Owner's Report dated November 28, 1984 indicates that voids 3CV and 6CV and cargo tanks 3C P/S and 6C P/S were due for internal examination during November 1984.

52. During this shipyard period, Keystone employed the services of a welding and coating specialist. As part of his duties, he inspected the aft bulkhead of 5CP from top to bottom and from side to side using a high intensity, battery-pack light belonging to the ship. He did not discover any holes or cracks in this bulkhead. He testified that such holes or cracks could be detected by telltale rust streaks from the mild steel that would run down the stainless steel cladding. The only flaws he found in 5CP were in the forward end of the port longitudinal bulkhead about 16 feet above the deck of the tank. He testified that, as part of his inspecting 5CP and supervising the repairs, he entered the tank on May 16, 17, 23, 24, June 6, 7 and 11, 1984.

53. Pennsylvania Shipbuilding Company Shipyard Invoice Number 12-4 for the PUERTO RICAN dated September 7, 1984 includes the following work items:

a. Item 128. Deck Piping Modifications: Modify deck cargo piping so each of the following tanks has its own segregation: 2P F/A, 2S F/A, 4P F/A, 4S F/A.

b. Item 129. Cargo tank heating coils and deck steam supply and return lines: Install heating coils in cargo tanks 2P F/A, 2S F/A, 4P F/A, 4S F/A.

c. Item 147. Nitrogen Control Cabinet: Remove.

d. Item 164. Obsolete Nitrogen Piping: Remove.

e. Item 171. Nitrogen Padding System 4PA - 4PF Tanks: Install.

54. A handwritten note from Jim G. (a member of the Coast Guard) to the Executive Officer (of U.S.C.G. Marine Inspection Office, Philadelphia, Pennsylvania) dated 0930 July 24, 1984 refers to the PUERTO RICAN and the above ABS special notice concerning CVK fractures. This note indicates the ABS Surveyor, the owner's representative, and a U. S. Coast Guard Inspector were in each double bottom-tank and did not notice any problems in those areas.

55. A hand-written, undated memorandum to Vessel File concerning certificates for the PUERTO RICAN states: "Vessel arrived dead ship with no crew or certificates aboard....(when preparing COI) leave day of expiration and issue blank - just type month and year. Changes in other persons in the crew, persons in addition to the crew and total persons allowed IAW Keystone written request.... Perchloroethylene added (to COI Amendment) as per owner written request....Month and year should be entered into current COI blocks and issue date block. Will add exact date later." Another undated, handwritten memorandum to ASIM (Assistant Senior Inspector, Material) regarding paperwork for PUERTO RICAN includes the following information: "IOPP FORM B - Item 3.1 - Slop Tank Capacity - leave blank. Is being calculated and will be provided when available."

GAS CHEMIST

56. Marine Chemist Certificate, Serial Number B88360, Certificate Number 605, issued to the SS PUERTO RICAN, on May 14, 1984 contains the following entries: "Void/cofferdams around numbers 3C and numbers 6C....Safe for workers - not safe for hot work....Center Cargo Tanks numbers 3P, 3S, 6P, 6S .... not safe for workers - not safe for hot work. (Tanks are inerted. Any work shall require reinspection.) Ventilation recommended. Spaces are free of flammable gases and combustible liquids." Marine Chemist Certificate Serial Number B88361, Certificate Number 605, issued to the SS PUERTO RICAN on May 16, 1984 includes the following entries: "Cofferdam/Voids Center Number 1 & 2 (around C/L Nos.3 and Nos.6) .... Safe for workers - not safe for hot work."

ISSUANCE OF CERTIFICATES OF INSPECTION

57. The Inspection for Certification was originally scheduled to be completed on June 22, 1984. The Certificate of Inspection (COI) and its amendments were delivered to the Coast Guard Inspectors at the shipyard by a courier from their office that night. However, the inspection was not completed until Saturday, June 23, 1984, which is noted in the Tankship Hull Inspection Book and the Machinery Inspection Book. The final check-off and issuance of the COI was done by the attending Coast Guard Inspector's supervisor.

58. The Certificate of Inspection dated June 22, 1984 issued to the PUERTO RICAN by the Officer In Charge, Marine Inspection Philadelphia, Pennsylvania lists the vessel as a "Chemical Carrier" authorized for the carriage of: "Grade "B" and lower other than oil; also specified dangerous cargoes (46 CFR Subchapter O Authority Part 153)". The Certificate of Inspection Amendments, issued at the same time and place, include an authorization for the carriage of caustic soda solution in tanks 1C, 2C P/S, 4C P/S, 5C P/S and 7C P/S. In

addition, butadiene (inhibited) or vinyl chloride is authorized for carrage in tanks 3C P/S and 6C P/S. Temperature and pressure limitations on these tanks are specified as "Not less than -0- degrees Fahrenheit and not more than 3.8 PSI". Perchloroethylene is also authorized for tank 3P.

59. The previous COI issued in Mobile, Alabama on October 31, 1981 as amended included the same entries except it did not include an entry for perchloroethylene.

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POST SHIPYARD OPERATIONS

GENERAL

60. After receiving it's Certificate of Inspection in June of 1984, the vessel resumed operation as a chemical tanker in the coastwise trade between the Gulf of Mexico and the West Coast. There is no evidence that 3CV and 6CV were inerted with nitrogen subsequent to being declared Safe for Workers by a gas chemist on May 16, 1984.

61. Keystone used a numerical-alphabetical system of designating voyages. Voyages commenced and new numbers were assigned in the Gulf after the vessel discharged all eastbound cargo loaded on the West Coast. An "A" was added to the voyage number for the return voyage after the vessel completed discharge of all cargo from the Gulf Coast on the West Coast. The dates of the PUERTO RICAN's last three voyages were:

a. Voyage 237A - September 11 to 30, 1984.

b. Voyage 238 - September 30 to October 28, 1984.

c. Voyage 238A - October 28, 1984 to....

CAUSTIC SODA AND ALKANE 60 CARGOES

62. The vessel's Bridge Log Book for October 1984 reveals that from October 1 to October 8 the PUERTO RICAN was docked at five different terminals in Louisiana and Texas; the cargoes loaded are indicated in table 1. Caustic soda was loaded at two ports:

a. On October 1, 1984 at Occidental Chemical Corporation, Taft, Louisiana, 16,842 barrels were recorded as loaded into 2C P/S between the hours of 0015 and 0630. This amount was based on ullaging of the ship's tanks by an independent cargo surveyor. The final ullages were:

(1) 2CP was 9'- 4-7/8"
(2) 2CS was 9'- 4-3/8"

b. At PPG Industries, Lake Charles, Louisiana, 71,418.1 barrels were recorded as loaded into tanks 1C, 4C P/S, 5C P/S, and 7C P/S from 2400 on October 7, 1984 to 1755 on October 8, 1984. An independent Cargo Surveyor from Charles Martin Company gauged the tanks after cargo loading was completed and the Second Mate, Mr. CHARLES EBERSOLE, witnessed the ullages. The following ullages were recorded:

(1) 1C was 11'- 0-1/4"

(2) 4CP was 7'- 3"

(3) 4CS was 6'- 11-1/2"

(4) 5CP was 13'- 2-3/4"

(5) 5CS was 15'- 10-1/4"

(6) 7CP was 6'- 11"

(7) 7CS was 7'- 0"

c. According to these figures, the total caustic soda loaded as cargo at the two Gulf Coast ports was recorded as 88,260.1 barrels.

63. The PUERTO RICAN's ullage records indicate the following quantities of caustic soda at loading and immediately prior to discharge were initially accounted for on Voyage 238. For the purpose of this report, these figures are not corrected for temmperature. The figures are for comparison purposes only. All figures were determined by independent surveyors.

TANK NUMBER	BBLS AT LOADING	BBLS PRIOR TO DISCHARGE
* 1C	10,024	10,019
# 2CP	8,445	8,417
# 2CS	8,480	8,453
* 4CP	10,634	10,615
* 4CS	10,641	10,598
* 5CP	9,142	(NO ENTRY MADE)
* 5CS	8,414	8,365
* 7CP	11,309	11,276
* 7CS	11,257	11,203
TOTAL BARRELS	88,346	(INCOMPLETE)

* Indicates PPG Industries cargo loaded at Lake Charles, Louisiana.

# Indicates Occidental Chemical cargo loaded at Taft, Louisiana.

There is an 85.9 barrel difference between the loading figures based on independent surveyors' records for the ship and the ship's ullage records.

64. Comparison of the figures in the immediately preceeding paragraph indicates the following differencs between the loading and the pre-discharge quantities:

TANK NUMBER	BARREL DIFFERENCE	PERCENTAGE DIFFERENCE
1C	5	.05
2CP	20	.332
2CS	27	.318
4CP	19	.179
4CS	43	.404
5CP	UNKNOWN	UNKNOWN
5CS	49	.582
7CP	33	.292
7CS	54	.480

The industry-standard allowable differential is one-half of one percent. Of those tanks for which information is available, 5CS falls outside this range; however, the cummulative figure of .330 is within this range.

65. At 2118 on October 8, 1984, the PUERTO RICAN sailed from Lake Charles, Louisiana via the Panama Canal to the GATX Terminal in San Pedro, California, the first of the three West Coast ports at which it would discharge the caustic soda. The vessel docked at 1030 on October 21, 1984. An employee of Caleb Brett, an independent cargo surveying company, gauged the cargo tanks before they were discharged. Third Mate DEBROAH K. COBB started recording the ullages on the 0800-1200 watch. Just before noon, Mr. CARSON JORDAN, the 12-4 Third Mate, relieved her. The Caleb Brett Surveyor's ullage record shows the 5CP ullage as 23'-1/2". Mr. JORDAN recorded the ullage for 5CP in the Chief Mate's workbook which he then gave to Chief Mate SPILLANE immediately after he had completed the gauging. MR. JORDAN testified that it is the Chief Mate's responsibility to compare the loading ullage with the pre-discharge ullage. MR. SPILLANE had earlier testified that the Chief Mate is responsible for cargo operations. The pre-discharge ullages in San Pedro were not compared with the loading ullages recorded in the Gulf. Therefore, the difference between the loading ullage of 13'-3"

and pre-discharge ullage of 23'-1/2" for 5CP was not noted nor reported to anyone prior to the start of cargo discharge. The PUERTO RICAN'S ullage tables for 5CP indicate the cargo difference between an ullage of 13'-3" and an ullage of 23'-1/2" is 2546 barrels.

66. The PUERTO RICAN commenced discharging the 50% caustic soda from 1C, 5CP, and 5CS to the GATX Terminal during MR. JORDAN's watch at 1320 on October 21, 1984. At 0400 on October 22, 1984 the 0400-0800 Deck Watch Officer, Second Mate CHARLES EBERSOLE, was told by a terminal employee that the ship would finish discharging the caustic soda scheduled for GATX at approximately 0600. Shortly before 0600, 2/M EBERSOLE was notified by a terminal employee that the terminal still needed about 3,000 more barrels. He notified Chief Officer SPILLANE because he did not want to discharge more cargo than the scheduled amount. It was at this time, approximately sixteen hours after the start of the caustic soda discharge began, that the loading ullages recorded at Lake Charles were compared with the pre-discharge ullages taken by the Caleb Brett Surveyor and the discrepancy in the recorded readings for 5CP was noted. Chief Mate SPILLANE and 2/M EBERSOLE discussed with the Caleb Brett Surveyor the ullage differences and the terminal's request for additional cargo. Captain WODKA was notified and became involved in these discussions.

67. The Caleb Brett Surveyor checked the gauge on the receiving tank ashore and computed the volume that had been received from the vessel. He determined the shore figures supported a nominal 23-foot ullage reading.

68. Captain WODKA asked the Caleb Brett Surveyor to determine the shoreside figures for 5CP at the loading port. The surveyor contacted an employee of PPG in Lake Charles, Louisiana and received the loading figures. He gave Captain WODKA these figures, which included a loading ullage of 13'-3" for 5CP. Captain WODKA noted that the terminal figures for 5CP from Lake Charles matched the loading ullages recorded by the ship and this differed from the pre-discharge reading by approximately 10 feet. He testified that he felt the number "2"in the "23" foot ullage was a recording error and that the ullage was actually 13'-1/2". He also testified the discharge rate at the GATX Terminal substantiated the error to be a recording error and that, basically, he did not believe there was any loss to begin with.

69. Captain WODKA, Chief Mate SPILLANE, and the Chief Pumpman, MR. NATHANIEL DAY, sounded all double bottom and void spaces around 5CP, with the exception of 6CV. They also checked the adjacent cargo tanks to ascertain if there was any leakage of caustic soda from 5CP. They found no evidence of caustic soda from 5CP leaking into any of these spaces. Captain WODKA testified he had been told 6CV was inerted with nitrogen. He and the other men looked for a means of sounding 6CV for liquid. They did not find any sounding tubes for 6CV. Captain WODKA

decided to inspect 5CP after the tank was cleaned rather than open 6CV for inspection. There was a fixed eductor system for 6CV. The piping for this system had a removable blank where it penetrated the main deck. Captain WODKA did not use the eductor system as a means to check for the presence of liquid in 6CV.

70. It was normal practice on the PUERTO RICAN during cargo transfer operations for the Deck Watch Officer to take interim ullages, usually hourly, to determine transfer rates. These interim ullages were ultimately recorded on a shipboard form called a rate sheet. Ship's officers often made notes of these hourly ullages on a pad in the ship's office and later transferred them to the rate sheets. This information was useful for estimating the time cargo operations would be completed. During preliminary investigative questioning on November 27, 1984, 3/M JORDAN indicated he had personal notes pertaining to hourly ullages for cargo being discharged at GATX San Pedro during his watch on Voyage 238. Although subpoenaed, Mr. JORDAN never produced these notes and testified he had lost them. No rate sheets, hourly transfer ullages, or other shipboard information could be obtained by the Board as a means of determining what the pre-discharge ullage for 5CP probably was. There was no evidence produced to indicate interim ullage readings were taken by anyone or were checked by Captain WODKA or anyone else to determine whether a pre-discharge ullage of approximately 13 feet or of approximately 23 feet appeared most probable.

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71. The scheduled time for the PUERTO RICAN to shift berths on October 22, 1984 was changed from 0800 to 1200 in order for the ship to discharge the additional caustic soda requested by the GATX Terminal, San Pedro. Tanks 1C and 5CP were completely discharged and more cargo was discharged from 5CS than originally planned. Caleb Brett records indicate that the PUERTO RICAN discharged the following amount of caustic soda to the GATX Terminal by 1036 on October 22, 1984:

TANK NUMBER	BBLS PRIOR TO DISCHARGE	BBLS AFTER DISCHARGE	BBLS DELIVERED
1C	10,019	-0-	10,019
2CP	8,417	8,417	-0-
2CS	8,453	8,453	-0-
4CP	10,615	10,615	-0-
4CS	10,598	10,598	-0-
5CP	6,591	-0-	6,591
5CS	8,365	2,830	5,535
7CP	11,276	11,276	-0-
7CS	11,203	11,203	-0-
TOTAL BBLS	85,537	63,392	22,145

Compared to the figures in paragraph 62 all the "BBLS PRIOR TO DISCHARGE" figures fit within the one-half of one percent tolerance except for 5CP.

72. Chief Mate SPILLANE did sign The Caleb Brett Surveyor's ullage report but added a clause to dispute the arrival ullage of 5CP; he thought the approximate 10 foot ullage discrepancy was probably due to an error in either reading the gauge or in writing down the ullage during pre-discharge ullaging. The Surveyor signed the ship's Record of Ullages and Soundings, but he added a dispute notation to indicate he determined the arrival ullage in 5CP to be "23'-00 1/2" instead of "13'-0 1/2".

73. At 0818 on October 23, 1984, the vessel shifted to Wilmington Liquid Bulk Terminal (WLBT), Wilmington, California, where it discharged 27,469 barrels of caustic soda commencing at 1140 on October 23, 1984:

Tank Number	BBLS PRIOR TO DISCHARGE	BBLS AFTER DISCHARGE	BBLS DELIVERED
1C	-0-	-0-	-0-
2CP	8,417	-0-	8,417
2CS	8,453	-0-	8,453
4CP	10,615	10,615	-0-
4CS	10,598	10,598	-0-
5CP	-0-	-0-	-0-
5CS	2,765	-0-	2,765
7CP	11,256	7,196	4,060
7CS	11,211	7,437	3,774
TOTAL BBLS	63,315	35,846	27,469

This discharging was completed at 0721 on October 24, 1984.

74. On the morning of October 24, 1984, the vessel sailed for Encinal Terminal in the San Francisco Bay area. While the vessel was at sea enroute San Francisco, 5CP was washed and made safe for entry. Captain WODKA and Chief Mate SPILLANE entered and inspected 5CP using portable lights. They inspected it while standing on the ladder leading into the tank, located at the forward inboard corner, and from the deck of the tank. They did not find any cracks or holes in the tank. Captain WODKA testified that he believed he would be looking for a large hole or crack, as it would take something that size to account for an approximate 2,500 barrel loss. After they could not find anything like that, they inspected the welds.

75. The PUERTO RICAN entered San Francisco Bay on October 25, 1984 and was scheduled for four terminals in this area: Encinal Terminal in Alameda, Paktank Terminal in Richmond, the GATX Terminal, also known as the Union Tank Terminal, and the Chevron, U.S.A., Inc., Refinery Terminal in Richmond, also known as the Richmond Longwharf. She did not handle caustic soda or Alkane 60 at the first or the last terminal.

76. On October 28, 1984, at 0530 the PUERTO RICAN shifted from Encinal Terminal to Paktank Terminal in Richmond, California, arriving at 0918. Supervisory personnel tied-up and worked the ship at the Paktank Terminal. Several cargoes were loaded, including Alkane 60 between 1250 and 2220. The ship's records show that 7206 barrels of Alkane 60 were loaded in 3S and 10,446

barrels were loaded in 5CP. The final loaded ullage for 5CP was 8'-4". An independent surveyor's report indicates that 17,984 barrels were pumped from shore to the PUERTO RICAN. The difference of 332 barrels between the ship and the shore figures equals a discrepancy of 1.846%.

77. At 0618 on October 29, 1984, the ship shifted to the GATX Terminal, Richmond, arriving at 0830. Here 35,794 barrels of caustic soda, the remainder known to be carried as cargo on Voyage 238, were discharged between 1050 on October 29 and 0235 on October 30:

TANK NUMBER	BBLS PRIOR TO DISCHARGE	BBLS AFTER DISCHARGE	BBLS DELIVERED
1C	-0-	-0-	-0-
2CP	-0-	-0-	-0-
2CS	-0-	-0-	-0-
4CP	10,615	-0-	10,598
4CS	10,598	-0-	10,592
5CP	-0-	-0-	-0-
5CS	-0-	-0-	-0-
7CP	7,196	-0-	7,116
7CS	7,437	-0-	7,505
TOTAL BBLS	35,846	-0-	35,794

The 52 barrel net difference between these figures is caused by using gauging data from three seperate cargo surveyors employed by two different surveying firms.

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CAUSTIC SODA - SHORE TANK FIGURES

78. To complement the above figures, independent surveyors' shore quantities for Voyage 238 of caustic soda delivered to the PUERTO RICAN on the Gulf Coast and received from the PUERTO RICAN on the West Coast were compared. The audit shows:

LOADED:

	LONG TONS	BARRELS
Occidental, Taft, LA.	4,021	16,808
PPG, Lake Charles, LA.	17,051	71,273
TOTAL	21,072	88,081
DISCHARGED:		
GATX, San Pedro, CA.	5,276	22,054
WLBT, Wilmington, CA.	6,550	27,379
GATX, Richmond, CA.	8,549	35,735
TOTAL	20,375	85,168
NOT DELIVERED:	697 LT	2,913 BBL

79. The vessel then shifted at 0418 on October 30, 1984 to the Richmond Longwharf, arriving at 0636. Cargo loading was completed at 2320 on October 30, 1984 and the PUERTO RICAN was readied for sea. Specifics of cargo onboard upon sailing are provided in table 1.

TANK 5CP - PRIOR CARGOES

80. Table 1 indicates that 5CP did not carry cargo on Voyage 237A. On Voyage 237 at PPG Industries Terminal, Lake Charles, Louisiana, 10,657 barrels of caustic soda solution were loaded into 5CP on August 21, 1984. On September 3, 1984, 10,607 barrels of caustic soda solution were discharged from this tank at GATX Terminal, San Pedro, California.

PICKETING ACTIVITY

81. On October 25, 1984, the PUERTO RICAN entered the San Francisco Bay area. At 1203 it attempted to tie up at the Encinal Number 5 berth in the Oakland Estuary but was unable to obtain line handlers due to picketing activities against Keystone

by the International Organization of Masters, Mates, and Pilots. As part of these activities, a small boat, the GEORGE MEANY, was used to establish a waterborne picket line. A mooring line was put over by ship's personnel and made fast to either a cleat or a bollard on the dock by members of the International Longshoremen Workers' Union (ILWU). Persons from the GEORGE MEANY approached the ILWU members and told them this was a strike action. The ILWU members left the area without working any more lines from the ship. The people from the GEORGE MEANY then threw the ship's mooring line off the dock. Captain WODKA sent some crewmembers on the dock to tie-up the ship but, because of the chance of an altercation under such circumstances, decided not to have them do so. Towboats held the ship alongside Encinal Number 5 berth until 1600 the following day when men came by boat to tie-up the ship.

82. The Duty Office at the USCG Marine Safety Office San Francisco Bay was notified by a person from Keystone Shipping Company at 1225 on October 25, 1984 that a person from the picket boat had cast off the ship's mooring lines at the Encinal Terminal. Persons were dispatched from the Marine Safety Office to investigate. At 1300 the Duty Office received a call from the Pilot aboard the PUERTO RICAN indicating that dockside line handlers were honoring the picket activity by refusing to tie-up the ship. Coast Guard personnel on scene reported that crew members attempted to tie-up the vessel at 1340 but by 1350 had returned to the ship without doing so. They also reported that although there was heated language between the parties, acts of physical violence did not appear imminent. The Coast Guard people at the Encinal Terminal were told by a person in the Duty Office that this was a labor dispute and that the Coast Guard would not become involved unless there was a violation of federal law. They were then told to return to the office. Responsible persons at the Marine Safety Office continued to monitor picketing activities involving the PUERTO RICAN until the night of October 30, 1984.

83. 46 CFR 5.03-20(a) cites Coast Guard's policy regarding maritime disputes. It states that

> "Under no circumstances shall the statutory machinery of the Coast Guard be used for the purpose of favoring any party to a maritime or other labor controversy. However, if a situation affecting the safety of the vessel or persons on board is presented, and a complaint in writing is lodged, the matter shall be thoroughly investigated and when a violation of existing statutes or regulations is indicated appropriate action shall be taken".

84. In response to telephone calls from a person representing Keystone, a Sergeant from the Alameda Police Department visited Encinal Terminal at approximately 1233 and again at 1421 on October 25, 1984. He departed at the request of a representative

of the facility owner; the Sergeant advised him he did not observe the commission of any criminal acts under the jurisdiction of the Police Department.

85. Shoreside picketing and picket boat activities continued as the PUERTO RICAN shifted between October 28 and October 30, 1984 to Paktank, GATX, and the Richmond Longwharf.

86. There were numerous verbal threats made by the persons engaged in picketing activities. These threats were directed at the ship and its crew, and also involved a foreign vessel moored at an adjacent dock at the Encinal Terminal, which they threatened to burn at the dock. Testimony indicated that threats by pickets included the following statements:

> "We are not going to let you sail, even if we have got to put on skin diving gear and blow you out of the water."
>
> "We'll get you. If you come ashore you're dead....If you come ashore you better have a gun with you....Don't think that if you get out of here we don't have people on the East Coast."
>
> "Looks like you will be dead tomorrow....You will never work again when you get off the ship....We are going to take care of you."

87. There were also physical acts against the vessel by pickets at the Encinal Terminal in Alameda, California and at other places in the San Francisco Bay area. On October 25, 1984 two persons got off the picket boat, ran down the dock, and took one of the ship's mooring lines off the dock. On October 26, a unidentified person made an attempt to climb onto the rudder from the picket boat but was thwarted by a stream of water from one of the PUERTO RICAN's fire hoses. On October 26, a person identified as with the pickets attempted to cut a mooring line with a long knife. On October 30, a person on the picket boat threw an object at a tug which was assisting the PUERTO RICAN in docking. Because of the threatening statements and acts against the PUERTO RICAN and it's crew, security guards were hired and the ship's personnel were restricted from going ashore while the vessel was in the San Francisco Bay area.

88. One Mate testified he was afraid for his family back East. A ship's senior officer testified he felt that the threats and activities by pickets had an adverse affect on the ability of himself and the crew to carry out their duties to the best of their ability.

REASSIGNMENT OF OFFICERS

89. On October 29, 1984, Captain WODKA and 2/M EBERSOLE were issued subpoenas to testify in court on November 5, 1984 regarding the strike activity. After being relieved, they left the vessel about 2300 on October 30, 1984. Captain WODKA was relieved as Master by C/M SPILLANE. Chief Mate SPILLANE was replaced by MR. MORTON J. GELB, who reported aboard at approximately 2200. Third Mate CONSTANTINOS VAFIADES moved up to Second Mate and was replaced by Third Mate PHILIP R. LEMPRIERE, who came aboard the same time as C/M GELB.

90. A summary of the rotation of ship's officers and the time each was in his or her position just prior to the vessel departing Richmond Longwharf at 0124 on October 30, 1984 is:

POSITION	ASSIGNED TO POSITION	REPORTED TO VESSEL
Master	October 30	September 29
Chief Mate	October 30	October 30
Second Mate	October 30	October 22
Third Mate	October 6	October 6
Third Mate	October 30	October 30
Chief Engineer	October 4	October 4
First Assistant	October 4	October 4
Second Assistant	October 22	October 22
Third Assistant	October 22	October 22
Third Assistant	October 22	October 22

All of the above are 1984 dates.

The Master had been assigned to this ship previously as Permanent Chief Mate and the Chief Engineer had been assigned previously as Permanent First Assistant Engineer.

91. All Officers and crewmembers held the appropriate Merchant Mariner Licenses and Documents as required by federal regulations; the ship was manned in accordance with her Certificate of Inspection.

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FIRE AND BOAT DRILLS

92. The PUERTO RICAN's Bridge Log for October 1984 indicates that fire and boat drills were conducted on October 10 and October 19, 1984. There were not any other entries in the logbook regarding fire and boat drills. When questioned about the number of fire and boat drills conducted during October 1984, Captain WODKA testified:

> "We were in port most of that time, and I tried to hold fire and boat drills while we were at sea because of the conditions in port....just doesn't warrant for one....It was just normal that we did not hold them in port."

93. This concept was reiterated by a safety consultant for Keystone who examined the PUERTO RICAN and its safety procedures in August 1984. He testified that:

> "...you are not able to do one while you are conducting cargo operations....If I were a deck officer..., an oil spill or something that could occur as a result of my distraction, to me, would be much more important than the training I may have received from the fire drill."

94. The safety consultant also testified that the Station Bill for fire and boat drills that he saw on the PUERTO RICAN was the CG-848 series form, which was developed in the late 1940's. He was not aware of Coast Guard Navigation and Vessel Inspection Circular (NVIC) number 7-82 entitled "Sample Format of Vessel or Facility Station Bill" issued on April 13, 1982, which speaks of the deficiencies in structuring firefighting, emergency response, and abandon ship evolutions in contemporary situations along lines developed over two decades ago. However, even without being familiar with this NVIC, he had recommended to Keystone as a result of conducting firefighting drills on the PUERTO RICAN, that the ship establish its firefighting response efforts around a team concept. He felt that "....with that sort of an organization, the firefighting effort proceeded much more effectively".

95. A report to the company of the safety inspection conducted aboard the PUERTO RICAN from August 5 to 10, 1984 by this safety consultant states:

> "...while it appeared that many crewmen felt that they were sufficiently familiar with firefighting and respiratory protection that they did not feel it was necessary to attend the remaining training sessions. We found this attitude to be somewhat distressing, particularly when this espoused familiarity was not evident during the subsequent drills....there does appear to be a need to guard against complacency."

96. It was normal procedure on the PUERTO RICAN to dismiss the members of the Steward Department after they mustered for the fire and boat drills; they usually did not participate in the instructional training, which was sometimes held after the drills.

97. The Federal Regulations applicable to fire and boat drills on tank vessels, 46 CFR 35.10-5, state:

> a. Paragraph (d): "It shall be the duty of the master...to conduct a fire and boat drill at least once in every week...."
>
> b. Subparagraph (e)(5): "In port, every lifeboat shall be swung out, if practicable, and the unobstructed lifeboats shall be lowered to the water and the crew exercised in the use of oars and other means of propulsion if provided for the lifeboat ... The Master shall be responsible that each lifeboat is lowered to the water at least once in each 3 months."
>
> c. Paragraph (f): ".... If in any week the required fire and boat drills are not held or only partial drills are held, an entry shall be made stating the circumstances and extent of the drills held."

THE CASUALTY, OCTOBER 31, 1984

98. The weather at the time of the casualty was mild: temperature was approximately 55°F, the wind was North-Northwesterly at 5 to 15 knots, and the visibility was 8 to 10 miles. The sea was calm, with a 1 to 2 foot chop and a low swell of 2 to 3 feet from the West.

99. The Pilot, Captain JAMES S. NOLAN, boarded the vessel at approximately 0100 on 31 October 1985 when it was moored at the Richmond Longwharf. The vessel sailed at 0124 with drafts of 22' 6" forward, 28' 10" aft, mean draft 25' 8". On its transit from the Longwharf to the Golden Gate Bridge, it was followed by the picket boat; however, the picket boat did not come close aboard.

100. On the bridge during the outboard passage through the Bay were Captain JAMES C. SPILLANE, the Master, Captain JAMES S. NOLAN, the Pilot, Third Mate PHILIP R. LEMPRIERE and Able Seaman CHARLES R. PALMER, the Helmsman. The lookout, stationed forward on the main deck, was Able Seaman JOHN PENG.

101. The PUERTO RICAN passed underneath the Golden Gate Bridge at approximately 0300 and proceeded out the main channel toward the San Francisco Approach Lighted Horn buoy, also known as the Large

Navigational Bouy (LNB). The vessel proceeded out the San Francisco Main Ship Channel on a heading of 270°T. As it cleared buoys 1 and 2 and approached the LNB just prior to 0320, speed was reduced to approximately five knots and the heading changed to 180°T to head the vessel toward her next course and make a lee for disembarking the pilot to the pilot boat SAN FRANCISCO. The engine order telegraph was put on "Dead Slow" at 0323.

102. After passing traditional seakeeping information and amenities, Captain NOLAN took his leave of Captain SPILLANE and, escorted by 3/M LEMPRIERE, departed the bridge for the pilot disembarking station on the port side of the main deck over 4PF tank. They used the deckhouse interior stairways to proceed to the main deck level. During their walk up the deck to the disembarkation ladder, neither Captain NOLAN nor 3/M LEMPRIERE smelled, felt, nor heard anything unusual.

103. The port pilot ladder was located in way of the kingpost 120 feet forward of the deck house. When not in use, it was suspended from the kingpost by a line reeved through a block and tackle. The ladder was lowered by manually slacking the line. This lowered the ladder over the vessel's side at a spot where the siderail consisted of three courses of removable chain, each approximately three feet long. The pilot disembarkation area was illuminated by two explosion-proof rated floodlights. One was on the port wing of the bridge and was located 120 feet aft and 40 feet above the location of the pilot ladder. The other was located on the forward side of the kingpost approximately twenty feet above the deck and 12 feet inboard of the ship's rail. There was no other main deck illumination on at the time. The electrical power was energized to various pieces of deck equipment and machinery, but none of this equipment or machinery was in operation.

104. Able Seaman PENG was standing near the pilot ladder, which he had made ready for use except for detaching the top course of chainrail. Captain NOLAN and 3/M LEMPRIERE joined AB PENG at the disembarkation station and waited for one or two minutes while the pilot boat made its approach. The three men were standing somewhat in a semicircle by the ladder. Third Mate LEMPRIERE was after-most facing forward; AB PENG was in the center and facing outboard; and Captain NOLAN was forward-most facing aft. There were no other persons on deck. None of the three men were smoking. None of them dropped anything on deck. Captain NOLAN did not make nor receive any communications on his portable radio. The switch on Captain NOLAN'S radio was in the "Off" position. None of the three men were using flashlights.

105. Captain NOLAN was wearing his normal work clothes which included a nylon floatcoat that covered the full length of his arms and extended to just below his buttocks. Third Mate LEMPRIERE was wearing work shoes, jean-type pants, a wool "CPO shirt" with the sleeves rolled up, and a lined polyester wind breaker. It is not known what AB PENG was wearing.

106. Shortly after Captain NOLAN and 3/M LEMPRIERE left the bridge, Captain SPILLANE directed the Helmsman, AB PALMER, to deliver a manila envelope to Captain NOLAN which contained reports to be mailed to the company office. This package was not delivered. Captain SPILLANE had just stepped through the port doorway and was about a foot outside the pilot house on the port wing of the bridge when the explosion occurred at approximately 0324.

107. At the time of the explosion, sixteen of the twenty-nine persons aboard were in their rooms. Most of them were asleep. The other thirteen people on board were located in six areas. Pilot NOLAN, 3/M LEMPRIERE, and AB PENG were at the pilot disembarkation station. This can be identified in photograph 2, which shows the pilot ladder still attached. Captain SPILLANE was on the port bridge wing. Able Seaman PALMER was in the house interior stairway leading from the bridge. Chief Engineer CHARLES R. KALMBACH, First Assistant Engineer DAVID A. CHISHOLM, Third Assistant Engineer HARRIS ALLEYENE, Engineman MARION P. HOUSTON, and Engineman R. E. BROUILLETTE III were in the engine room. Boatswain DUDLEY SMITH, Able Seamen DAVID ROMAN, MARK M. BRAUDIS, STAVROS MANOUSARITIS, and GVA/DK MARCEL GOULET were stowing lines on the fantail and in the after lazarette. Able Seaman CLORD FUERTADO was just stepping out onto the fantail from the after door of the deckhouse.

108. The approximate position of the PUERTO RICAN at the time of the explosion was Latitude 37-45.8N, Longitude 122-38.6W. It was just seaward of San Francisco Main Ship Channel buoys numbers 1 and 2.

109. Just prior to the explosion, 3/M LEMPRIERE heard a hissing sound originating behind him. The explosion occurred approximately two seconds after the hissing sound started and before 3/M LEMPRIERE had time to turn around to identify where it was coming from. Captain NOLAN heard a click, like the sound of the plunger on a Boatswain's clip striking home, followed by a "woosh" and an explosion. While hearing the "woosh", he saw a bead of light go diagonally across the deck from the vicinity where AB PENG was standing toward the center of the deckhouse. While hearing the "wooshing" sound, he also smelled an odor that was so acrid he felt it burn his nostrils. He also felt the sensation of having the air pulled out of him.

110. The explosion separated the main deck plating from gunwale to gunwale just forward of the bulkhead at frame 54 to the bulkhead at frame 64. The bulkhead at frame 54 is the aftermost boundary of 4PA wing tank, 6CV and 4SA wing tank. The bulkhead at frame 64 is at the forward end of 4PF wing tank, 6CV and 4SF wing tank. This 112-foot long by 90-foot wide section of the main deck with its associated piping and equipment, the total weight of which is estimated at 300 short tons, was thrown forward, coming to rest in an inverted position nearly in a plumb line over

numbers 4 and 5 center tanks and the adjacent wing tanks. This condition is shown in photographs 3, 4, and 5.

111. Captain NOLAN testified there were two distinct explosions: the second one was in the vicinity of the kingpost and was greater than the first one forward of the deck house. The force of the first explosion threw the three men standing on deck over the port side. Captain NOLAN saw AB PENG between himself and 3/M LEMPRIERE when the three men were in the air. Neither Captain NOLAN nor 3/M LEMPRIERE saw nor heard AB PENG again. Captain NOLAN landed in the water approximately 50 to 100 feet from the side of the PUERTO RICAN; 3/M LEMPRIERE was in the same area 30 to 50 yards forward of him relative to the ship's heading. By 0345, Captain NOLAN and 3/M LEMPRIERE had been picked up in the emergency man-overboard retrieval net of the pilot boat. Captain NOLAN and 3/M LEMPRIERE were then hoisted from the pilot boat to a Coast Guard helicopter. This transfer began at approximately 0358 and was concluded at approximately 0420. They were flown to the helicopter landing pad at the U.S. Army Presidio, San Francisco, arriving at approximately 0434. The two men were immediately transferred to Letterman Army Hospital, San Francisco. Both were burned extensively. Captain NOLAN's burns were more serious on the right side of his body and 3/M LEMPRIERE's burns were more serious on the left side of his body. Captain NOLAN also received extensive bone damage to his right heel, leg, and hip. Both men were extensively covered with a melted, waxlike substance.

112. At the time of the initial explosion, Captain SPILLANE was facing outboard. He was knocked off balance but not down. When he looked forward, he first saw a yellowish light and then flames ranging from one side of the vessel to the other in the area of 6C tank and adjacent wing tanks. It appeared to him as though the entire area of these tanks was in flames. The color of the flame was bright orange; the smoke was black. The fire did not exhibit any other distinctive colors. The flames appeared to cover the entire cargo area uncovered by the removal of the deck. The 6C independent tank was not observed at this time.

113. A Coast Guard C-130 aircraft was approximately 15 miles from the PUERTO RICAN when the explosion occurred. The pilot of the aircraft stated he observed an initial fireball that was approximately four or five hundred feet high and a secondary explosion several seconds later sending a fireball as high as 1,000 to 1,200 feet. Though there were chronic flareups, he noted that thereafter the flames were generally about 40 to 50 feet high, about level with the top of the deckhouse.

114. Almost immediately after the explosion, Captain SPILLANE re-entered the pilothouse. There were eleven windows across the front of the bridge area. Four of the five center windows were blown out. This is shown in photograph 6. He sounded the general alarm and rang for water on the firemain and the foam systems. The emergency generator had come on-line almost immediately following the explosion. Though the engine order telegraph on the

bridge was never changed from the "Dead Slow" position, C/E KALMBACH put the throttle in the "Stop" position almost immediately after the explosion.

115. A person on the pilot boat SAN FRANCISCO reported the explosion aboard the PUERTO RICAN to the Coast Guard Vessel Traffic Service on VHF Channel 13 at 0324:57.

116. Within minutes of the explosion, several people reported to the bridge. Able Seaman PALMER, who had been in the interior stairway, returned to the pilothouse to put on his lifejacket. He then went to the stern. Second Mate VAFIADES, who had been in his room dressing to come on watch, arrived on the bridge almost immediately. Captain SPILLANE ordered him to take charge of the deck, and he left to look after the preparation of the lifeboats and the firefighting equipment. He did not take a portable radio with him. Third Mate DEBORAH COBB, who had been asleep in her stateroom two decks below, reported immediately to the bridge. During drills she had reported to fire station number 20, located on the stern. Captain SPILLANE told her to return to her room to finish dressing.

117. Captain SPILLANE's first radio transmission was at 0331:50. At that time he exchanged the following on VHF Channel 16 with the radio operator at Coast Guard Group San Francisco, California:

0331:58	PUERTO RICAN	This is the tanker PUERTO RICAN, tanker PUERTO RICAN. We are off the sea buoy, the San Francisco Bar Sea Buoy. We are on fire and we are fighting the fire. This is a distress call. This is a distress call.
0332:21	GRU SFRAN	Tanker PUERTO RICAN, Coast Guard Group San Francisco. Roger, Sir. We got a report that you had an explosion. We have a boat underway at this time. It should be underway within a few minutes. Can you tell me, Sir, do you have any people in the water? Over.
0332:33	PUERTO RICAN	I do not know yet. I'm on the bridge right now and I do not believe anyone is in the water. But it is possible. There was a man standing by at the pilot ladder.

Captain SPILLANE then briefly reported the extent of the damage to the PUERTO RICAN. One second after he completed this transmission, a person from the pilot boat came on Channel 16 to report there were people in the water, they had already picked up one, and were circling looking for others.

restored. Able Seaman ROMAN estimated 10-15 minutes. Mr. DAY estimated this time to be 10 minutes. At 0407:59 3/M COBB made the following radio transmission: "...we don't have any water to fight the fire...". At 0409:05, 2/M VAFIADES made a similar radio transmission. He testified they actually had firefighting water at the time of his transmission and his statement was an exaggeration to stress their need for assistance.

121. Because of the break in the forward firemain, hoses had to be rigged from the deckhouse and led forward to fight the fire. Captain SPILLANE went to the fantail and told crewmembers gathered there to rig these hoses. He told the men there were spare 2-1/2-inch hoses in the emergency gear locker on the Boat Deck. Pumpman DAY and AB ROMAN went there but could not find them. They returned to the fantail, got a flashlight, went back to the gear locker, and found two 75-foot sections of 2-1/2-inch hose. Then, joined by Boatswain SMITH and an unidentified Seaman, they ran these hoses up the starboard side from fire station number 20, located on the main deck at the after bulkhead of the house. Ultimately, two hose lines were run up the starboard side of the main deck: the 2-1/2-inch line from fire station number 20 and one 1-1/2-inch line from an inside station. A third line, a 1-1/2-inch hose from an inside station, was led out the port door of the deckhouse and led forward up the port side of the main deck. The 2-1/2-inch hose was ready within 15 to 20 minutes after the men started. Boatswain SMITH opened the fire station valve and got approximately 100 pounds pressure. He testified this was approximately twenty minutes after the explosion. The laying out of the second two hoses was delayed by Boatswain SMITH having to direct his attention to the lowering of the lifeboats. When those lines were ready, he also opened the valves and got water pressure.

122. Soon after returning to her room following the explosion, 3/M COBB returned again to the bridge. No one was there. She looked over the wing of the bridge and noticed AB ROMAN was attempting unsuccessfully to get foam monitor stations numbers 5 and 6 on the line. She went down to the main deck to help him, but could not get the monitors to operate either. She told AB ROMAN she would find the Captain and ask him what to do about this. She went to the bridge and informed the Captain of the foam problem when he arrived shortly thereafter. The initial problem was due to the broken firemain on deck. Captain SPILLANE had earlier closed the block valve in the water/foam line just forward of the outboard corner of the cargo control room to stop water running on deck from the broken foam lines forward of stations 5 and 6. Chief Engineer KALMBACH realigned valves to isolate and cut off water to the 8-inch firemain; he then saw water but no foam coming from foam monitor stations 5 and 6. On one of his earlier trips past the foam room, he saw Boatswain SMITH and at least one other person attempting to

line up the foam system and get it operating. This was Boatswain SMITH's normally assigned duty for a cargo fire on deck.

123. Chief Engineer KALMBACH went into the foam room, which was now filled with smoke. He found the proportioning pumps working but the suction valves to the foam tanks closed . While attempting to correct this situation, he was forced to leave the room several times because of the smoke. However, he finally succeeded in properly aligning the system. He then checked foam monitor stations 5 and 6 and saw foam coming out, but estimated the water pressure was only about 40 to 50 pounds. This pressure was sufficient for the water/foam mixture to reach the fire, although the system normally operated at approximately 175 pounds pressure. The first transmission reporting any success in getting the foam system on-line was at 0433:33 when 3/M COBB stated, "We got some foam monitors working now". Third Mate COBB testified that this information was actually transmitted 20 to 30 minutes after the foam monitors began working. Chief Engineer KALMBACH testified the foam system was on-line approximately 45 minutes after the explosion. Once the monitor started putting out foam, the foam mixed with the water already flowing down the port side of the vessel, making that part of the deck increasingly slippery.

124. The total firefighting response equipment consisted of the three hose lines and of the foam monitors at stations 5 and 6. There were breakwater shields on the main deck approximately 25 feet forward of the corner of the deckhouse which provided some protection from the fire, so the hose nozzlemen positioned themselves there. This placed the nozzlemen over the number 5P and number 5S wing tanks. Able Seaman ROMAN testified that when he and C/M GELB, who had donned an aluminum colored firefighting suit, initially opened the hose nozzles on the starboard side there was only a little water pressure. There was a similar lack of pressure when 2/M VAFIADES and GVA/DK GOULET opened the hose nozzle on the port fire hose. Second Mate VAFIADES went to the bridge and telephoned the engineroom to request more water pressure. By the time he returned to the port hose location, there was adequate water pressure. While he was involved in firefighting efforts on the port side, 2/M VAFIADES did not suffer any caustic soda irritation to his skin. While he and the other men were manning the hoses, they used both the "Stream" and the "Fog" settings on the nozzles.

125. On the starboard side of the vessel, C/M GELB, Boatswain SMITH, Pumpman DAY, Engineman HOUSTON, and AB ROMAN were applying hose streams of water onto the fire. Able Seaman ROMAN noticed that the foam monitors, which had been discharging only water, were beginning to discharge foam. When the foam came on line, it came at high enough pressure

to reach the fire. Able Seaman ROMAN went up to the two foam stations by himself and began directing foam into the fire. He would direct one monitor high and one low and then alternate their positioning. The other men continued to put water on the fire with both "Fog" and "Stream" settings from the fire hoses while AB ROMAN applied the foam solution. Able Seaman ROMAN testified that the foam appeared to have a greater effect in decreasing the flames on the port side than on the starboard side. Able Seaman ROMAN continued to operate the foam monitors for approximately twenty-five minutes. Pumpman DAY was with him for about fifteen minutes. During the time these men were at the foam monitors, they could feel the effects of a substance in the air burning their eyes and faces. Something was also making the decks very slippery While on the monitors, AB ROMAN noticed a solid object rising up in the center of the flames. Ultimately, and to his surprise, after approximately twenty-five minutes on the foam monitors AB ROMAN found himself to be the only person still fighting the fire. Second Mate VAFIADES had earlier told everyone fighting the fire to leave and to board the boats waiting at the stern, as he felt further firefighting efforts were useless. Able Seaman ROMAN was directed by a person using a loudhailer on a Coast Guard boat to leave the vessel. He went to his room to get some valuables and then to the stern. When he arrived at the stern, there were no other people there. He boarded the towing vessel HARRY M at approximately 0459.

126. Preparations to abandon ship were initiated almost simultaneously with firefighting efforts. While Boatswain SMITH was on the stern just after the explosion, 2/M VAFIADES arrived and told him to get the lifeboats over the side. Boatswain SMITH took Pumpman DAY, AB PALMER, and an unidentified person from the Engine Department and began preparing the starboard boat. Boatswain SMITH was not aware of an order to lower the boat being given by anyone, but Pumpman DAY lowered the starboard lifeboat directly to the water. Able Seaman PALMER was in the boat and pulled the releasing gear lever when the boat reached the water. Since a sea painter had not been rigged to the ship, AB PALMER and the lifeboat began drifting away toward the stern of the PUERTO RICAN. The lifeboat had drifted approximately 300 feet astern of the PUERTO RICAN when Able Seaman PALMER was taken aboard the HARRY M at approximately 0416.

127. The port lifeboat was readied and lowered by a Third Assistant Engineer and other unidentified persons at about the same time as the starboard lifeboat was being readied and lowered. It was released into the water after the starboard boat, but its sea painter had been rigged to keep it attached to the PUERTO RICAN. Two or three people were in the port lifeboat when it was lowered to the water and released. They were later taken aboard the towing vessel HARRY M.

128. Second Mate VAFIADES testified that he interpreted the order received on the bridge from Captain SPILLANE to "Take charge of the deck" to include preparing and launching the liferafts and lifeboats. With Boatswain SMITH and Pumpman DAY, 2/M VAFIADES went to the inflatable, 20-person liferaft on the starboard Boat Deck. The men easily freed it of its lashings and, with great effort, manhandled it over the 42-inch high rail. It inflated properly and was led by its sea painter to the stern where it was tied-off. Four men, including the Chief Steward, boarded the raft at the order of 2/M VAFIADES. They were later taken aboard Coast Guard boat number 30606 sometime prior to 0452.

129. Second Mate VAFIADES testified that he gave the order to lower both lifeboats to the embarkation deck and then to the waterline because he was concerned that the port list of the PUERTO RICAN would interfere with lowering and releasing the boats later.

130. All davits and releasing gear worked properly during the lowering and launching of both lifeboats. Deck lighting at the lifeboat stations operated properly.

131. The vast majority of persons not already identified as taking part in emergency response activities stood-by on the fantail. This included most if not all members of the Steward's Department and some people who could not muster at their assigned emergency stations, because their stations were foreward of the explosion area and were inaccessable. Almost everyone initially put on lifejackets and several put on exposure suits. Some persons had initially put on exposure suits and then removed them because it was difficult getting around in them during emergency response activities.

132. The crew that had gathered on the stern of the PUERTO RICAN boarded the towing vessel HARRY M between 0438:43and 0443:40. Around that time, 2/M VAFIADES ordered the men manning the hoses and the foam monitors to leave the ship. Boatswain SMITH heard the abandon ship order from 2/M VAFIADES. Second Mate VAFIADES also took GVA/DK GOULET, who had been with him on the port firehose, to the stern and saw that he got off onto the HARRY M. He then went forward because he knew one person had stayed on the monitor. He could not find him there, so he searched the house passageways on the main deck, which were now filled with smoke. He still could not find him, so he went to the stern and got off on the HARRY M. There were no other people on the stern when he boarded the tug at approximately 0445. His last direct verbal communication with Captain SPILLANE had been on the bridge when he was told by the Captain to take charge of the deck.

133. At approximately 0445, Chief Engineer KALMBACH was on deck. Someone shouted from the HARRY M, "Come on, Chief, get

on board. She is going to sink." or something to that effect. He was also told that Captain SPILLANE had left the PUERTO RICAN. He went back through the house passageways on two decks hollering for the Captain but got no answer. He then went to the engineroom. He had earlier noticed that the paint near the top of the engineroom forward bulkhead, in the area where the eductor room was located, was beginning to bubble. He had to immediately remove his hand when he touched the bulkhead because it was so hot. When he went back to the engineroom, he checked all the spaces and told the two persons still there, 3A/E ALLEYNE and Engineman BROUILLETTE, to leave the ship. They secured the boiler fires, the fuel oil pumps, and the fans. They took several logs and records, turned the lights off, left the firemain pumps operating, went to the stern and boarded the HARRY M at approximately 0445. At the time they left the engineroom, the bilges had no more than the normal accumulation of water.

134. After he was on the HARRY M for about three minutes, C/E KALMBACH saw 1A/E CHISHOLM, 3/M COBB, and Captain SPILLANE come to the fantail. As the HARRY M made another approach to the fantail, he asked the Captain if he should get back on the PUERTO RICAN; Captain SPILLANE told him he should not. Captain SPILLANE assisted the other three people in boarding the HARRY M and then he went forward toward the deckhouse.

135. Between 0352 and 0440, 3/M COBB made 35 transmissions on VHF Channel 16 with various Coast Guard and civilian assisting units. Her's were the first radio transmissions from the PUERTO RICAN after Captain SPILLANE's distress call between 0331:58-0333:15. There were several radio transmissions which gave an indication of times that various events were taking place. The following transmissions were made by 3/M COBB:

> 0352:40: "This is the PUERTO RICAN, the Mate on the bridge. If anybody can tell me anything about where to tell these people to go, just go ahead. I'm standing-by".
>
> 0400:00: "Well, some of our guys are standing by in both the lifeboats and they just put one of the rafts over and there is about eight of them. I can't see anybody. Nobody is badly hurt."
>
> 0400:30: "This is the PUERTO RICAN. Anybody. We got two boats in the water. They are staying by the vessel as best they can".
>
> 0407:59: "Right. Also, we don't have any water to fight the fire so it's ... there's a chance they are going to explode again. So we need to get everybody off as soon as we can".

Ø411:56: "This is the PUERTO RICAN to the Coast Guard. Okay. We are leaving the bridge. The fire is too close and we are going to gather on the stern. We have two boats in the water. Over".

Ø421:Ø5: "Somebody already launched two life boats. Most of the people are on deck. So ....."

Ø423:28: "Roger. We've got a pretty bad port list".

Ø433:33: "This is the tanker PUERTO RICAN. We got some foam monitors working now ...."

Her last radio transmission was at Ø44Ø:55. At that time, in reply to a question as to whether or not the ship had dropped anchor, she replied "Negative". She testified that twice during her time on the bridge she left the pilothouse and went behind the bridge structure because flareups in the fire gave her concern for further explosions. She received caustic soda burns from touching parts of the ship while moving about on deck and from caustic soda "rain" while she was on open parts of the bridge deck.

136. Third Mate COBB was the only person continuously on the bridge from approximately Ø335 to approximately Ø445. Captain SPILLANE was on the bridge with her during her Ø433:33 radio transmission. The two of them left the bridge shortly thereafter to check the ship for any persons still aboard. The only person they saw on board the vessel was C/M GELB. He left the vessel right after they saw him. Third Mate COBB boarded the towing vessel HARRY M from the stern of the PUERTO RICAN at approximately Ø5ØØ; then only Captain SPILLANE remained on the ship

137. Captain SPILLANE had been constantly moving about the ship from the time he left the bridge after his Ø331:58 radio transmission. One of the first things he did was go to the fantail and get volunteers to rig hoses from the deckhouse. He had been on the deck forward of the house several times checking on the operation of the foam monitors and fire hoses. He had been on the port side to close the block valve on the water/foam line. He returned to the bridge several times and on three occasions between Ø423 and Ø426 was overheard asking 3/M COBB if the Pilot had gotten off the PUERTO RICAN. He testified that he wanted the lifeboats ready for use but never gave the order to abandon ship. He did, however, hear what he considered to be an order to abandon ship broadcast by a loudhailer from a Coast Guard helicopter. Also, he never had a muster taken nor was he able to maintain communications with key persons on the PUERTO RICAN because neither he nor anyone else was carrying a portable radio. He slipped and fell several times because the deck was slippery with a

mixture of water from the broken firemain lines, foam and what he identified as caustic soda. He estimated the depth of the caustic flowing down the portside to be from an inch to a feather's edge. In fact, there "... seemed to be caustic all over the ship..." to such an extent that it was categorized as a "caustic rain".

138. Shortly after 0500, as Captain SPILLANE was preparing to leave the PUERTO RICAN, he made and received the following transmissions:

"0506:44	PUERTO RICAN	This is the Captain of the PUERTO RICAN. I went through every room and as far as I know, I am the only one aboard right now.
	CG 1451	Roger. 1451 copy. The Captain is the only one aboard right now?
0506:58	PUERTO RICAN	Roger. This is the Captain. My cargo is lube oil, caustic sodas, and fuel oil additives, oloas, and polybutene. That's my cargo.
	CG 1451	Thank you, Skipper. Can you repeat one more time? We'll get a copy.
0507:xx	PUERTO RICAN	Mostly lube oils on board with caustic sodas. A lot of caustic soda. And also some fuel oil additives, oloas, and polybutane.
	CG 1451	Roger. Copy that."

He then went to the fantail where he boarded the HARRY M. He was reported aboard the HARRY M at 0526. The twenty-six persons remaining on the vessel after the explosion were evacuated from the PUERTO RICAN on the following vessels: 21 aboard the HARRY M, 4 on Coast Guard UTB number 30606, and 1 on the towing vessel SANDY.

ASSISTING RESOURCES

PILOT BOAT SAN FRANCISCO.

139. The pilot boat SAN FRANCISCO is owned by the San Francisco Bar Pilot Benevolent and Protective Association.

The vessel has a length of 85 feet and a beam of 22 feet; it is 135 gross tons, single screw, single rudder, and diesel propelled. Approximately three months prior to the explosion of the PUERTO RICAN, the SAN FRANCISCO was equipped with special lifesaving apparatus on the port and starboard sides designed to retrieve persons from the water. Each apparatus consists of an 8-foot long, 14-foot wide nylon net, similar in construction and line spacing to a traditional cargo net, which is attached to the vessel's 42-inch high rail. In the stowed position, it is rolled up and lashed to the rail with a small line using quick-release knots. Six-foot long booms made of steel pipe are mounted atop the deckhouse on each side. These can be raised, a block and tackle attached to the outboard end, and rigged pointing outboard. The net is attached to the bitter end of the line reeved through the block. The outboard end of the net has a spreader bar made of 2-inch diameter steel pipe covered with PVC; a similar pipe runs fore and aft across the middle of the net. The pipe in the middle acts as a spreader and as a weight to keep the net in the water.

140. The Operator of the pilot boat at 0325 on October 31, 1985 was MR. FRITZ MENDER. MR. ROY BRADSHAW was in the pilothouse preparing to relieve him. Four other crew members and one Pilot were also aboard. The SAN FRANCISCO was approximately one-hundred yards off the port quarter of the PUERTO RICAN at the time of the casualty. At 0324:57, a person on the SAN FRANCISCO broadcast a Mayday to Coast Guard Vessel Traffic Service (VTS), San Francisco on Channel 13. The SAN FRANCISCO was approaching the PUERTO RICAN when the explosion occurred. Captain NOLAN and 3/M LEMPRIERE landed in the water close to it. Captain NOLAN was off the port side and 3/M LEMPRIERE was off the starboard side. Everyone on the SAN FRANCISCO except the Operator began deploying both retrieval nets. MR. BRADSHAW heard the first cry for help from 3/M LEMPRIERE and located him with a spotlight. The Operator maneuvered the boat toward him. Someone on the deck threw 3/M LEMPRIERE a line and he pulled himself closer to the vessel. The net was at the water's edge but the boom was not yet fully deployed. Third Mate LEMPRIERE pulled himself part way up the net and MR. BRADSHAW reached down and pulled him the rest of the way on board. MR. JAMES BOULIET, the cook, brought 3/M LEMPRIERE to the mess room of the SAN FRANCISCO and covered him with blankets.

141. Mr. Peter CROWELL, a Pilot aboard the SAN FRANCISCO, made and received the following transmissions on Channel 16:

0333:22	PILOT BOAT	There are survivors in the water. We've picked up one. We are circling for additional survivors at this time.

0333:28	CG GROUP	Pilot Boat. San Fran. Can you give me an idea of how many people you might have in the water. Over.
0333:32	PILOT BOAT	I can't say, can't say. There are more. I hear their voices.

142. Mr. MENDER maneuvered the SAN FRANCISCO toward Captain NOLAN. By now the net and boom assembly on the port side was fully rigged. However, because of his physical injuries and the fact that he was beginning to suffer from hypothermia, Captain NOLAN was not able to roll himself into the net. He wrapped his arms through the openings and draped the upper half of his body into the netting. The men on the deck hauled on the line and raised him to a point where they could grab him by his clothing and pull him on board. He was moved to the mess deck, his float coat removed, and he was covered with blankets.

143. By 0345:28, twenty minutes and thiry-one seconds after first reporting the explosion, the pilot boat Operator advised VTS on Channel 13 he had retrieved two people. He also advised the Coast Guard that the men were badly burned and injured and needed immediate medical attention.

144. The SAN FRANCISCO continued to search for survivors in the water. Someone from the boat fired at least two flares to illuminate the surface of the water. The Operator kept his vessel in the area and he continued his search while waiting to evacuate the two injured people to a Coast Guard helicopter which was enroute. The hoist to the helicopter began at approximately 0358 and concluded at approximately 0425. The injured were taken to Lettermen Army Hospital, San Francisco, California.

145. The SAN FRANCISCO continued to be used as a search platform until it left the scene at 0451 to take a Pilot off an outbound vessel. No other persons were found in the water by people on the SAN FRANCISCO or by other rescue craft on-scene.

COAST GUARD C-130 AIRCRAFT, NUMBER 1451.

146. Aircraft number 1451 is a standard configured Model C-130H aircraft manufactured by Lockeed-Georgia Corporation and equipped for Coast Guard missions. It was flying at an altitude of between 500 to 1,000 feet engaged in assisting an overdue fishing boat approximately fifteen miles northwest of the PUERTO RICAN's location. The aircraft, under the command

of Lieutenant JAMES A. FAVERO with seven other Coast Guard aircrew aboard, was on a heading which gave the three persons in the cockpit a direct line-of-sight to the PUERTO RICAN at the time of the casualty. All three saw the fireball from first explosion almost simultaneously. The initial fireball was approximately 400 to 500 feet-high. Several seconds later the fireball grew to approximately 1,000 to 1,200 feet from an apparent subsequent explosion. LT FAVERO ordered the current case aborted at approximately 0325 and directed his aircraft toward the site of the fireball, arriving approximately seven minutes later. At this time the PUERTO RICAN was on a north-northeast heading.

147. He established communications with personnel at Coast Guard Group San Francisco on Channel 16 at 0334:13, and assumed the role of On Scene Commander. He subsequently had direct communications with the Operator of the pilot boat, the Aircraft Commander on Coast Guard helicopter number 1395, 3/M COBB and Captain SPILLANE aboard the PUERTO RICAN, and personnel aboard Coast Guard motor utility boats numbers 30606, 41403, 41404, 44347, the Operators of the towing vessels HARRY M and the SANDY, and the Commanding Officers of the USCGC POINT HEYER (WPB 82369) and the USCGC CAPE CROSS (WPB 95321).

148. Initially, LT FAVERO directed his aircraft into several counterclockwise orbits at altitudes between 500 and 1,000 feet with a half to three-quarter mile radius from the PUERTO RICAN; airspeed was 180 to 200 knots. Realizing from radio transmissions that there were persons in the water, he directed his aircraft into a right-turn, race course pattern and dropped two liferafts within 500 yards of the PUERTO RICAN. He then returned to the counterclockwise orbit around the vessel and remained on-station until he transferred the On Scene Commander responsibilities to the Commanding Officer of the USCGC POINT HEYER.

149. Because of his location, LT FAVERO was afforded some graphic views of the fire aboard the PUERTO RICAN. The flames filled the area opened by the inversion of the deck. At times the flames appeared more yellow than orange in color and at times the intensity of the flames was concentrated on the starboard side. The fire was more intense during the first hour but it continued to have sporadic flare-ups. At 0345:54 he reported a secondary explosion, with flames rising about 100 feet in the air. The flames built up like a pyramid, emitting a column of thick black smoke. At 0458:57, he received the following radio transmission from the Coxswain of CG-44347:

> "....It looks like they have a big fire fighting foam nozzle right forward of the bridge here. I can't tell if it is being manned. It is moving up and down though. Over."

When two boats arrived and put their firefighting capabilities into the action between 0500 to 0600, LT FAVERO said he saw a noticeable effect in decreasing the size of the flames. LT FAVERO never noticed the 6C tank in the flames.

150. LT FAVERO also coordinated the evacuation of the PUERTO RICAN. His first indication of this need came just after 0400 when he and 3/M COBB had been discussing that lights off the stern may indicate the presence of survivors:

0407:27	1451	Roger PUERTO RICAN. This is Coast Guard aircraft. Just advising vessels coming to your assistance to look for survivors. It looks like you have some lights in the water off your stern. It looks like survivors in that area.
0407:43	PUERTO RICAN	Okay Yeah. You're right.
0407:54	1451	(stepped on) survivors in the water off your stern and the sides as well.
0407:59	PUERTO RICAN	Right. Also, we don't have any water to fight the fire so it's... there's a chance they are going to explode again. So we need to get everybody off as soon as we can.
0408:10	1451	Roger that. We'll coordinate as many boats as we can off the stern. It looks like the safest place right now.

As a follow-up to 2/M VAFIADES' transmission at 0409:05 that they were leaving the bridge because they feared another explosion, LT FAVERO radioed him to:

0410:11	1451	(stepped on) take your survivors to the stern of your boat. We are directing vessels to the stern of your vessel. Over.

He then advised the Operator of Coast Guard boat number 30606:

0410:27	1451	Break, Break. 30606. 1451. Look for survivors off the stern of the tanker. Over.

0410:32	30606	1451. 30606. Roger on that. You say you are directing survivors to the stern of the vessel? Over.
0410:40	1451	That is affirmative. They have two lifeboats in the water at this time off the stern. There is also another vessel off the stern. I can't make out what it is; he is not responding. There is another vessel to the northwest with a helicopter overhead doing a hoist for survivors. Direct rescue boats to the stern of the tanker. Stay away from the sides. They fear another explosion. Over.

Several minutes later, in directing the Operator of the HARRY M, he said:

0415:11	1451	Roger, HARRY M. 1451. The crew reported they were abandoning the bridge and heading toward the stern of the vessel and looking for the lifeboats. So look for anyone in the water; also people in lifeboats. Over.

There were a number of rapid conversations among LT FAVERO, the Coxswains of the Coast Guard boats, the Operator of the HARRY M , and 3/M COBB regarding evacuating people. At 0430:18, in emphasizing the situation to the Coxswain of CG-41403, LT FAVERO said, "The name of the game tonight is just get them off." Less than a minute later in reporting the situation to Coast Guard Group San Francisco, LT FAVERO stated:

> "...Everybody is standing at the railing and looking for a way to get over the side. We're trying to encourage ropes or jump or something. But the boats are having a hard time getting the people off the stern of the boat."

About five minutes later, at 0435:30, in talking to the Coxswain of CG-41403, he said:

"...I need to have someone down there directing traffic. I can't do it all from up here. I'd like you to assist me in that way; direct the traffic as best you can to expedite the survivors off the stern of the vessel. How that? Over."

The Coxswain of CG 41403 acknowledged the transmission and advised LT FAVERO that the four persons aboard the liferaft were boarding the HARRY M and that he was going to the south side of the PUERTO RICAN to illuminate the liferaft with his boat's spotlight.

151. There were several passes by the boats, particularly the HARRY M, to maneuver to the stern to remove people. Just after 0509, LT FAVERO broadcast:

"...It looks like the only person aboard the vessel at this time is the Captain. Keep an eye out in case he does show up at one of the railings for evacuation."

The Operator of the HARRY M advised LT FAVERO at 0521:27 that he saw the Captain on the stern. LT FAVERO told him to "Go ahead and get him if you can." At 0526:39, the Operator informed him that "We have the Captain aboard.... He advises us there are no other personnel aboard. Over."

152. Simultaneously, LT FAVERO was also involved in the search for persons in the water. He became aware that people may be in the water while he was flying to the scene and he heard conversations between times 0332:21 and 0333:39 involving Captain SPILLANE, the person on the radio at Coast Guard Group San Francisco, and the Operator of the pilot boat. At 0350:55 and 0351:49, he asked the Operator of the pilot boat to continue searching, as the SAN FRANCISCO was the best available platform until other resources arrived. At 0417:59 he instructed the Coxswain of CG-41403 to look for persons in the water off the stern. At 0419:25 he received a transmission from the Operator of the HARRY M that a survivor he had taken aboard said that there were no persons in the water but that they were all on the stern of the PUERTO RICAN. At 0424:45, the radio operator at Coast Guard Group San Francisco made an Urgent Marine Information Broadcast advising all persons in the area to be aware that, among other things, "There are possibly still people in the water." At 0431:59, LT FAVERO asked the Operator of the pilot boat:

"Roger, Skipper. If you can, could you make your way around the tanker and look for any survivors that may be in the water away from the stern? How that? Over."

The reply was:

> "Roger. Roger on that. Stay away from the stern and make a round turn or so around the bow and the sides. Will do. Over."

The majority of the radio traffic after that dealt with firefighting, evacuation of persons from the stern, and getting a towing hauser to the PUERTO RICAN. At approximately 0530, the Pilot of Coast Guard helicopter number 1395, who had returned from delivering Captain NOLAN and 3/M LEMPRIERE ashore, was requested by the Controller at Coast Guard Group San Francisco to commence searching the water in the area of the ship for the missing crewmember; as On Scene Commander, LT FAVERO concurred with this request. This search duty was transferred to other units upon the departure of helicopter number 1395 at approximately 0558. Also, prior to leaving the scene, LT FAVERO used his aircraft and crew in a search for the missing crewman, Able Seaman PENG.

153. Around 0545, LT FAVERO began to transfer the On Scene Commander responsibilities to Lieutenant (Junior Grade) RICHARD ARNOLD, Commanding Officer of the USCGC POINT HEYER, which was now on-scene; the transfer took place at 0551.

COAST GUARD HELICOPTER, NUMBER 1395.

154. Helicopter CG-1395 is a Model HH-52 manufactured by Sikorski and used by the Coast Guard primarily for its Search and Rescue mission. Its operating base is the U.S. Coast Guard Air Station, adjacent to the San Francisco International Airport. The Air Station is approximately 12 miles southeast of the site of the casualty. The duty Pilot for CG-1395 the morning of 31 October 1984 was Lieutenant RAYMOND J. MILLER. The crew included a co-pilot and an aircrewman.

155. LT MILLER was alerted to the casualty between 0330 and 0333. He and his crew were airborne at 0345 and were approaching the PUERTO RICAN within ten minutes. At that time the wind was at 10 knots from 270^{o}T; it subsequently shifted to 5 knots from 320^{o}T. The waves were approximately one foot from 290^{o}T and the swells were two to three feet from 270^{o}T.

156. When LT MILLER first saw the flames, they were approximately 100-feet high. As he approached closer, he detected the smell of burning petroleum. The PUERTO RICAN was drifting on a heading of approximately 320^{o}M. The flames were orange and there was a column of black smoke rising 1,200 to 1,500 feet in the air.

157. LT MILLER flew his aircraft around the PUERTO RICAN to the pilot boat, which was approximately a mile west of the tanker. Captain NOLAN and 3/M LEMPRIERE were hoisted aboard

his aircraft and taken to the U.S. Army Presidio, San Francisco, arriving at approximately 0434. He was airborne again at approximately 0438 and back on-scene at approximately 0450.

158. Upon his return, his initial assignment was to search the area around the PUERTO RICAN for persons that might have been thrown in the water and injured. He ran a search pattern using the two liferafts dropped by CG-1451 as datum points. He continued search efforts until approximately 0520 when he was asked by the On Scene Commander to conduct a damage assessment survey of the PUERTO RICAN. He put CG-1395 at an altitude of 50 feet on a radius from 100 to 500 feet from the ship and circled it several times. He also checked the bow, using the helicopter's Forward Looking Infrared Radar and the nose light, looking for the missing crewman. He did not find anyone on the vessel forward of the fire.

159. From his vantage point, LT MILLER had a very good perspective of the fire. Though his first sortie had been dominated by the evacuation, his return trip provided a better opportunity for examining and evaluating the flames. He did note on his first trip, however, that the flames not only varied in intensity as to location but that the flame "hot spots" moved. The flames would spread and die out, followed by black smoke and then more flames. When he returned from the Presidio, he noticed the flames had subsided somewhat and they did not cover the entire width of the deck, although they chronically flared-up. The flames appeared more intense on the after-starboard side of the flame area. He was not able to see the 6C tank in the flames until first light at approximately 0515. He then saw what he described as "a railroad tank car" floating in 6CV and raised approximately five feet above the main deck.

160. LT MILLER noticed a non-conformity between the bow section and the stern section of the PUERTO RICAN. When he initially saw the ship at approximately 0355, he noticed a slight difference between the motion of the bow and the stern. During the damage assessment he conducted shortly after 0500, he noticed a discernable bend between the bow and stern sections, and that the hull plating was starting to tear in way of number 4P wing tank. He also noted that the hull plating in this area as well as in the way of number 4S wing tank was glowing red hot. He was not able to report on the presence or absence of a tear in the starboard hull plating. He testified that he was not able to get as close a look at the same area on the starboard side because the smoke was blowing across that side. He testified that at approximately 0520 he made a strong recommendation to the On Scene Commander that any persons remaining aboard evacuate the PUERTO RICAN. LT FAVERO, the On Scene Commander, concurred. Since radio transmissions to the vessel were not being answered at the time, LT MILLER brought his helicopter to a hover at

approximately a 75-foot altitude on the port side just forward of the deckhouse and broadcast over the helicopter's loudhailer three times in succession: "This is the Coast Guard. We recommend you evacuate your vessel at this time." The only person he saw on the vessel after that was a man going from the third deck of the house to the stern to board the HARRY M.

161. Shortly thereafter, LT MILLER resumed his search for persons in the water. He continued this effort until he had to depart the scene at approximately 0558 to refuel his helicopter. The PUERTO RICAN had been drifting at approximately one mile per hour in an easterly direction since the casualty.

TOWING VESSEL HARRY M

162. The HARRY M is owned by Manson Construction and Engineering Company of Seattle, Washington. The Operator at 0325 on October 31, 1984 was MR. MORRIS MORTON, referred to as Captain MORTON. The three other persons aboard were Messrs. MIKE GALLIGAN, KEVIN KELLY, and CLAY LEWIS. The HARRY M has a length of 92 feet and beam of 30 feet. It is 148 gross tons, twin screw, twin rudder, diesel propelled, and of 1,250 brake horsepower. The vessel is constructed with a pushing knee that has two vertical uprights that are even with the bow. On the morning of October 31, 1984 the freeboard of the bow and pushing knee was approximately ten feet. At the time of the casualty, the HARRY M was engaged in work associated with the San Francisco Sewage Outfall Project approximately a mile west of Ocean Beach, San Francisco and approximately seven and a half miles southeast of the PUERTO RICAN. When Captain MORTON noticed the fire, he informed his office by radio that he was going to investigate.

163. Captain MORTON headed his vessel to the northwest, arriving in the vicinity of the PUERTO RICAN at 0413. As the PUERTO RICAN's bow was in a northerly direction, the HARRY M approached its stern. At that time the height of the fire ranged from as high as the bridge to twenty feet above it. As he was directing the HARRY M toward the stern of the PUERTO RICAN, he noticed a lifeboat adrift approximately 300 feet off its stern. He removed the one person on board and left the lifeboat drifting. At that time, one lifeboat and one liferaft were also tied to the PUERTO RICAN's stern. People were entering them by sliding down lines; a ladder was not rigged. The freeboard at the stern of the PUERTO RICAN was approximately 10 feet at this time. On one occasion, a man jumped from the stern of the PUERTO RICAN to the liferaft, hitting a person already on the raft. Captain MORTON testified that swells at the stern were approximately four-feet high.

164. By now there were several Coast Guard small boats in the area. However, the relatively low freeboard of the Coast Guard boats, their surging under the stern of the PUERTO RICAN, and the lack of a disembarkation ladder made it difficult for people to board them from the PUERTO RICAN. Though concerned for the safety of his vessel and crew from the continuing threat of explosions, Captain MORTON discussed this problem with the OSC and proposed a solution:

0429:09	HARRY M	Tug HARRY M to the Coast Guard. Can we put our bow right in against their stern and get them off. That little 41 footer is having trouble. Over.
0429:15	1451	HARRY M. 451. If you think that will work, go ahead. Be ready to back out if necessary. Over.
0429:21	HARRY M	Roger. We've got a pretty good chance. We've got a big wide bow here. I think I'll give it a try if they give us a chance here. There is quite a bunch of them right on the very stern.

The Coast Guard boats then towed the liferaft and lifeboat clear of the stern. The four persons in the liferaft boarded the HARRY M while the three persons in the lifeboat went aboard a Coast Guard boat. At 0437:30, Captain MORTON informed the On Scene Commander that he had five persons aboard.

165. Captain MORTON was now able to maneuver the bow of the tug up to the stern of the PUERTO RICAN. He made repeated approaches to the PUERTO RICAN and evacuated people as follows:

TIME OF RADIO TRANSMISSION	TOTAL EVACUATED
0443:40	8
0445:31	11
0446:11	12
0451:34	19
0508:14	20
0526:39	21

166. From his vantage point, Captain MORTON was able to observe the change in freeboard at the stern. When he

arrived, the freeboard at the stern was approximately ten feet. Approximately 30 minutes later, at about 0445, the freeboard was reduced to five feet. He noted that, although the freeboard at the stern had decreased, the forebody was still relatively level. The stern section was now also listing to port. Though it was racked to port, he never heard any cracking of the hull. When Captain SPILLANE, the last person to be removed, attempted to board the HARRY M from the stern of the PUERTO RICAN, he had to step on a chock and jump up to the bow of the HARRY M. The orientation of the forebody and the stern section is shown in photographs 7 and 8.

167. Early in the rescue operation, Captain MORTON had been advised that a crewmember had been blown in the water. While he and his crew were working the HARRY M off the stern of the PUERTO RICAN, they were on the lookout for people in the water but did not see anyone.

168. While Captain MORTON and his crew were in the area, small particles in the atmosphere were irritating their skin and adhering to the windows of the HARRY M. One deckhand complained of his eyes burning.

169. At approximately 0730, the twenty-one survivors on the HARRY M were transferred to the USCGC POINT HEYER. Captain MORTON, his crew, and the HARRY M then returned to their former job on the Outfall Project.

COAST GUARD MOTOR UTILITY BOATS:

170. Four Coast Guard motor utility boats participated in the initial response:

NUMBER	DEPARTED STATION	ARRIVED PUERTO RICAN	DEPARTED PUERTO RICAN
30606	0331	0415	1050
41403	0335	0535	1249
41404	0335	0535	1315
44347	0331	0415	1050

An additional boat, CG-41507, arrived at 0750.

All the utility boats except CG-44347 have limited capability for operating in open seas or in heavy weather. Although there are always a number of factors that come to bear on any decision involving a search and rescue response, one rule of thumb is that the 30 foot and the 41 foot boats are in an environment beyond their designed operating limits if the seas are over five feet high and the winds are in excess of 20 knots.

The rated firefighting capability of each boat using its fixed fire monitor is:

NUMBER	GALLONS PER MINUTE	MAXIMUM DISTANCE OF STRAIGHT STREAM
30606	NONE	NONE
41403	250	133 FEET
41404	250	133 FEET
44347	120	240 FEET

Operatonal information on each boat is:

NUMBER	DISPATCHED FROM CG STATION	COXSWAIN	ADDITIONAL CREW
30606	FORT POINT	BMCM D. DUREN	1
41403	SAN FRANCISCO	BM3 S. MAWHINEY	2
41404	SAN FRANCISCO	BM2 J. WALKER	2
44347	FORT POINT	BM3 D. GREENLEE	3

171. The Coast Guard boats were engaged in the following tasks while on scene: searching for AB PENG and possibly other persons in the water, removing people from the stern of the PUERTO RICAN and from the liferaft, towing the liferaft and a lifeboat clear of the vessel, damage assessment and firefighting. The firefighting effectiveness of the boats was limited due to the heights and distances involved, and the size of the fire. At 0506:09 the Coxswain of CG-41404 advised the On Scene Commander:

> "....We're not able to get any foam. We are only able to apply foam by fire hose and not through our monitor. The monitor is barely sprinkling on it and our fire hoses will not reach up there. Over."

At 0508:23, the Coxswain of CG-41403 concurred: (Ex 43B, P34):

> "....Roger. I agree with the 04. There is not much the 41's can do. We are just barely reaching the top of it. We are cooling down the sides but that is about it.... I recommend getting all actual fire fighting boats out here that we could. There is a danger, an explosion factor of course. As close in as the 41s have to get to put water on it, I have to get about six foot to put it up to the top. Over."

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COAST GUARD PATROL BOATS

172. Two larger Coast Guard Patrol Boats were dispatched to assist the other vessels on scene:

NAME	DEPARTED STATION	ARRIVED PR	ASSUME OSC	RELINQUISH OSC	DEPARTED PR
POINT HEYER	0445 OCT 31	0551 OCT 31	0551 OCT 31	0856 NOV 1	0857 NOV 1
CAPE CROSS	0450 OCT 31	0545 OCT 31			1610 OCT 31
CAPE CROSS	0528 NOV 1	0755 NOV 1	0856 NOV 1	1830 NOV 1	2250 NOV 2

The Commanding Officer of the USCGC POINT HEYER was Lieutenant RICHARD L. ARNOLD. The Commanding Officer of the USCGC CAPE CROSS was Lieutenant (Junior Grade) DANIEL J. MCCLELLAN. Both vessels were moored at Coast Guard Base San Francisco, California, located on Yerba Buena Island. Both vessels were in Bravo 24 status (ready to get underway within 24 hours) and both got underway within 50 minutes after being notified. The USCGC CAPE CROSS got underway with a full complement of 13 crewmembers on board. The USCGC POINT HEYER sailed with a minimum manning of 8 persons in the crew.

173. The Patrol Boats were approaching the scene as the last persons were leaving the PUERTO RICAN. The Commanding Officer of the USCGC POINT HEYER relieved LT FAVERO as On Scene Commander at 0551 on October 31, 1984. The USCGC CAPE CROSS returned to Yerba Buena Island, San Francisco on the afternoon of October 31, 1984 to bring out representatives of the U.S.C.G. Marine Safety Office, the U.S.C.G. Pacific Strike Team, the U. S. Navy Firefighting Team, and civilian marine surveyors and salvors representing the PUERTO RICAN'S owner. The Commanding Officer of the CAPE CROSS relieved the Commanding Officer of the POINT HEYER as On Scene Commander on the morning of November 1, 1984. As On Scene Commander, the Commanding Officers of the USCGC POINT HEYER and USCGC CAPE CROSS were engaged primarily in firefighting and salvage efforts. They were assisted by the people aboard the towing vessel SANDY, three U. S. Navy YTB-type tugboats, and the fireboat CITY OF OAKLAND. The On Scene Commander function terminated at approximately 1830 on November 1, 1984; however, various

Coast Guard and other resources continued to be involved on-scene in connection with ongoing pollution response activities.

THE TOWING VESSEL SANDY

174. The SANDY is owned by Marine Logistics Corporation, Seattle, Washington. It is 130 feet long, 38 feet wide, 198 gross tons and 5,650 brake horsepower. At the time of the casualty it was working at the Ocean Beach Sewage Outfall Project, San Francisco, approximately seven and one half miles southeast of the PUERTO RICAN. The Operator was MR. JERRY WHITE; he had five crewmembers aboard. The SANDY arrived on-scene at approxmately 0415. At 0521:45 the On Scene Commander asked the Operator of the SANDY if he could get a towline aboard the PUERTO RICAN. At that time, the PUERTO RICAN was drifting in an easterly direction at about one mile per hour. At 0631 the operator and crew of the SANDY succeeded in securing a towline to the stern of the PUERTO RICAN and began towing the vessel on a course of 250^{0}T. At that time the PUERTO RICAN was within 3.8 miles of Point Bonita, the nearest land.

U.S. NAVY YTB TOWBOATS

175. Two YTB's initially responded from the Port Services Division of Naval Station Treasure Island, San Francisco, California; they were numbers 812 and 813. They arrived on scene between 0605 and 0705. YTB 812 had to depart mid-morning on October 31, 1984 due to mast damage and was replaced by YTB 785. After being repaired, the 812 returned on the afternoon of November 1, 1984.

176. These towboats, built in 1945, were normally assigned for duties only inside the Golden Gate Bridge, San Francisco Bay. They are 109 feet long, have a 28 foot beam, draft of 14 feet, and are 344 gross ton single screw vessels. They are equipped with two fixed fire monitors and have both a water and a foam firefighting capability. They can deliver a straight water stream of 2,000 gallons per minute.

177. The YTB standard complement is a Craftmaster plus 8 crewmembers. Minimum manning is a Craftmaster plus 5 crew. Both boats got underway, and operated in excess of 24 hours each with less than full complements. These boats were involved primarily in firefighting operations and in cooling the hull in way of the fire.

YTB	CRAFTMASTER	UNDERWAY	ARRIVED	DEPARTED
813	QM1 F. MEISNER	0507 OCT 31	0605	1000 NOV 1
812	BMCS G. JONES	0615 OCT 31	0745	0931 OCT 31
812	BMCS G. JONES	0545 NOV 1	0945	1705 NOV 1
785	QMC R. MACKEY	1100 OCT 31	1300	1800 NOV 1

178. Lieutenant B. SMITH and Chief Warrant Officer W. EXXUM of the Port Services Division were on board the YTB's to direct and coordinate Navy on-scene activities.

FIREBOAT CITY OF OAKLAND

179. The fireboat, CITY OF OAKLAND, is 99'6" long and has a 27' beam. It is owned by the City of Oakland, California. It is a modified U. S. Navy seagoing tugboat presently equipped to operate only within the protected waters of San Francisco Bay and its tributaries. It has six fixed fire monitors plus capability for additional hand-held hoses and a capacity for pumping 10,000 gallons of water per minute while not making way. At the time of the casualty, it was berthed at its dock at Clay Street in Oakland. Its normal complement in this status is a Firefighter/Marine Operator, in this case Mr. GEORGE LEE, and a crew of three persons.

180. In response to a message from the Controller at Coast Guard Group San Francisco, the CITY OF OAKLAND got underway at 0414 after being augmented by four additional firefighters from Truck 3, Oakland Fire Department. It arrived on-scene at 0630. Its firefighting capabilities were directed toward cooling the port side of the hull while the CITY OF OAKLAND stayed close aboard the PUERTO RICAN. It was released by the On Scene Commander at 0840 because it was experiencing chronic electrical system failures which interfered with its steering capability.

SINKING OF THE STERN SECTION

181. The PUERTO RICAN remained under tow offshore of San Francisco by the SANDY for the next several days. A storm passed through the area on November 2, 1984, subjecting the PUERTO RICAN's hull to winds gusting to 35 miles per hour and seas of up to 16 feet. At approximately 0000 on November 3, 1984 in approximate position Latitude 37°-30'N, Longitude 123°-02'W the stern separated from the forebody roughly in the middle of 6CV and sank in approximately 1,500 feet of water. The 6C tank floated free and was towed to a ship repair yard in Oakland, California on November 4, 1984.

ENVIRONMENTAL ISSUES.

182. As a result of this casualty, oil and/or hazardous polluting substances were discharged into the waters of the contiguous zone and territorial sea of the United States. In accordance with the provision of the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977, (33 USC 1321 et seq.) and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), the pre-designated federal On-Scene Coordinator for pollution response activities was the Commanding Officer, Marine Safety Office San Francisco Bay, California. The North Coastal Regional Response Team for federal Region IX, which includes federal and state agency representation, was activated. Information pertaining to the pollution response activities associated with the PUERTO RICAN from 0700 on October 31, 1984 until May 10, 1985, which is after the forebody was towed from San Francisco Bay on April 6, 1985, is contained in USCG Marine Safety Office San Francisco Bay's On Scene Coordinator's Report, dated May 28, 1985.

DAMAGE ASSESSMENT

SHIP STRUCTURE

183. On November 1, 1984, Federal Bureau of Investigation agents inspected the visible areas of the 6CV, the 6C independent tank exterior, and the deck area in way of the damage. They did not find evidence of a point source detonation and described the damage as like that produced by a vapor/air explosion. They could not identify a source of the ignition. Also that day, U.S. Navy divers using SCUBA gear examined various areas of the underwater body. They did not detect any evidence of holes or a point source detonation in the areas they examined. They had to abort their inspection due to deteriorating weather conditions.

184. The Board examined the salvaged forebody of the PUERTO RICAN in a graving dock at Triple A Shipyard, San Francisco, California, on November 19, 1984 and January 10-11, 1985. The condition of the forebody is shown in photograph 9. With minor exceptions, the entire deck area above the 6CV and its adjacent wing tanks from frame 54 to 64 was blown off and landed in an inverted position on the deck area immediately forward of 6CV. The inverted deck was oriented along the centerline axis of the vessel. All underdeck transverse web frames were still attached. In the inverted position, the upper side of the deck corresponding to the area above 4S wing tank was concave in shape and the upper side of the deck corresponding to the area over 4P wing tank was convex. Photographs 2, 4, and 5 show this condition. There was a significant longitudinal tear in the deck

plating that had been above 4PA in the vicinity of where the longitudinal bulkhead had been welded to the deck. This tear ran approximately the full length of the 4PA deck area.

185. The following major areas fractured to release the main deck section: the welds between the deck and the port and starboard longitudinal bulkheads; the vertical welds between the nine transverse deck webs in 6CV and the port and starboard longitudinal bulkheads; the deck plating along the transverse bulkheads at frames 54 and 64; and the sideshell plating, port and starboard, at its intersection with the main deck plating.

186. Most of the upper side of the deck in the inverted position was blackened by a material which had an oily or greasy texture. There was no directionality to the way the deposits were laid down. Two areas were notably different. First, most of the fracture surfaces, except for the fracture surface where the deck and longitudinal bulkheads had been welded in the area of 4PA, were free of black deposits and had a layer of rust on them. Second, several sites between frames 63 and 64 were covered with a gray, powdery material.

187. The main deck forward of the inverted deck was not coated with the soot or black oily deposits found on the inverted deck. Pictures taken of the vessel after the fire and explosion, but before the vessel broke in half, such as photographs 3 and 4, also showed the forward deck area to be clean.

188. All butterworth openings and expansion trunks on the inverted deck were closed and undamaged except for the expansion trunk cover to 4PA. This cover was loose and the dogs were deformed.

189. The underside of the deck in the inverted position, originally the weatherdeck surface, showed evidence of heat damage and coatings of combustion deposits only in the area of 4PA expansion trunk.

190. One side of one U-shaped bracket supporting the perforated N_2 purge piping in the top of 6CV was not bolted and was hanging loose.

191. The transverse bulkhead at frame 64 separated the 5C P/S tanks from the 6CV. There were penetrations of the bulkhead at the after end of 5CP where it connected with the main deck and with the port longitudinal bulkhead. There was also a hole in the after bulkhead in 5CP tank approximately 6 feet from the longitudinal centerline bulkhead separating 5CP and 5CS and 16 feet 6inches from the deck of the tank. Photographs 10 and 11 show this. This hole was located at an ullage level of approximately 32 feet 6 inches.

192. The hole was easily observed while inspecting 5CP in the graving dock because sunlight was coming through the hole from

the open 6CV area. As shown in photograph 11, there was not any rust discoloration in the area of the hole. There was, however, rust discoloration from pinhole penetrations of the stainless steel cladding on the port bulkhead and on the deck of 5CP.

193. Pictures taken of the vessel after the fire and explosion but before the vessel broke in half reveal the transverse bulkhead at frame 54 separating the 6CV from 7C P/S was missing, thereby removing any liquid boundary between the tanks.

194. After the water was pumped out of the graving dock, the remaining sides and bottom of the hull in way of 6CV were examined. No evidence of damage resulting from a point source detonation was found.

6C INDEPENDENT TANK

195. The Board examined the 6C independent tank on November 6, 1984, while it was afloat at Pacific Drydock and Repair, Oakland, California. See photographs 12 and 13. The top of the tank and after transverse bulkhead were dished inward on either side of the tank's centerline longitudinal watertight bulkhead. The forward transverse side received minimal structural damage. The upper portion of the port and starboard sides, including the upper knuckle area, were buckled near the tank's transverse centerline. The bottom and the lower 3 feet of the sides of the tank were undamaged, and the nominal 3 inch polyurethane insulation covering this area was intact and undamaged by the fire. All other polyurethane insulation was either charred significantly or burned away completely. The sideshell and top plating was dented and penetrated in several locations. All penetrations in the plating were small, consisting of approximately 1-foot tears. No evidence of damage resulting from a point source explosion was found.

196. The inside of 6C independent tank was examined at Pacific Drydock and Repair on January 25, 1985. The refrigeration and piping systems, though damaged, were still present. There were no cargo pumps in the tank, though there was evidence that such pumps had at one time been installed. There was approximately a one-foot deep oily water mixture in the bottom of the tank. Though the steel showed effects of fire damage, there was not any evidence of fire inside the tank.

TECHNICAL STUDIES

GENERAL

197. Several technical studies of the PUERTO RICAN casualty were conducted at the Board's request by Failure Analysis Associates

(FaAA), consultant for PPG Industries, Inc., and by Chevron Research Company, consultant for Chevron Shipping Company. The results of these studies are contained in the following three reports, which have been made exhibits of the Board:

a. Examination and Metallurgical Analysis of Samples from the SS PUERTO RICAN --Exhibit 161;

b. Combustion Testing and Analysis of Samples from the SS PUERTO RICAN --Exhibit 162; and

c. Analysis of Samples from the SS PUERTO RICAN --Exhibit 164-- and its addendum --Exhibit 165.

198. These studies included:

a. Metallurgical analysis of various penetrations of the transverse bulkhead at frame 64 separating 5CP from 6CV and of a hole in the vacuum breaker riser serving 6CV;

b. Chemical analysis of: the coatings on bulkheads and nitrogen purge piping in 3CV and the remaining section of 6CV; the reaction of these coatings and of polyurethane foam insulation with 50% caustic soda solution and Alkane 60; the deposits taken from the underside of the inverted deck after the casualty.

199. Several other studies were conducted by the Board with the assistance of the U.S. Coast Guard Office of Merchant Marine Safety, Marine Technical and Hazardous Materials Division, which is located at USCG Headquarters. These included:

a. H_2 concentration in 6CV;
b. Burning characteristics of H_2/air mixtures;
c. Dispersion of vented H_2 on deck;
d. Overpressure of 6CV;
e. Electrostatic discharge in 6CV.

THE HOLE

200. A hole existed in the transverse bulkhead separating 5CP from the 6CV. This bulkhead was 7/16 inch carbon steel clad with a 0.08-0.09 inch layer of AISI Type 316 stainless steel on the 5CP side. The hole's opening through the 5CP cladding was an irregular horizontal ellipse of the following dimension: major axis = 1.4 inch, minor axis = 0.5 inch. In the carbon steel behind the cladding, the hole widened immediately and then narrowed. The hole in the carbon steel bulkhead was approximately elliptical in shape and oriented vertically on the 6CV side with the following dimensions: major axis = 0.6 inch, minor axis = 0.4 inch. The hole was situated approximately 16 feet 6 inches above the tank bottom and 6 feet from the

centerline bulkhead separating 5CP and 5CS. Photographs 10 and 11 show its relative location.

201. Figure 3 shows the position of the hole from the 5CP side. The hole was located below a horizontal stiffener plate and behind a cutout in a vertical gusset plate which are parts of a horizontal corner bracket. The hole was between the horizontal fillet weld attaching the stiffener plate to the bulkhead, and the vertical fillet welds attaching the vertical gusset plate to the bulkhead. On the 6CV side, the hole was located near the intersection of a vertical stiffener and a transverse stringer plate welded to the bulkhead.

202. Examination of the area near the hole on the 5CP side revealed a gouge in the underside of the horizontal stiffener plate immediately above the hole and the cutout corner in the vertical gusset plate.

203. Examination of similar vertical gusset plates on other horizontal corner brackets in 5CP showed that some had cutout corners while others did not. Next to one of the other gussets with a cutout corner there was a welding repair made to a gouge in the stainless steel clad on the transverse bulkhead. The position of that repair, relative to the gusset, was identical to the position of the hole, relative to the other gusset.

204. The section of bulkhead plate containing the hole was removed by the Board for further metallographic study. After removal, the plate was cut in half through the center of the hole using a small band saw and a diamond abrasive saw. One of these plate sections, containing one half of the hole, was further cut into three sections, each containing one-sixth of the surface of the original hole. One of these sections of the hole's surface was examined by Electron Spectroscopy Chemical Analysis (ESCA), another section examined by Scanning Electron Microscopy (SEM), and the third section by Metallography. SEM and metallographic examination of the surface of the hole showed considerable corrosive attack on the mild carbon steel but no appreciable corrosive attack on the stainless steel clad. The lip of the stainless steel cladding around the hole was thinned to a fine edge and there was a layer of melted stainless steel, not weld metal, on this surface. The melted layer was partially attacked by corrosion. A cross section of the hole's configuration is shown in figure 4.

205. Metallography and non-destructive dye penetrant examination revealed no notable cracks or deformation around the hole even at the point of maximum thinning of the carbon steel.

206. Metallographic examination of a cross-section of the stainless steel welds adjacent to the hole indicated the welds were made in several passes and the weld toes penetrate deeply into the mild carbon steel plate. These welds formed part of the upper and lower edges of the hole and had a matte, etched

appearance similar to surrounding welds and less bright than more recent repair welds.

207. ESCA analysis did not provide any reliable or definitive information.

208. Loss of liquid from 5CP through this hole can be described by the following equation:

$$\sqrt{H_o} - \sqrt{H_1} = C \left(\frac{A_o}{A_T}\right) \left(\frac{T}{2}\right) \sqrt{2g}$$

Where:

H_o is the initial height in feet of liquid above the hole.
H_1^o is the height in feet of liquid above the hole at time T.
A_o is the cross-sectional area of the hole in $feet^2$.
A_T^o is the surface area of the liquid in 5CP in $feet^2$.
T^T is time in seconds.
g is the gravitational constant, g = 32.2 $feet/second^2$.
C is the orifice discharge coefficient, C = 0.6.
The volume of liquid lost (ft^3) in time T is then given by:

$$V = A_T(H_o - H_1)$$

CORROSION

209. Stainless steels in general have good corrosion resistance to 50% caustic soda solutions. This is due to their ability to readily develop a passive surface layer. This passive surface layer is stable to the chemical environment and protects the material from further chemical reaction. Pitting corrosion can occur if this passive layer is broken down or penetrated locally.

210. The corrosion rate of mild carbon steel by 50% caustic soda solution at ambient temperatures is less than 2 mils/yr. The reaction is accelerated as temperature increases. The maximum loading temperature for 50% caustic soda solution into 5CP was approximately 120°F, resulting in a corrosion rate of no more than 20 mils/yr. The caustic soda solution was not heated while onboard. At 120°F and below, stress corrosion cracking (caustic embrittlement) of mild carbon steel is not expected to be a significant concern.

211. Corrosive attack of mild carbon steel may be accelerated by developing a galvanic electrochemical cell, to wit: a battery. In the electrochemical cell, corrosion occurs at the anode. The rate of charge transfer, and hence corrosion rate, is dictated by the size of the electrodes and the difference in galvanic potential of the electrode materials. Considering the construction of 5CP, a galvanic cell would be established once the stainless steel clad is penetrated and the mild steel is

exposed to caustic soda solution. The stainless steel clad, being the more noble metal, becomes the cathode and the mild carbon steel becomes the anode. Caustic soda solution is the electrolyte. Although the galvanic potential for stainless steel and mild carbon steel are similar, the large cathodic area (the clad wetted by caustic soda solution) and the small anodic area (the mild carbon steel wetted by caustic soda solution) could result in accelerated corrosion of the mild carbon steel in what would otherwise be a relatively passive system. This is a well-known phenomena; accordingly, the use of mild carbon steel fittings in stainless steel cargo tanks is not permitted.

TRANSVERSE BULKHEAD FAILURE AT FRAME 64

212. Figure 5 is a schematic of the failure between the after transverse bulkhead of 5CP and the port longitudinal bulkhead. The failure extended from the main deck downward. The junction between these bulkheads separated along the upper two-thirds of its length. This separation was approximately 20 to 30-feet long. Below this separation, a crack propagated into the mild carbon steel transverse bulkhead. This crack extended approximately 5 feet. There was significant plastic deformation surrounding the failed junction, particularly in the transverse bulkhead.

213. Examination of samples of the separated junction indicated the stainless steel clad on the port longitudinal bulkhead had separated from the carbon steel base along the bond interface. SEM examinations showed ductile dimples on the cladding fracture surface. This was indicative of an overload failure. No evidence of other modes of failure were noted.

214. The fracture in the mild carbon steel transverse bulkhead showed a chevron-type fracture pattern characteristic of brittle fractures. The orientation of the chevron pattern indicated crack propagation from the top towards the bottom. Extensive branching of the crack was also noted in the carbon steel bulkhead.

VACUUM BREAKER

215. A portion of the riser for the vacuum breaker servicing the 6CV was examined. The riser was 2-1/2 inch diameter carbon steel pipe and contained a hole approximately 2 inches by 2 inches in size approximately 2 feet above the deck. The pipe was heavily corroded on the outside. The edges of the hole showed extensive corrosion and were very thin when compared to the original pipe thickness. The edges were bent outwards in several areas. The inside of the pipe had a thin layer of rust but was not coated with soot or other combustion deposits.

VOID COATINGS AFTER THE CASUALTY

216. The remaining 6CV was examined after the casualty. Approximately 60% of the deck plating had no coating remaining. On the other 40%, the coating varied in thickness between 0.8 to 8 mils and in zinc composition between 0.1% to 75% by weight. The estimated average thickness of the coating for the entire remaining deck was 2 mils. The transverse and longitudinal bulkhead coatings varied considerably depending upon where they were examined. About 14 feet above the bottom of the void there was essentially no epoxy remaining and the coating contained approximately 74% by weight metallic zinc or zinc compounds. The original coating was approximately 82% by weight metallic zinc or zinc compounds. Near the bottom of the void, the bulkhead coating consisted of a soft red pliable material. This material was about half epoxy and half an oily substance consisting of alkyl benzene and lubricating oils. This material contained approximately 0.2% by weight zinc.

217. Sections of remaining N_2 purge piping were removed from the 6CV area and examined. No zinc coatings were detected on either the inside or outside surfaces.

218. Analysis indicates that the protective coatings in 3CV and 6CV were the same material, a zinc rich epoxy, and that the coating in the 3CV had not degraded in service. The average thickness of the zinc-rich epoxy coating in 3CV was 6.9 mils on the deck and 5.8 mils on the bulkheads. The coating contained approximately 77% by weight metallic zinc (40 grams of metallic zinc per cubic inch of coating); 5% by weight zinc oxide, 3.5% by weight iron, and 14.5% by weight epoxy binder. Various areas of the deck of 3CV were covered with a layer of non-skid type material of random thickness.

219. The N_2 purge piping installed beneath the 3C and 6C independent tanks was 3-inch Schedule 40, zinc galvanized pipe. The zinc layer was applied by hot dipping. Examination of a section of the pipe from the 3CV indicated the zinc galvanized layer was on both the inside and outside of the pipe and was of 8 mils average thickness.

REACTIONS IN 6CV: CARGOES/MATERIALS OF CONSTRUCTION

220. Fifty percent caustic soda solution (50% by weight NaOH in water) reacts with zinc metal producing hydrogen gas (H_2) and sodium zincate. No other gases are evolved. Assuming excess caustic soda solution is available, the theoretical quantity of H_2 evolved from the reaction is approximately 370 ml of H_2 gas per gram of metallic zinc consumed. Table 3 is an excerpt from the Coast Guard's Chemical Hazard Response Information System (CHRIS), Volume I, which describes various hazards and characteristics of caustic soda solution. There was no testimony given by persons who had sailed the PUERTO RICAN regarding the

possible generation of hydrogen by a caustic soda reaction with epoxy coatings found in spaces adjacent to caustic soda tanks.

221. A 0.62 in^2 specimen of plating from the 3CV with a zinc rich epoxy coating 10 mils thick was reacted with 50% caustic soda solution. This specimen was representative of the coated plating in 3CV and 6CV prior to the casualty. Care was taken to ensure that only the zinc rich epoxy coating contacted the caustic soda. Test results indicate that at least 57 ml. of H_2 were evolved from the specimen and that all of the zinc was consumed in the reaction. (The exact amount of H_2 gas evolved could not be determined due to losses of H_2 from the test apparatus by diffusion through tygon tubing and a water seal during the 700 hour test.) No other gases were evolved. This was 61% of the theoretical amount of H_2 expected based upon the amount of metallic zinc present, which was 40 grams per in^3 of coating.

222. One side of a 0.54 in^2 piece of the N_2 purge pipe from 3CV with a 9.5 mil thick galvanized layer was reacted with 50% caustic soda solution. Test results indicated that at least 192 ml of H_2 were evolved. (H_2 losses via diffusion out of the test apparatus were expected to be small in this test since the reaction was completed in about 150 hours.) No other gases were evolved. Assuming the galvanized layer was 100% metallic zinc, this was 87% of the theoretical amount of H_2 that could have been expected.

223. Coating experts who were consulted expect no reaction between Alkane 60 (alkyl benzene) or lubricating oils and the zinc rich epoxy coating material. No experimental tests were conducted.

224. Polyurethane foam used to insulate the 6C independent tank was tested with 50% caustic soda solution and Alkane 60. No reaction was expected and no reaction was observed.

SAMPLING AND TESTING

225. Samples representative of the deposits found on the upper side of the PUERTO RICAN's main deck in the inverted position, on the pilot boat SAN FRANCISCO, and of the oily liquid in 6C independent tank were examined by gas chromatography/mass spectrometry (GC/MS) techniques. These results were compared to GC/MS analysis of control samples of Polybutene 24, Alkane 56, Alkane 60, OLOA 246B, and their combustion products. Table 2 lists the deposits and control samples analyzed and indicates their source. Photograph 14 indicates the locations of the sample deposits taken from the inverted deck. The combustion control sample of OLOA 246B was not useful in the comparison since it did not show detectable organics in the GC/MS analysis.

226. A comparison of the test results indicated the following:

a. The samples of Polybutene 24 and Alkane 60 (numbers 19 and 20) carried as cargo match with exemplar samples obtained from Chevron Corporation, Richmond, California.

b. The samples taken from the pilot boat (numbers 17 and 18) matched with Polybutene 24.

c. The deposits taken from the after end near the mid-line of the inverted deck (numbers 1, 2, 3, 4, 6, and 7) matched with only the Polybutene 24 combustion control samples, numbers 8 and 12.

d. The deposit samples from the forward end of the inverted deck (numbers 5 and 14) matched with Alkane and Alkane combustion control samples or with both Alkane and Polybutene combustion control samples.

e. The sample of oily liquid from 6CP matched with both Alkane and Polybutene combustion control samples.

HYDROGEN CONCENTRATION IN 6CV RESULTING FROM CAUSTIC SODA REACTION WITH ZINC

227. Calculations were performed to estimate the upper and lower limits on H_2 concentration achievable in 6CV from the reaction of 50% caustic soda solution and zinc. Uncertainties considered for the calculations included:

a. Whether the reaction follows stoichiometry: i.e., one mole of zinc consumed evolves one mole of H_2, or is better characterized by the experimentally determined minimum H_2 evolution rates;

b. Whether H_2 produced from the reaction of caustic soda solution with the zinc galvanized layer inside the N_2 purge piping contributes to the void space H_2 content;

c. Whether the void was vapor tight or whether vapor was vented from the void as a result of H_2 generation or liquid flowing into the space; and

d. The H_2 concentration of any vented vapor.

228. The following assumptions apply to both the upper and lower limit calculations:

a. 6CV contained approximately 2,550 barrels of 50% caustic soda solution, which corresponds to approximately a 2-foot liquid level in the void; it also contained approximately 1,100 barrels

of Alkane 60, corresponding to an additional 3-1/2' liquid level of caustic soda in the void. This condition is illustrated in figure 6.

b. The reaction was complete before Alkane 60 leaked into the void;

c. No sloshing;

d. All of the zinc in the coating on the deck, bulkheads, supports, and on the inside and outside of the N_2 purge piping in contact with caustic soda solution is consumed;

e. A 2 mil zinc rich epoxy coating remains on the deck;

f. H_2 is not soluble in 50% caustic soda solution;

g. H_2 behaves as an ideal gas;

h. The vapor space of the void is well mixed and of uniform concentration;

i. Breathing of the void due to thermal variation is insignificant due to the presence of the large constant temperature sink created by the insulated independent tank.

229. The upper limit of H_2 concentration achievable in the 6CV is estimated as 9.6% by volume. This estimate was made by assuming that the evolution of H_2 follows the stoichiometric reaction, that H_2 generated inside the N_2 purge pipe escapes into the void, and that the displaced vapor is pure air.

230. The lower limit of H_2 concentration in the 6CV is estimated as 4.3% by volume. This estimate was made by assuming that the evolution of H_2 is characterized by the experimentally determined minimum H_2 generation rates noted previously, that all H_2 generated inside the N_2 purge pipe is trapped inside the pipe, and that an H_2/air mixture is displaced from the space while caustic soda solution is leaking into 6CV and the reaction is proceeding. To simplify the estimate, the H_2 concentration of the displaced vapor was chosen as 5.5% by volume, which is the estimated H_2 concentration in the space assuming only pure air is vented.

231. If the 6CV is assumed tight, i.e. no vapor is displaced from the space during liquid inflow and H_2 evolution, the upper and lower bound H_2 concentrations are estimated as 7.6% by volume and 4.5% by volume respectively. The vapor pressure of the atmosphere in 6CV under these conditions would be approximately 3 to 4 psig.

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HYDROGEN

232. Hydrogen (H_2) exists as a diatomic gas at ambient conditions. It is odorless, non-toxic and, non-corrosive. It has a specific gravity of 0.07 (Air = 1.0) and therefore pure H_2 is extremely buoyant relative to air and will rise. The flammable limits of H_2 in air are: lower flammable limit (LFL) = 4% by volume; upper flammable limit (UFL) = 75% by volume. Its autoignition temperature is 1075°F. H_2/air mixtures readily ignite when exposed to spark ignition sources. The minimum ignition energy required for a stoichiometric H_2/air mixture being approximately 0.02 millijoules. (For comparison, the minimum ignition energy for a stoichiometric methane/air mixture is 0.33 millijoules). H_2/air mixtures burn very rapidly and cleanly, leaving no residue or soot except water vapor. Ignition of H_2/air flammable mixtures in closed containers can produce significant overpressures. Published results indicate the magnitude of the overpressure developed is dependent upon both the H_2 concentration of the mixture and the degree of turbulence in the near limit mixtures. For example, ignition of 5% and 8% by volume turbulent mixtures resulted in respective overpressures of approximately 10 and 38 psi; in quiescent mixtures these concentrations resulted in overpressures of approximately 2 and 25 psi.

ON-DECK DISPERSION OF H_2 GAS

233. Openings from the 6CV to the open deck may have existed at the time of or prior to the fire and explosion. These would allow direct communication between the environment on deck and the environment within 6CV. Air drawn into the void from the open deck would dilute any flammable environment within the void. A flammable gas vented onto the open deck would disperse in the environment.

234. A model and computer routine for prediction of downwind vapor concentrations of vented gases were developed by Southwest Research Institute for the U. S. Coast Guard. The model, including experimental verification, is well documented in the literature. The model was used to estimate the dispersion characteristics of H_2 gas in the environment under extremely conservative input conditions relative to the actual conditions on the PUERTO RICAN. The conditions examined were:

a. Exhaust gas = pure H_2 and 10% H_2/air mixture (assumed neutrally buoyant);

b. Vent height = 2 feet above deck;

c. Vent diameter = 3 to 6 inches;

d. Vent volumetric flow rate = 9.4 to 23.4 $feet^3$/min;

e. Wind velocity = 1.25 to 5 mph.

235. For all cases examined, the plume centerline concentration (the highest concentration within the plume) fell below the LFL for H_2, 4% by volume in air, within approximately 2 feet downwind of the vent exit. The worst case, producing a 2-foot downwind flammable envelope, occurred for the highest vent volumetric flow rate and lowest wind speed. At wind speeds above 5 mph, no detectable flammable envelope existed.

OVERPRESSURES REQUIRED FOR STRUCTURAL FAILURES

236. The following connections were ruptured as a result of overpressure in 6CV and adjacent wing tanks:

a. Connection A: The welds between the port and starboard longitudinal wing tank bulkheads and the underside of the main deck.

b. Connection B: The vertical welds between the nine transverse deck webs in 6CV and the port and starboard longitudinal bulkheads.

c Connection C: The sideshell plating, port and starboard, just below its connection with the main deck plating.

237. Estimates of the overpressures required to rupture these connections were made using structural engineering approaches for failure analysis. The loads necessary to fail these connections were determined using a Shear and Bending Analysis and also a Plastic Hinge Model. The results indicate that Connection B is the strongest; it requires approximately 10 to 20 psi overpressure in 6CV for failure. Connection A or C are of approximately equal strength and require 7 to 11 psi overpressure for failure.

ELECTROSTATIC DISCHARGE WITHIN 6CV

238. Static electricity presents a fire and explosion hazard in the handling of hydrocarbon products. Electrostatic discharge, if of sufficient energy, can ignite flammable environments. The potential for generation of an electrostatic hazard is greater if the hydrocarbon product has a low electrical conductivity, like alkane, or has water droplets dispersed throughout it. To assess the potential for this ignition mechanism, the three basic stages necessary for electrostatic discharge must be addressed in the context of the PUERTO RICAN casualty and, specifically, the conditions in 6CV. The stages are: charge separation, charge accumulation, and spark discharge.

239. The generation of static electricity takes place at the interface of dissimilar materials: solid/solid, solid/liquid, and liquid/liquid. Charging can occur through contact followed by separation. Motion of a charged liquid can produce the needed

separation. The generation of a static charge in 6CV may have occurred by any of the following methods:

a. Alkane, flowing from 5CP into 6CV through a hole, hitting the insulation and running down the insulation of 6C independent tank.

b. Splashing, sloshing, or agitation of the alkane in 6CV against itself, against the 6C tank insulation, or against the ship's structure.

c. Mixing of alkane with 50% caustic soda solution.

The latter mechanism is especially important since the settling of charged water droplets out of a non-conducting, less-dense medium have been shown to produce significant potentials at the surface of the non-conducting medium. Also, shipboard investigations conducted by the Tanker Committee of the International Chamber of Shipping demonstrated that static discharges can occur in tanks partially filled with oil and water as a result of ship motion.

240. Charges which have been separated attempt to recombine and neutralize each other. If one of the separated materials is a good insulator, i.e. of low electrical conductivity, recombination is difficult and the material accumulates charges upon it or within it. Both the alkane (electrical conductivity 10^{-15}ohm^{-1}cm^{-1} at 70°F) and the polyurethane foam insulation of 6C independent tank are good insulators.

241. The accumulation of charge is accompanied by an increase in potential of the material and this gives rise to an electric field. When the electric field exceeds that necessary to ionize air, sparks are produced. Sparks can also occur locally when the overall electric field strength is less than this value. Besides sparks, there is another type of electric discharge, corona discharge, that may occur. However, corona discharges are usually of low energy and insufficient to ignite flammable mixtures.

242. Electrostatic discharges can occur between any two surfaces where there is a sufficient difference in potential. For the spark to be a hazard, it must be of sufficient energy to ignite the flammable mixture. The energy associated with a spark not only depends upon the amount of accumulated charge but also upon the mobility of that charge, i.e.: the ability of the charge to move to the point of discharge. For this reason, sparks between electrically isolated conductors (metal objects) are known to be much more energetic than those between a metal and an insulator or between two insulators. All of the charge on the metal object is released in the spark due to its good conductivity rather than just a portion of the charge as on an insulator. In 6CV, discharge could be accomplished between the liquid surface and the insulation (both insulators) or between either the liquid surface or insulation and the metal of the ship's structure.

CARGO AUTHORIZATIONS

"OTHER THAN OIL"

243. The Certificate of Inspection for the PUERTO RICAN dated June 22, 1984 lists the vessel as a "Chemical Carrier" and includes the following cargo authorization: "Grade 'B' and lower other than oil; also specified dangerous cargoes (46 CFR Subchapter O, Authority Part 153)". The entry restricting carriage to "other than oil" was initially included in a June 30, 1983 amendment to the previous Certificate of Inspection issued in Mobile, Alabama on October 31, 1981. This amendment indicated the restriction was made in accordance with NVIC 1-83. NVIC 1-83 deals with "Painters for Life Floats and Bouyant Apparatus". NVIC 1-81 provides guidance pertaining to "Enforcement of the Requirements of the Port and Tanker Safety Act of 1978 (PTSA) Pertaining to SBT, CBT, COW, IGS, Steering Gear, and Navigation Equipment for Tank Vessels".

244. Many of the cargoes specified in table 1 that were carried on the PUERTO RICAN are both "oils" and "products" as defined in 33 CFR 157.03. None are crude oil. The guidelines in NVIC 1-81 indicate that the standards in 46 CFR 32.53 and in 33 CFR 157.11 and 157.15 for an existing product carrier of 20,000 to 40,000 deadweight tons (DWT) apply to the PUERTO RICAN.

245. Officers who had sailed on the PUERTO RICAN and a company offical stated they were aware of the "other than oil" restriction on the Certificate of Inspection but considered it to apply only to the carriage of crude oil.

246. The Board contacted the Coast Guard offices located in ports to which the PUERTO RICAN called after the "other than oil" restriction was entered on the vessel's COI on June 30, 1983 until it went into lay-up in September 1983 and from the time it left the shipyard on June 23, 1984 until it departed Richmond Longwharf on October 30, 1984. The purpose was to determine if Coast Guard personnel had boarded the vessel to check compliance with 33 CFR 157.11 and the vessel's Certificate of Inspection while cargo was on board. No record or indication was found of any Coast Guard boardings during these periods.

247. The safety standards in 46 CFR Subpart 32.53 require an inert gas system on vessels 20,000 to 40,000 DWT that are crude oil tankers or are existing product carriers having high capacity tank washing machines. High capacity is defined as more than 60 m^3/hr. The Coast Guard's Marine Safety Information System (MSIS) indicates the PUERTO RICAN was equipped with high capacity tank washing machines. However, all tank-washing devices on the PUERTO RICAN were portable DASIC Jetstream Model B tank washing

machines of 28 m^3/hr maximum capacity. The PUERTO RICAN was not equipped with an inert gas system.

248. The intital publication of pollution prevention standards in 33 CFR 157.11 and 33 CFR 157.15 required all vessels in oil trade to have a slop tank and a fixed piping system from each oil tank to the slop tank. A Commander, Third Coast Guard District (mmt) Policy File Memorandum on this issue dated March 6, 1979, recognizing that a single common piping system could pose serious incompatibility problems for chemical and product tank vessels, stated:

> "Under 33 CFR 157.07, which allows equivalents, this office will accept the following:
>
> a. The use of vessel's normal cargo piping and pumping system with the use of cargo jumper hoses at the cargo manifold to connect any tank to the designated slop tank when operationally necessary."

Commandant (G-MMT) concurred with this policy and indicated it would be incorporated into the Marine Safety Manual. To date, this has not been done. At the time, the Memorandum was distributed only to the four Coast Guard Merchant Marine Technical offices and not to the field inspection offices in the various ports.

249. A revision of 33 CFR 157.11(a) published in 48 Federal Register 45720 on October 6, 1983 states:

> ".... On a vessel that has two or more independent piping arrangements, the arrangements collectively form the fixed piping system required by this paragraph."

VINYL CHLORIDE MONOMER/BUTADIENE

250. The PUERTO RICAN's Certificate of Inspection dated June 22, 1984 authorizes the carriage of vinyl chloride monomer (VCM) and butadiene (inhibited) in tanks 3CP, 3CS, 6CP and 6CS. Both products are liquefied flammable gases and their carriage on existing tankships is regulated under 46 CFR Part 38. For the purposes of applying the standards in Part 38, independent tanks 3C and 6C are considered non-pressure vessel type tanks.

251. The vessel was taken out of VCM service sometime in 1978. Independent tanks 3CP, 3CS, 6CP and 6CS were then gas freed and inerted. Neither VCM nor butadiene was carried as cargo on the PUERTO RICAN while Keystone Shipping Co. operated the vessel since February 1982; nor did Keystone carry any other cargoes in those tanks.

252. The Coast Guard inspection for reissuance of the vessel's most recent Certificate of Inspection was conducted during the May-June, 1984 shipyard period. The independent cargo tanks and associated safety and operating equipment for liquefied flammable gases were not inspected at this time because the cargo pumps had been removed from the tanks and liquefied flammable gases were no longer being carried. The following list describes the status of several systems necessary for VCM carriage:

a. The submerged cargo pumps and associated electrical wiring, installed in accordance with 46 CFR 38.10-10 and 38.15-15(d)(5), were removed in 1979 and stored at the PPG plant in Lake Charles, LA.

b. The N_2 supply system, installed in accordance with 46 CFR 38.15-15(d)(2), was inoperative due to removal of the N_2 piping at the N_2 storage tank on deck.

c. The VCM cargo refrigeration system, required by 46 CFR 38.05-25 and 38.05-4(e), was inoperative and disconnected.

d. The analyzer for the ARCUS Leak Detection System, required by 46 CFR 38.15-10, was removed from the vessel in March or April, 1983 but the sampling lines remained in 3CV and 6CV.

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CONCLUSIONS

THE CAUSE AND CONSEQUENCES

1. The breaking in half, sinking of the stern section on November 3, 1984 and total constructive loss of the PUERTO RICAN resulted from explosions and fires occurring in the 6CV and the 4 P/S wing tanks on October 31, 1984.

a. The proximate cause of this casualty was the failure to repair a gouge through the stainless steel cladding on the bulkhead separating 5CP and 6CV. The gouge was most probably made while the tank was being constructed. This exposed the mild steel bulkhead behind it which then corroded due to repeated exposure to caustic soda. The corrosion process created a hole that fully penetrated the 5CP after bulkhead sometime prior to the vessel's arrival at the GATX Terminal, Wilmington, California on October 21, 1984.

b. Approximately 2,500 to 3,000 barrels of caustic soda leaked through the hole from 5CP into 6CV. This amount of caustic soda created a liquid level height in 6CV of approximately 2 feet.

c. Prior to Voyage 238 the interior tank coatings and N_2 purge piping in 6CV were the same as in 3CV. The caustic soda solution which leaked into 6CV during Voyage 238 reacted with the zinc-rich epoxy coating on the bulkheads, tank supports, and deck of 6CV up to a level of approximately 2 feet from the deck, and with the zinc galvanized layer on the N_2 purge piping in 6CV, consuming the zinc and liberating H_2 gas. No other flammable gas was in the atmosphere of 6CV at this time.

d. The Alkane 60 loaded into 5CP on October 28, 1984 also leaked into 6CV through the hole in the 5CP after bulkhead. Based on the time Alkane 60 was loaded, the final ullage and, using the formula in paragraph 208, approximately 1,100 barrels leaked into 6CV. Alkane 60 has a flash point of approximately 280°F. It is less dense than caustic soda solution and therefore, remained on top of the caustic soda in 6CV. Due to the introduction of Alkane 60, the liquid level in 6CV rose from approximately 2 feet to approximately 5.5 feet.

e. Sufficient H_2 was generated in 6CV, by the reaction of caustic soda solution with the zinc-rich epoxy and galvanized piping, to cause the atmosphere in the void to be in the flammable range. This flammable mixture was ignited in 6CV shortly prior to the explosion which inverted the main deck section on October 31, 1984.

f. The ignition source of the H_2/air mixture in 6CV is unknown. The most probable ignition source was a spark within 6CV, either from metal-to-metal contact or from an electrostatic discharge.

g. The ignition of the H_2/air flammable mixture in 6CV did not alone produce a sufficient overpressure within that space to totally lift and invert the main deck above 6C void.

h. The following sequence occurred after ignition of the H_2/air mixture in 6CV:

(1) Sufficient overpressure was produced to rupture the fillet welds between the main deck and the longitudinal bulkhead separating 4PA and 6CV. This overpressure was produced either directly by the H_2/air ignition or indirectly by a subsequent ignition and burning of an Alkane 60 pool fire within 6CV.

(2) Hot gases from the 6CV exhausted into 4PA through the ruptured weld, vaporized sufficient Polybutene 24 in 4PA to produce a flammable environment, and ignited that flammable mixture to produce an explosion in 4PA. This was the first explosion noted by Captain NOLAN.

(3) As a result of the explosion in 4PA, unburned Polybutene 24 was sprayed into the 6CV where it achieved a flammable mixture in the atmosphere, either alone or with vaporized Alkane 60.

(4) The flammable mixture in the atmosphere of 6CV was ignited in the after end of that space either by remaining hot gases or burning Alkane 60.

(5) If the Alkane 60 pool fire did not occur as a result of the ignition of the H_2/air mixture in 6CV, it occurred when the Polybutene 24 was sprayed into 6CV from 4PA. In either case, the overpressure which inverted the entire deck area over 6CV and the adjacent wing tanks resulted from the ignition of unburned Polybutene 24 being sprayed into 6CV.

(6) Sufficient overpressure was produced in 6CV to release the deck above 6CV and the adjacent port and starboard wing tanks and project it forward to land inverted on a centerline axis immediately forward of 6CV.

2. Contributing to the cause of this casualty was the failure of Captain K. Z. WODKA to use all reasonable means to account for the caustic soda discrepancy from 5CP after being notified of it on October 22, 1984.

3. The dispersion characteristics of H_2 gas in the open environment makes on-deck ignition and flashback into 6CV unlikely.

4. Captain JAMES S. NOLAN's testimony concerning the explosion sequence can be compared to the above probable cause scenario in the following manner. The click he heard could have been the release of the welded joint between the deck and the longitudinal bulkhead separating 6CV and 4PA. The "whoosh" could have been the sound of a pressure release through either a PV valve in 4PA or a safety relief valve in 6CV. The first explosion he heard was the explosion in 4PA and the second explsoion he heard was the explosion in 6CV.

5. This casualty was not caused by foul play or sabotage.

6. Due to the explosion, Able Seaman JOHN PENG was thrown overboard along with Captain JAMES. S. NOLAN amd third Mate PHILIP R. LEMPRIERE. Able Seaman JOHN PENG was last seen being hurled overboard toward the water. He is missing and presumed dead as a result of this casualty.

7. Captain JAMES S. NOLAN and Third Mate PHILIP R. LEMPRIERE incurred severe and substantial injuries as a direct result of this casualty.

8. The ship's "back was broken" as a result of the explosions and fire on October 31, 1984. This is evidenced by the early reports on October 31, 1984 of twisting between the bow and the stern sections, the decreasing freeboard of the stern, and the tearing of the hull plating in way of 4P wing tank.

9. Contributing to the breakup of the PUERTO RICAN on November 3, 1984 were the forces that the weather and seas exerted on the vessel during the storm encountered on November 2, 1984.

10. Under the circumstances and the scenario as it subsequently developed, the breaking up of the vessel would still have occurred, even if the firefighting efforts had been more timely and effective.

11. Had environmental considerations not delayed the towing of the vessel into port, the vessel may not have broken in two.

CAUSTIC SODA DISCREPANCY

12. The caustic soda ullage discrepancy for 5CP on Voyage 238 was neither a gauging nor paperwork error, but was due to the leakage of caustic soda solution from 5CP into 6CV. The pre-discharge ullage recorded for 5CP by the Caleb Brett Surveyor on October 21, 1984 was correct. Based on the following figures, caustic soda remained aboard the PUERTO RICAN after the seven tanks into which it was known to be loaded as cargo on Voyage 238 were pumped empty:

a. Ship's Cargo Tank Figures:

LOADED:

	BARRELS
Occidental, Taft, LA.	16,842
PPG, Lake Charles, LA	71,418
	88,260

DISCHARGED:

GATX, San Pedro, CA.	22,145
WLBT, Wilmington, CA.	27,469
GATX, Richmond, CA.	35,794
	85,408
NOT DISCHARGED:	2,938

b. Shore Tank Figures:

LOADED:

	LONG TONS	BARRELS
Occidental, Taft, LA.	4,021	16,808
PPG, Lake Charles, LA.	17,051	71,273
TOTAL	21,072	88,081

DISCHARGED:

GATX, San Pedro, CA.	5,276	22,054
WLBT, Wilmington, CA.	6,550	27,379
GATX, Richmond, CA.	8,549	35,735
TOTAL	20,375	85,168
NOT DELIVERED:	697 LT	2,913 BBL

c. Ullage Table: The above figures are consistent with the data in the ship's ullage table for 5CP, which indicates the difference in ullage between 13'-3" and 23'-1/2" amounts to 2,546 barrels.

d. Formula: The above figures are consistent with the 2,550 barrels which would be obtained using the formula in paragraph 208.

13. The pre-discharge ullages obtained at the GATX Terminal, San Pedro, California should have been compared with the shipboard record of final loading ullages for Voyage 238 at or about the time cargo discharge commenced on October 21, 1984 rather than approximately sixteen hours later. Had this been done, the ullage for 5CP would probably have been verified and the possibility that the ullage was read or recorded incorrectly would have been eliminated. Then a leak in 5CP would probably have been recognized by Captain WODKA to be the most likely reason for the cargo discrepancy. After the other checks for caustic soda leakage were made, 6CV would have been the most

likely remaining place to check for the missing caustic. This would have increased the probability that a positive check of 6CV for caustic soda would have been conducted.

14. If interim ullage readings were taken during the discharge of 5CP to determine discharge rates, they should have provided Captain WODKA sufficient information to ascertain that the cargo discharge from 5CP most probably commenced at a 23-foot ullage range rather than at a 13-foot ullage range.

15. 6CV had not recently been opened or entered and, therefore, was probably not illuminated when Captain WODKA and Captain SPILLANE inspected 5CP for leaks on October 24, 1984. Captain WODKA and Chief Mate SPILLANE used commonly accepted visual inspection procedures when inspecting the cargo tank. They did not detect the hole. However, without light penetrating through it, such as during the after-casualty inspection conducted on January 10, 1985, the hole would have been difficult to find due to its size and its location.

16. There was considerable testimony to indicate that most, if not all, persons on board the PUERTO RICAN thought of 6CV as being inerted because it was Keystone's policy to keep 3C, 6C and associated void spaces inerted to inhibit corrosion. In spite of numerous questions by the Board, no witness could identify when or where these areas may have been inerted subsequent to the May-June 1984 shipyard period. There are no safety regulations or requirements for 6CV to be inerted. The fact that combustion occurred in 6CV indicates it was not inerted at the time of the casualty. This, together with the fact 6CV was "safe for workers" during the May-June 1984 shipyard period, indicates the space probably was not inert on or after October 22, 1984 while the caustic soda cargo discrepancy was being accounted for.

17. In light of this casualty, the vessel construction regulations contained in 46 CFR Part 153 regarding the carrying of caustic soda have been reviewed and are determined to be adequate.

TECHNICAL

18. The fire and explosion damage to the deck over 4PA and to the expansion trunk for 4PA indicate an explosion most likely occurred in 4PA separate from the main explosion which subsequently lifted and inverted the entire deck section.

19. Combustion deposits were present on the fracture surface where the deck had connected to the longitudial bulkhead between 4PA and 6CV. Combustion deposits were not present on other welded areas within 6CV that fractured. This evidence indicates that the deck-to-longitudinal bulkhead welds failed prior to the others.

20. Polybutene and its combustion deposits were on the inverted deck. There were no such deposits on the main deck forward of the inverted deck or on weld areas within 6CV that fractured, other than the fracture surface where the deck had connected to the longitudinal bulkhead between 4PA and 6CV. This evidence indicates these products were deposited during or prior to the main explosion which inverted the deck above 6CV and its adjacent wing tanks. These products were not the result of the subsequent fire in 6CV.

INSPECTIONS AND DRILLS

21. 3CV and 6CV were not inspected either by the Coast Guard or the American Bureau of Shipping during the May-June 1984 inspection period. This was not a factor in this casualty nor was it a violation of any inspection requirements. However, since independent tanks 3C and 6C were authorized on the Certificate of Inspection to carry liquified flammable gas cargoes, they technically required external examination at the Inspection for Certification. To meet this requirement, 3CV and 6CV would have to be entered. The dichotomy here is that the Coast Guard inspector testified that 3C and 6C were treated as voids because they were no longer equipped for the carriage of cargo. Nevertheless, neither entry into nor inspection of 6CV would have revealed the hole, because it had not yet fully penetrated the bulkhead between 5CP and 6CV.

22. The gouge in the stainless steel cladding in way of the corner bracket in the 5CP after bulkhead, and the corroded area behind it, existed and was not detected during a number of internal inspections of this tank conducted by various inspection personnel prior to the corrosion fully penetrating the bulkhead.

23. The location of the hole in the stainless steel cladding in the 5CP after bulkhead is the most probable reason it was not detected during the various inspections of 5CP over the past years. At the inspection of January 10, 1985, there was rust discoloration on the cladding in the area of a number of tiny penetrations of the cladding. However, the cladding did not have a rust discoloration in the vicinity of the hole in the 5CP after bulkhead. A possible explanation is that after the hole penetrated the bulkhead, telltale rust from the mild steel ran into 6CV rather than showing up on the cladding in 5CP. However, it is not known for certain if there was rust discoloration below the hole in the cladding in the 5CP after bulkhead in the previous years during which many assumedly competent persons would have entered this tank. It is assumed that, if telltale rust had evidenced itself below the hole, further investigation would have led to the detection of the hole. A possible explanation why there may not have been rust discoloration by the hole in the cladding is that the corrosion in the mild steel behind the cladding was larger than the hole in the cladding thereby creating a pocket which may have prevented rust discoloration from showing up on the inside of the 5CP tank.

24. The fact that this hole was never detected during any inspections of 5CP prior to the casualty illustrates practical limitations inherent in the inspection of large, complex tank vessels by visual methods, rather than a lack of adequate inspection requirements. However, if the existence of a hole were ever suspected and not found by visual inspection, alternate inspection tests and procedures should have been used.

25. The hazards associated with the cargo transfer of hazardous bulk liquids, the brief port call turn-around times, and the navigating complexities of frequent in-port shifting between terminals makes conducting fire and boat drills difficult for certain tank vessels. The current Federal Regulations not only recognize these constraints but make provisions for them. Therefore, because of the hazards and problems already mentioned, it is more important than ever that Masters of tank vessels make a conscious management evaluation of the options available, record their decisions in their vessels' Log Books and, when appropriate, give the required safety drills special priority. This could result, as an example, in scheduling sufficient time after completion of cargo operations to conduct a lifeboat launching drill, which is required by 46 CFR 35.10-5(d)(5) to be done at least once every three months.

26. Fire and boat drills should have been conducted on a weekly basis. All available personnel not absolutely essential to the operation of the vessel at the time of drills should have been required to fully participate in drills and associated instructions. Had this been done, some of the personnel that did not materially contribute to this emergency response may have demonstrated more initiative and professionalism in reacting to this casualty.

27. Although circumstances may differ and the turnover of officers on the PUERTO RICAN may have been accellerated, personnel rotations occur often on board U.S. merchant vessels. If, as discussed in NVIC 7-82, functional emergency responsibilities for various crew positions were standardized by ship types and used throughout the U.S. merchant marine, personnel response to this emergency may have been more efficient and effective.

28. A casualty such as this should be a typical scenario used for drills on board all tank vessels. Many of the persons on board considered the PUERTO RICAN to be a relatively safe tanker because of the degree of volatility and potential hazard generally associated with the types and grades of cargoes it carried. This casualty points out the wide variety of potentials for a cargo fire and explosion on board vessels carrying bulk liquid cargoes.

CERTIFICATES

29. The reference to NVIC 1-83 contained on the June 30, 1983 amendment to the COI issued on October 31, 1981 by OCMI Mobile, Alabama was in error. This reference should have been NVIC 1-81.

30. The OCMI Philadelphia, Pennsylvania thought that the cargo piping on the PUERTO RICAN did not comply with Regulations for the Prevention of Pollution by Oil, MARPOL 73/78, or 33 CFR 157.11. For this reason, he issued a "Form A" Supplement to the IOPP Certificate rather than the "Form B". This may also have been the basis for the "other than oil" restriction initially issued by OCMI Mobile, Alabama on a COI amendment issued June 30, 1983. OCMI Philadelphia, Pennsylvania cargo entries on the COI dated June 22, 1984 may have been influenced by the entries on the vessel's previous COI and by the fact that the "other than oil" restriction was apparently not questioned or appealed by Keystone Shipping Company.

31. The Marine Safety Information System (MSIS) entry indicating this vessel was equipped with high capacity tank washing machines was in error. Applicable regulations require 20,000 to 40,000 DWT product carriers to be equipped with a cargo tank inert gas system only if high capacity tank washing equipment is used. This vessel was not equipped with an inert gas system for the liquid bulk product cargo tanks. Therefore, this fact together with the erroneous MSIS entry regarding tank washing machines was probably the basis for the "other than oil" restriction initially issued by the OCMI, Mobile, Alabama on the COI Amendment dated June 30, 1983.

32. The vessel met applicable cargo slop tank and piping requirements for the carriage of "oil other than crude oil" during the May-June, 1984 Inspection for Certification, in that any of the vessel's cargo tanks could have received cargo oil residues from any other cargo tank by using jumper cargo hoses between separate cargo piping systems. This piping arrangement complied with the October 6, 1983 revision of 33 CFR 157.11(a) and the March 6, 1979 Policy File Memorandum issued on this subject by the Third Coast Guard District Merchant Marine Technical Office.

33. The March 6, 1979 Policy File Memorandum on the subject of cargo piping systems on chemical and product carriers, originated by the Coast Guard's Third District Merchant Marine Technical Office and concurred with by Coast Guard Headquarters, should have been distributed to Coast Guard Marine Safety and Coast Guard Marine Inspection Offices as interim guidance for plan reviews and inspections for compliance with 33 CFR 157.11.

34. The second sentence in 33 CFR 157.11(a), added on October 6, 1983 by being published in Volume 48 Federal Register Page 4572, is not clear as to meaning or intent.

35. The PUERTO RICAN met applicable regulations and Coast Guard policy for the carriage of "oil other than crude oil". The cargo authorization entry on the vessel's Certification of Inspection issued June 22, 1984, restricting carriage to cargoes "other than oil", was in error. The vessel did not meet applicable regulations for the carriage of "crude oil".

36. There was a discrepancy between the inspection completion date of June 22, 1984 shown on the Coast Guard Certificate of Inspection and the June 23, 1984 date shown on the Hull and Machinery Inspection books. This occurred because the vessel was scheduled to complete inspection on Friday, June 22, 1984 and the Certificate of Inspection was typed and signed at the Marine Inspection Office, Philadelphia, Pennsylvania on or before that date. The dated and signed COI was then sent to the Coast Guard Inspectors for delivery when the vessel completed the Inspection for Certification. The inspection extended to June 23, 1984. If only minor items remained to be completed on June 23, 1984, the inspection record books could have reflected completion of the inspection on June 22, 1984 with outstanding requirements; otherwise, the date on the Certificate of Inspection should have been changed to June 23, 1984. This administrative matter was not material to this casualty.

THE CASUALTY

37. Of the twenty-six persons remaining on the PUERTO RICAN after the initial explosion, approximately half can be accounted for as participating in the firefighting, lifeboat and liferaft launching, and engineering efforts. Therefore, the total emergency response action was less than optimum.

38. Of the officers and the crewmembers in the Deck Department, only Boatswain SMITH can be identified as initially reporting to the same station during the actual casualty as assigned on the Watch, Quarter and Station Bill. No person in the Steward Department could be accounted for as reporting to his emergency station or otherwise participating in emergency response efforts. Though the Board did not seek specific testimony on the relationship between assigned emergency stations and the actual response locations of members of the Engine Department, the Engineering personnel worked cohesively, succeeded in keeping electrical power available, and eventually got the firefighting water on line.

39. Adequate water pressure to the firemains in the deckhouse became available approximately 20 to 30 minutes after the explosion. The foam system came on-line approximately fifteen minutes after that.

40. Once properly on-line, both the firemain and the foam system worked satisfactorily.

41. The incorrect simultaneous application of water from the fire hoses and foam solution from the monitors diluted the intended effect of the foam solution.

42. Only three of the available 17 hose fire stations were used in the effort to combat the fire. Combinations of hoses from additional fire stations either prior to application of the foam or after the foam supply was spent and the fire was still burning, might have increased the effectiveness of the firefighting effort.

43. Captain SPILLANE never gave the order to abandon ship. This process was evolutionary and resulted from individual decisions or orders from others.

44. The commands to lower the lifeboats and launch the liferaft were given by persons other than the Master. This, coupled with the failure to take a muster or otherwise account for the number of persons disembarking the vessel, could have been a critical element had the lifeboats or liferaft been required as the primary means of abandoning ship.

45. Had standard abandon ship signals and procedures been used and followed by all personnel, the launching of primary lifesaving equipment would probably have been better organized and the likelihood of the starboard lifeboat being launched and drifting away with only one person on board would probably have been reduced.

46. There was difficulty in lauching the liferaft because of its weight and the impediment of the rail. However, except for casualty damage that had to be corrected or compensated for, all primary lifesaving and firefighting equipment worked satisfactorily and to the standards required by applicable regulations.

47. The assisting resources were taking all necessary and appropriate action to search and account for the PUERTO RICAN's personnel who had been hurled into the water by the explosion as well as those subsequently evacuating the vessel. Captain SPILLANE was aware of the efforts being made to rescue the people hurled into the water and, therefore, appropriately focused his attention on the numerous problems confronting him on the vessel.

48. Under the circumstances, aggravated by the recent reassignment and replacement of Deck Officers, Captain SPILLANE's constant movement about the ship to direct emergency response activity rather than remaining on the Bridge, his normal station for an emergency, was appropriate.

49. Had the officers carried radios during this emergency, as was the practice during fire and boat drills, communications and coordination of the response effort would have been improved.

50. Had this casualty occurred under more severe weather and sea conditions and/or in a location remote from immediate outside assistance, the lifeboat launching control and procedures used on October 31, 1984 may have resulted in additional injury and possible loss of life while abandoning the vessel.

51. The PUERTO RICAN was in compliance with applicable Federal Communications Commission regulations, including the number and types of radios and antennas on board.

52. The UHF radio capability from the Radio Room was rendered inoperative because the UHF antennas were destroyed by the force and effect of the explosion.

53. Had this casualty occurred beyond the communication range of the VHF radio on the bridge, the radio communications could not have been established until a jury-rig UHF antenna was erected. This would have taken considerable time.

54. The high percentage of officer turnover and reassignments coupled with the failure to conduct emergency drills while the vessel was on the West Coast during October, 1984 were factors contributing to the less than optimal emergency response actions, coordination, and control. However, given these factors, the damage to firefighting systems, and the perceived potential for subsequent explosions, many of the officers and crew demonstrated a high degree of individual professionalism and heroism.

55. Characteristics commonly associated with caustic soda solution include: not flammable; stable; slightly toxic; very corrosive to some metals; severe skin irritant; causes burns on short contact with skin and is very injurious to the eyes. The corrosive effect of caustic soda solution on metals such as zinc and aluminum is more commonly known by most laymen and/or professionally qualified "tankermen" than the fact that its reaction with these metals can produce hydrogen gas. This was evidenced on the PUERTO RICAN in that few, if any, persons on board were aware of or concerned about the possible generation of H_2 in trying to account for and ascertain whether caustic soda may have leaked from 5CP to any adjacent tanks, some of which were coated with zinc-rich epoxies. Therefore, a lesson to be learned from this casualty is that considerations other than cargo compatibility must be a concern when bulk liquid cargo accountability becomes a factor.

COMMENDATORY AND OTHER ASPECTS

56. There is evidence of a literal violation of 46 USC 3311 for operating the vessel from it's layup location at Girard Point, Philadelphia, Pennsylvania to Pennsylvania Shipbuilding Co., Chester, Pennsylvania during May, 1984 without a valid Coast Guard Certificate: i.e., a Permit to Proceed.

57. There is evidence of violation of 46 CFR 31.01-15 by the Master, owner, or agent of the PUERTO RICAN in that a written Application for Inspection, form CG-3752, for the Coast Guard Biennial Inspection conducted during May-June 1984 was not submitted. A written Application for Inspection may have drawn the attention of the Coast Guard, the vessel's owner, and/or its operator to the questionable Certificate of Inspection entries pertaining to cargoes "other than oil" and VCM/Butadiene. Although these issues were not material to the cause of this casualty, a written application may have led to a clarification and resolution of whether there was VCM cargo residue on board and that "other than oil" was not intended to mean "other than crude oil".

58. Because of the removal of various safety systems, the PUERTO RICAN was no longer in compliance with U.S. regulations for the carriage of vinyl chloride monomer and butadiene (inhibited). Authorization to carry these cargoes should not have been included on the COI dated June 22, 1984. This error did not contribute to the casualty.

59. There is evidence that, since the PUERTO RICAN was carrying cargoes of lubricating oils and lubricating oil additives, it was operated in literal violation of the vessel's Coast Guard Certificate of Inspection dated June 22, 1984. However, the vessel did meet the applicable requirements for the carriage of these cargoes. This matter has been referred to Commander, Twelfth Coast Guard District for further investigation and action, if appropriate.

60. There is evidence of negligence on the part of MR. JAMES C. SPILLANE, the Chief Mate on October 21, 1984, at which time 5CP was gauged and cargo discharge commenced, for failing to compare pre-discharge ullages with the final loading ullages of 5CP for Voyage 238. This matter has been forwarded to the Commander, Twelfth Coast Guard District for further investigation under the suspension and revocation procedures.

61. There is evidence of negligence on the part of the Master, K. Z. WODKA, for failing to use all reasonable measures, while determining the basis for the possible ullage discrepancy in 5CP reported to him on October 22, 1984, to determine whether or not any cargo leaked from 5CP into 6CV. This matter has been forwarded to the Commander, Twelfth Coast Guard District for further investigation under the suspension and revocation procedures.

62. There is evidence of violation of 46 CFR 35.10-5(d) and 46 CFR 35.10-5(f) on the part of Captain K. Z. WODKA for failing to either conduct a fire and boat drill once each week during the period October 1 to October 30, 1984 or to make a log entry each week as to why such drills were not held. This matter has been forwarded to the Commander, Twelfth Coast Guard District for

further investigation under the suspension and revocation procedures.

63. Based on a verbal complaint, the Marine Safety Office San Francisco Bay, California became aware of and subsequently investigated activities being directed against and adversely impacting on the PUERTO RICAN in the Bay Area. Although a written complaint was not received, appropriate action should have been taken concerning actions that directly and adversely impacted upon the safety of the PUERTO RICAN and persons on board. This matter has been referred to Commander, Twelfth Coast Guard District for further investigation and action as appropriate.

64. It is not the purpose of this investigation to make judgement on valid labor-management concerns nor does the Board question the validity of the collective bargaining process or the right to picket as a part of that process. However, the right to picket and the manner in which it is conducted must be balanced against the rights of others to go about their business safe from harm, whether real or perceived. No evidence was found to indicate union picketing activities directed against this vessel caused or contributed to the cause of this casualty. However, certain actions against the PUERTO RICAN and her crew in the Bay Area had a direct adverse impact on the safety of this vessel, and verbal threats and threatening actions had an indirect adverse impact on the safety of this vessel by affecting the ability of the officers and crew to carry on their normal responsibilities to the best of their abilities.

65. There is evidence of violation of 18 U.S.C. 2275 on the part of the International Organization of Master, Mates and Pilots or its subordinate organization or individual members thereof for commission of the following acts which endangered the safety of this vessel:

a. Direct actions toward preventing the vessel from being moored to Encinal Terminal, Alameda, California on October 25 and 26, 1984.

b. Removal of the vessel's mooring line from either a cleat or a bollard on the dock at Encinal Terminal on October 25, 1984.

c. Action directed toward cutting one of the vessel's mooring lines at Encinal Terminal on October 26, 1984.

d. An unauthorized boarding of the vessel's rudder at the Encinal Terminal on October 26, 1984.

e. Assault through verbal threats and threating actions directed against the safety of the vessel and its crew members at Encinal Terminal from October 25 to 28, 1984.

f. Threatening words and gestures toward the Operator and crew of the tug assisting the PUERTO RICAN on October 30,1984 and the throwing of an object from the boat GEORGE MEANY toward the tug on that occasion.

This matter has been forwarded to Commander, Twelfth Coast Guard District for further investigation and action, if appropriate, under criminal penalty procedures.

66. There is evidence of violation of International Regulations for Preventing Collisions at Sea, 1972 (COLREGS), Rule 5, as authorized by 33 USC 1602 on the part of Captain JAMES C. SPILLANE for his failure to maintain a proper lookout at approximately 0324 on October 31, 1984 by permitting AB PENG, the designated lookout, to be engaged in duties other than acting exclusively as a lookout, to be improperly stationed to do his lookout duties, and to not be actually and vigilantly employed in the performance of those duties. This matter has been forwarded to the Commander, Twelfth Coast Guard District for further investigation under the suspension and revocation procedures.

67. The efficiency and effectiveness of the man overboard retrieval system on the Pilot boat SAN FRANCISCO materially contributed to saving the lives of Captain JAMES S. NOLAN and Third Mate PHILIP R. LEMPRIERE once they were in the water.

68. There is evidence of Commendatory Action on the part of:

a. Able Seaman DAVID ROMAN for his overall response and initiative and for his tenacity in manning foam monitors 5 and 6 at great personal risk.

b. Captain MORRIS MORTON and the crew of the HARRY M for, on their own initiative, travelling 7-1/2 miles to the site of the casualty and for their on-scene assistance in evacuating twenty-one of the twenty-six survivors from the vessel under hazardous circumstances.

c. The Operator and crew of the Pilot boat SAN FRANCISCO for assistance provided following this casualty, for the rescue of Captain JAMES S. NOLAN and Third Mate PHILIP R. LEMPRIERE from the water, and for their efforts in searching for Able Seaman JOHN PENG.

d. The Craftmasters, crews, and on-scene supervisors of the three U. S. Navy YTB's for responding to this emergency with minimal personnel and for providing extended fire fighting assistance in the open sea, an environment in which the vessels are not currently intended to operate.

e. The Coxswains and crews of the USCG YTB's 41403, 41404, 44347, and 30606 in maintaining hazardously close positions alongside the burning PUERTO RICAN to achieve maximum benefit from their limited fire fighting capability, which was less than adequate for these emergency conditions.

f. The Operator and crew of the fireboat CITY OF OAKLAND, a vessel currently not designed to operate beyond the protected waters of the San Francisco Bay and its tributaries. With MR. GEORGE LEE as the Operator and with an augmented crew of seven other firefighters, it promptly responded to the request for assistance in an area beyond the geographic boundaries of its mutual aid responsibilities. By its actions, it significantly contributed to the overall firefighting effort.

These matters have been referred to Commander, Twelfth Coast Guard District for review and action as appropriate.

69. Conclusions 21, 30, 32, 35, 36, and 58 contain evidence of administrative or procedural errors by Coast Guard personnel in the inspection and certification of the PUERTO RICAN. These matters have been referred to Commander, Third Coast Guard District for further investigation and action as appropriate.

70. Except as noted 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 this casualty.

RECOMMENDATIONS

1. That regulations pertaining to stowage and location of primary lifesaving equipment be reviewed and consideration be given toward revising same so that launching inflatable liferafts will not require them to be lifted manually over a rail. This could be facilitated by requiring a removable section of railing at the liferaft station.

2. That a copy of this report be furnished to the Federal Communications Commission for consideration of the following proposals pertaining to the antenna systems aboard tankers:

a. That the emergency long wire antenna be positioned so that if the cargo tank area is involved in a fire and explosion the probability of the emergency antenna system sustaining damage is minimized.

b. If tankers have both main and emergency long wire antennas leading forward above the cargo tank area, an additional vertical or whip antenna be required.

3. That this report be given wide dissemination to tank ship owners/operators and to maritime training schools.

4. That the Commandant review NVIC 7-82 in light of the lessons learned regarding the firefighting and lifeboat launching evolutions employed in coping with the results of this casualty and consider eliminating the discretionary compliance aspect of the procedure discussed in this NVIC.

5. That the Commandant review 33 CFR 157.11(a) with a view toward revising it to clarify its meaning and/or intent; or publish policy guidance on this matter in the Marine Safety Manual.

6. That the Commandant evaluate the man overboard retrieval system used on the pilot boat SAN FRANCISCO with a view toward describing and commenting on this system in appropriate publications.

7. That no further action be taken regarding Conclusion 56, operating the vessel without a Permit to Proceed, because of the nature and circumstances of the movement, the geographical areas and minimum distance involved, and the constructive approval of the Officer In Charge, Marine Inspection in whose area the entire movement took place.

8. That no further action be taken regarding Conclusion 57 against the Master, owner or agent of the vessel for failing to submit an Application for Inspection because of the Coast Guard's constructive knowledge.

9. That the applicability of 18 USC 2275 and its compatibility with 46 CFR 5.03-20(a) in this case be given wide dissemination at the appropriate Coast Guard resident training courses so that Coast Guard personnel responsible for responding to similar incidents have a better understanding of policy, their law enforcement responsibilities, and the rights of the parties.

10. That a copy of this report be forwarded to the International Maritime Organization.

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11. That this casualty investigation be closed.

ROBERT A. JANECEK
Captain, U.S. Coast Guard
Chairman

ANTHONY L. ROWEK
Ph.D., U.S. Coast Guard
Member

JAMES J. McCARTIN
Commander, U.S. Coast Guard
Member and Recorder

APPENDICES

TABLE 1

CARGO LOADING PLAN

WING TANKS	VOYAGE 238A	VOYAGE 238	VOYAGE 237A
1P	SLOPS	300 NEUTRAL OIL {S}	ALKANE 56 {C}
1S	SLOPS	300 NEUTRAL OIL {S}	ALKANE 56 {C}
2PF	PALE OIL 325 {C}	100 NEUTRAL OIL {E}	PARAFFIN WAX 143 {C}
2PA	PALE OIL 325 {C}	100 NEUTRAL OIL {E}	PARAFFIN WAX 143 {C}
2SF	EMPTY	100 NEUTRAL OIL {S}	PARAFFIN WAX 143 {C}
2SA	OLOA 247E {C}	100 NEUTRAL OIL {S}	PARAFFIN WAX 143 {C}
3P	ALKANE 56 {C}	PERCHLOROETHYLENE {P}	ALKANE 60 {C}
3S	ALKANE 60 {C}	1,1,1, TRICHLOROETHANE {P}	ALKANE 56 {C}
4PF	EMPTY	100 NEUTRAL OIL {S}	EMPTY
4PA	POLYBUTENE 24 {C}	100 NEUTRAL OIL {S}	POLYBUTENE 24 {C}
4SF	OLOA 2468 {C}	100 NEUTRAL OIL {S}	EMPTY
4SA	OLOA 2468 {C}	100 NEUTRAL OIL {S}	OLOA 247E {C}
5P	2033TR 300 {W}	100 NEUTRAL OIL {S}	EMPTY
5S	2033TR 300 {W}	100 NEUTRAL OIL {E}	EMPTY
CENTER TANKS			
1C	2033TR 300 {W}	CAUSTIC SODA {P}	PALE OIL 20 {C}
2CP	PROPYLENE TETRAMER {C}	CAUSTIC SODA {O}	ALKANE 60 {C}
2CS	PROPYLENE TETRAMER {C}	CAUSTIC SODA {O}	ALKANE 60 {C}
3CP & 3CS	EMPTY	EMPTY	EMPTY
4CP	EMPTY	CAUSTIC SODA {P}	EMPTY
4CS	EMPTY	CAUSTIC SODA {P}	EMPTY
5CP	ALKANE 60 {C}	CAUSTIC SODA {P}	EMPTY
5CS	ALKANE 56 {C}	CAUSTIC SODA {P}	EMPTY
6CP & 6 CS	EMPTY	EMPTY	EMPTY
7CP	CAUSTIC HEEL {P}	CAUSTIC SODA {P}	ALKANE 56 {C}
7CS	CAUSTIC HEEL {P}	CAUSTIC SODA {P}	ALKANE 56 {C}

MANUFACTURER:

C = CHEVRON U.S.A., Inc.
E = EXXON CORPORATION
O = OCCIDENTAL CHEMICAL CORPORATION
P = PPG INDUSTRIES
S = SUN OIL COMPANY
W = WITCO CHEMICAL CORPORATION

TABLE 2

SAMPLES ANALYZED

SAMPLE NUMBER	DESCRIPTION	SOURCE
1	Black residue from ship	Access trunk to 4PA at frame 55 1/2
2	Black residue from ship	Upperside of the inverted deck in the aft/starboard corner of 6CV at frame 54 1/2
3	Black residue from ship	Upperside of the inverted deck, flange at frame 55 near centerline at the aft end of 6CV
4	Black residue from ship	Upperside of the inverted deck in the forward starboard corner of 4PA at frame 58 3/4
5	Black residue from ship	Upperside of the inverted deck, flange at frame 63 near centerline in the forward end of 6CV
6	Black residue from ship	Upperside of the inverted deck, in 6CV several feet starboard of centerline just aft of the expansion trunk at frame 57 1/4
7	Black residue from ship	Upperside of the inverted deck, flange at frame 59 near centerline at the mid-length of 6CV
8	Soot from polybutene	Control
9	Soot from Alkane 56	Control
10	Residue from Alkane 56 with insulation material	Control
11	Residue from Alkane 60	Control
12	Residue from polybutene	Control

13	Residue from polybutene with soot	Control
14	Grey powder residue	Upperside of the inverted deck, several sites between frames 62 and 63 in the forward end of 6CV
15	Soot from OLOA 246B	Control
16	Residue from OLOA 246B	Control
17	Clear white liquid	Pilot Boat
18	Milky sample	Pilot Boat
19	Alkane 60, from loading of vessel	USCG
20	Polybutene 24, from loading of vessel	USCG
21	Exemplar Alkane 56	Chevron
22	Exemplar Alkane 60	Chevron
23	Exemplar Polybutene 24	Chevron
24	Sample of oily surface layer on liquid found in the interior of Tank #6 Center Port	USCG

TABLE 3

CSS — CAUSTIC SODA SOLUTION

Common Synonyms
Sodium hydroxide solution
Lye

Thick liquid | Colorless | Odorless

Sinks and mixes with water.

AVOID CONTACT WITH LIQUID. Keep people away.
Wear rubber overclothing (including gloves).
Stop discharge if possible.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Not flammable.

Exposure

CALL FOR MEDICAL AID.
LIQUID
Will burn skin and eyes.
Harmful if swallowed.

Remove contaminated clothing and shoes.
Flush affected areas with plenty of water.
IF IN EYES, hold eyelids open and flush with plenty of water.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.
DO NOT INDUCE VOMITING.

Water Pollution

Dangerous to aquatic life in high concentrations.
May be dangerous if it enters water intakes.

Notify local health and pollution control officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Issue warning—corrosive
Restrict access
Disperse and flush

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Sodium hydroxide solution; Lye
3.2 **Coast Guard Compatibility Classification:** Caustic
3.3 **Chemical Formula:** $NaOH—H_2O$
3.4 **IMCO/United Nations Numerical Designation:** 8.0/1824

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** None

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Wide-brimmed hat; safety goggles with rubber side shields; tight-fitting cotton clothing; rubber gloves under shirt cuffs; rubber boots and apron.
5.2 **Symptoms Following Exposure:** Causes severe burns of eyes, skin, and mucous membranes.
5.3 **Treatment for Exposure:** (Act quickly!) EYES: flush with water at once for at least 15 min. SKIN: flush with water, then rinse with dilute vinegar (acetic acid). INGESTION: give water and milk. Do NOT induce vomiting. Call physician at once, even when injury seems to be slight.
5.4 **Toxicity by Inhalation (Threshold Limit Value):** Not pertinent
5.5 **Short-Term Inhalation Limits:** Not pertinent
5.6 **Toxicity by Ingestion:** Grade 2; oral rabbit LD_{50} = 500 mg/kg
5.7 **Late Toxicity:** None
5.8 **Vapor (Gas) Irritant Characteristics:** Not pertinent
5.9 **Liquid or Solid Irritant Characteristics:** Severe skin irritant. Causes second- and third-degree burns on short contact and is very injurious to the eyes.
5.10 **Odor Threshold:** Not pertinent

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable
6.2 **Flammable Limits in Air:** Not flammable
6.3 **Fire Extinguishing Agents:** Not pertinent
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** Not flammable
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** Not flammable

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction
7.2 **Reactivity with Common Materials:** Corrosive to aluminum, zinc, and tin. Contact with some metals may generate hydrogen gas, which is explosive and flammable.
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Dilute with water, rinse with dilute acetic acid.
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 125 ppm/96 hr/mosquito fish/TL_m/fresh water
180 ppm/23 hr/oysters/lethal/salt water
(These figures are for 100% sodium hydroxide)
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** None
8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Diamond Shamrock Corp.
Electrochemicals Division
Painesville, Ohio 44077
2. Dow Chemical Co.
Midland, Mich. 48640
3. PPG Industries, Inc.
Industrial Chemicals Division
Barberton, Ohio 44203

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** 50-73%
10.2 **Storage Temperature:** Ambient or elevated
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Open

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-P

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Corrosive material
12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	0
Health	
Vapor Irritant	0
Liquid or Solid Irritant	4
Poisons	1
Water Pollution	
Human Toxicity	2
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	4
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	3
Flammability (Red)	0
Reactivity (Yellow)	1

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid
13.2 **Molecular Weight:** Not pertinent
13.3 **Boiling Point at 1 atm:** >266°F = >130°C = >403°K
13.4 **Freezing Point:** Not pertinent
13.5 **Critical Temperature:** Not pertinent
13.6 **Critical Pressure:** Not pertinent
13.7 **Specific Gravity:** 1.5 at 20°C
13.8 **Liquid Surface Tension:** Not pertinent
13.9 **Liquid-Water Interfacial Tension:** Not pertinent
13.10 **Vapor (Gas) Specific Gravity:** Not pertinent
13.11 **Ratio of Specific Heats of Vapor (Gas):** Not pertinent
13.12 **Latent Heat of Vaporization:** Not pertinent
13.13 **Heat of Combustion:** Not pertinent
13.14 **Heat of Decomposition:** Not pertinent
13.15 **Heat of Solution:** Not pertinent
13.16 **Heat of Polymerization:** Not pertinent

(Continued on pages 5 and 6)

NOTES

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TABLE 4

GLOSSARY OF TERMS REGARDING TANKS

1C	Number 1 center cargo tank.
1P/S	Number 1 port wing and number 1 starboard wing cargo tanks.
1P D/B	Number 1 port double bottom ballast tank.
1S D/B	Number 1 starboard double bottom ballast tank.
2CP	Number 2 center port cargo tank.
2CS	Number 2 center starboard cargo tank.
2C P/S	Number 2 center port and number 2 center starboard cargo tanks.
2P F/A	Number 2 port cargo tank, which is divided into a forward and an after section.
2S F/A	Number 2 starboard cargo tank, which is divided into a forward and an after section.
2P/S F/A	Number 2 port and number 2 starboard cargo tanks, each of which is subdivided into forward and after sections.
3CV	Number 3 center void: the void space, which ranges from 2' to 5', between number 3 center integral tank and number 3 center independent tank.
3C	Number 3 center independent cargo tank.
3P	Number 3 port wing cargo tank.
3S	Number 3 starboard wing cargo tank.
3C P/S	Number 3 center independent cargo tank, which is subdivided by a centerline bulkhead into a port and a starboard side.
4 PC	Number 4 center port cargo tank.

4CS	Number 4 center starboard cargo tank.
4C P/S	Both the above tanks.
4P F/A	Number 4 port wing cargo tank, which is subdivided into a forward and an after section.
4S F/A	Number 4 starboard wing cargo tank, which is subdivided into a forward and an after section.
4 PA	Number 4 port wing cargo tank, after section.
4 PF	Number 4 port wing cargo tank, forward section.
4 P/S F/A	Numbers 4 port and starboard cargo tanks, each of which is subdivided into forward and after sections.
5P	Number 5 port wing tank.
5S	Number 5 starboard wing tank.
5CP	Number 5 center port cargo tank.
5CS	Number 5 center starboard cargo tank.
5P/S	Number 5 port wing and number 5 starboard wing cargo tanks.
6CV	Number 6 center void; the void space, which ranges from 2' to 5', between number 6 center integral tank and number 6 center independent cargo tank.
6C	Number 6 center independent cargo tank.
6C P/S	Number 6 center independent tank, which is subdivided by a centerline bulkhead into a port and a starboard side.
7C P/S	Number 7 center port and number 7 center starboard cargo tanks.

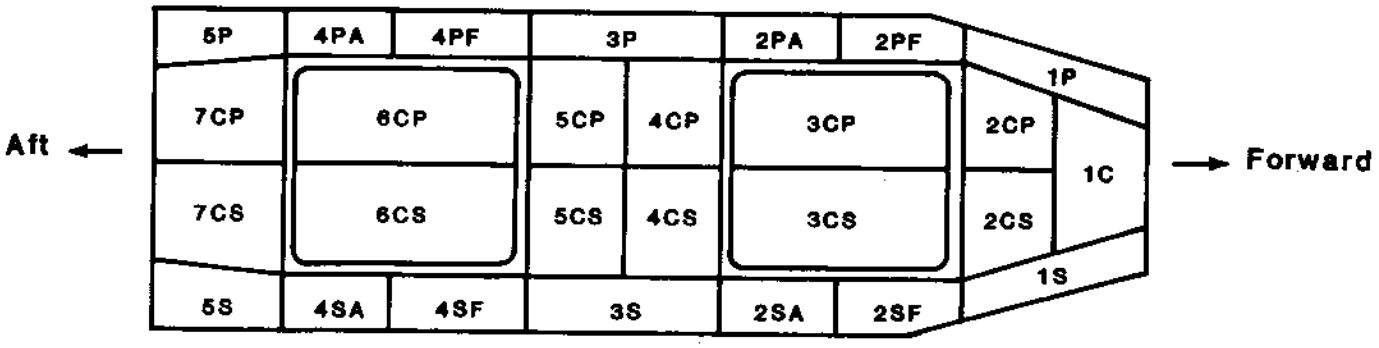


Figure 1. Schematic plan of cargo tanks on the S.S. Puerto Rican.

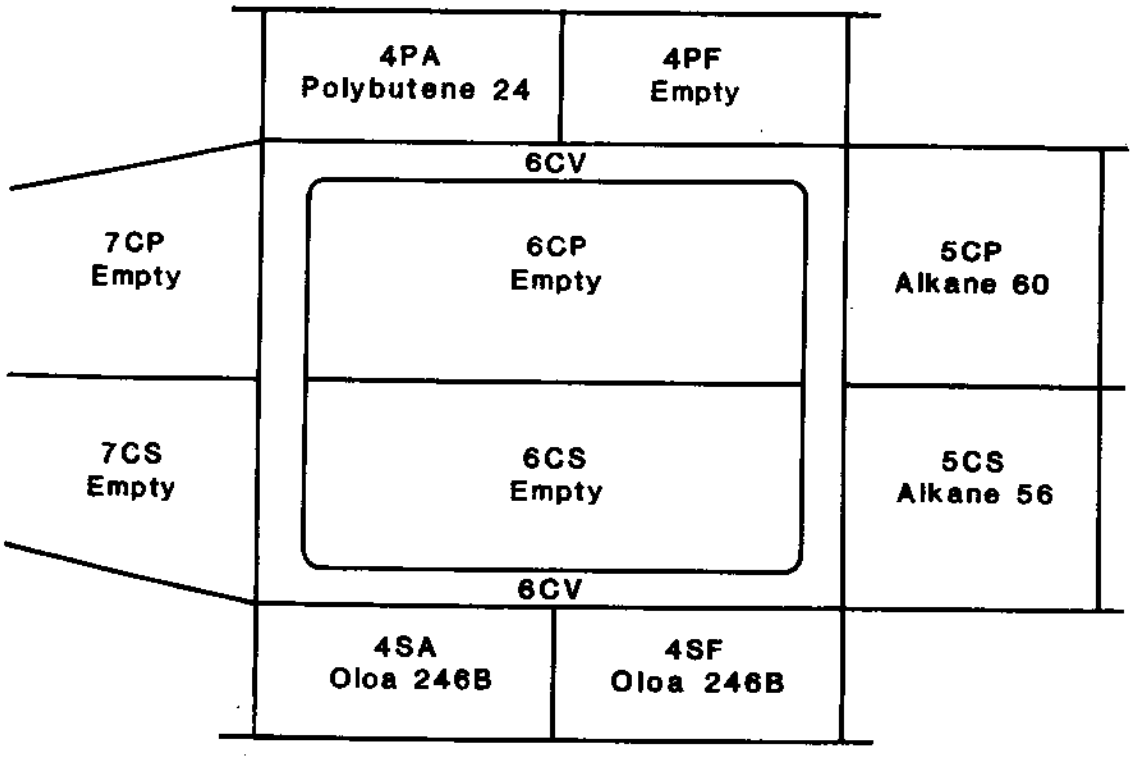


Figure 2. Cargoes in the tanks adjacent to 6CV, at the time of the casualty.

(FaAA Drawing)

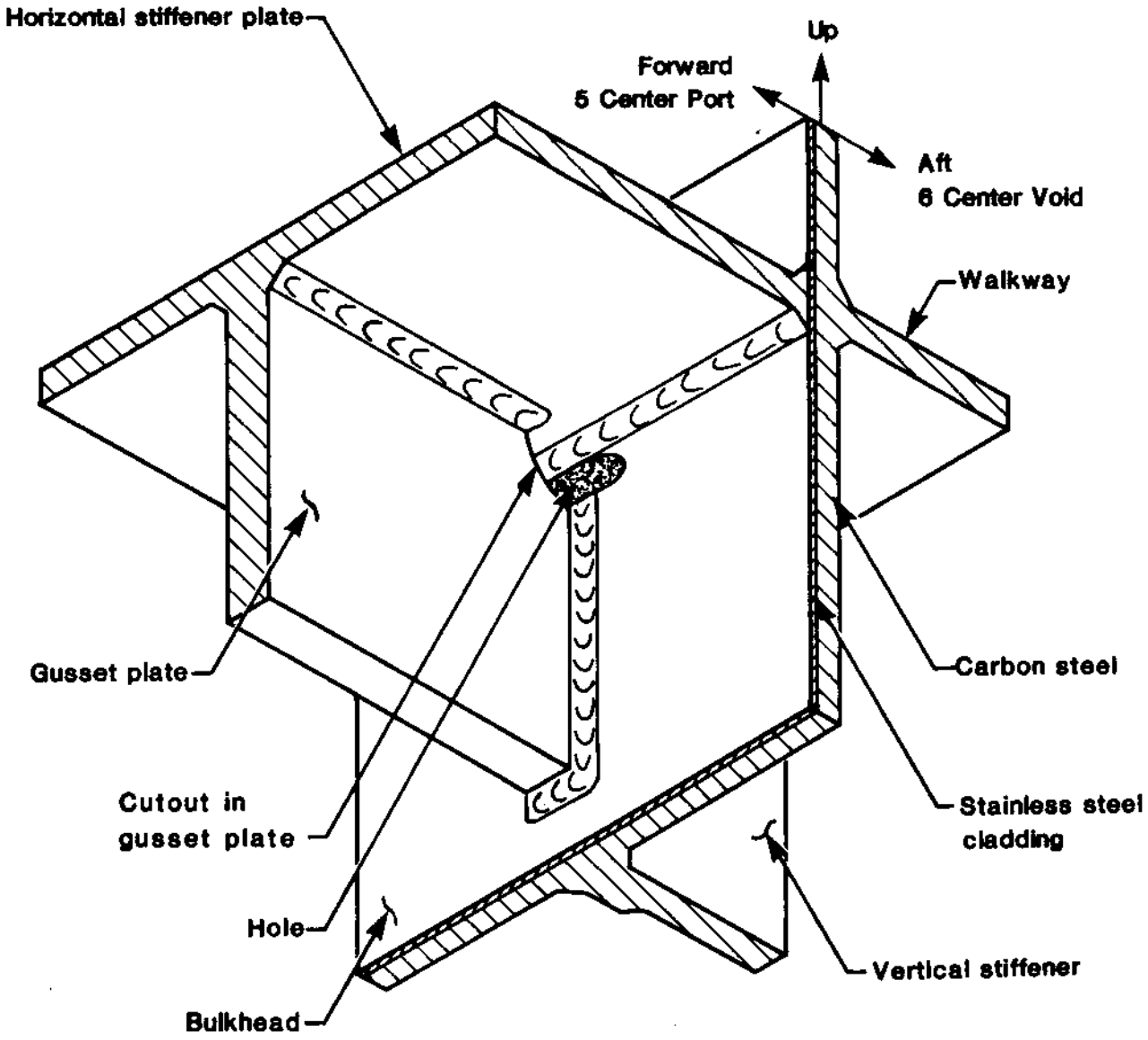


Figure 3. Sketch of hole in bulkhead between Tanks 5 Center Port (5CP) and 6 Center Void (6CV) for Case 1, seen from inside Tank 5CP below the hole.

(FAA Drawing)

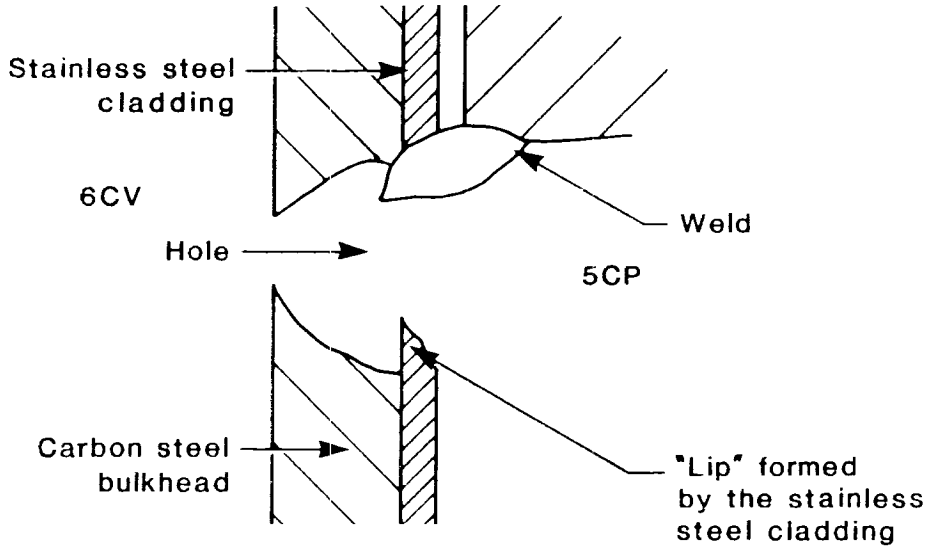


Figure 4. Schematic vertical cross section of the hole in the bulkhead between 6CV and 5CP.

(FaAA Drawing)

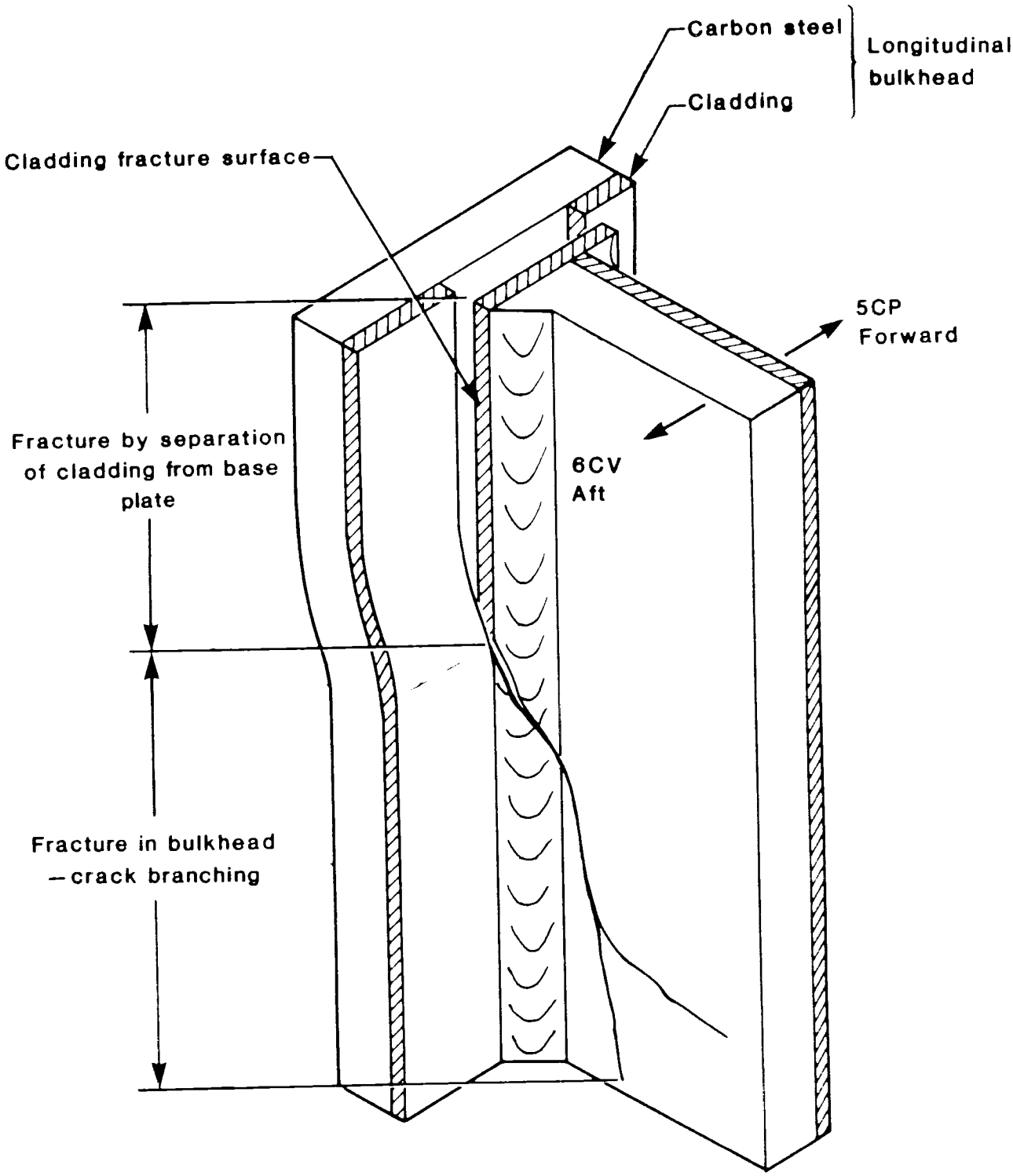


Figure 5. Sketch of different fracture paths in Cases 2 and 3.

(FaAA Drawing)

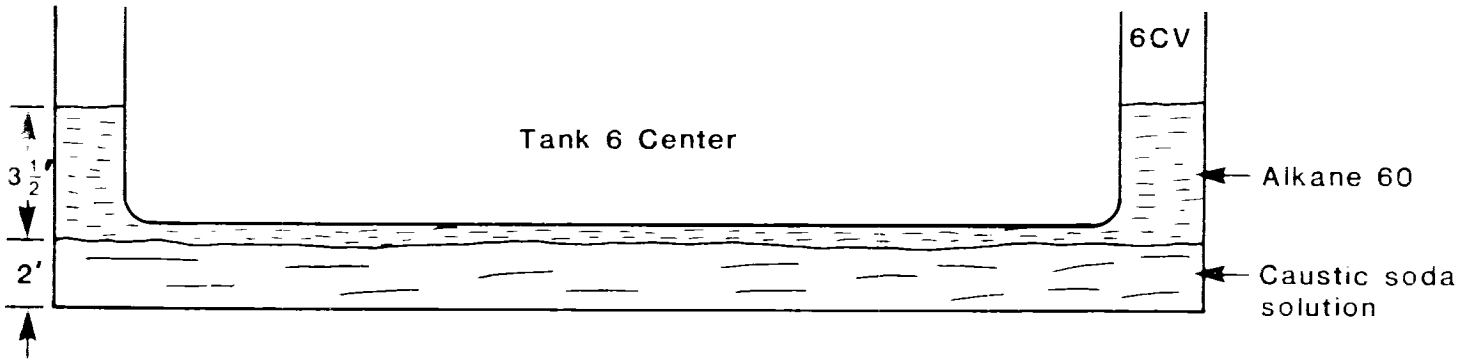
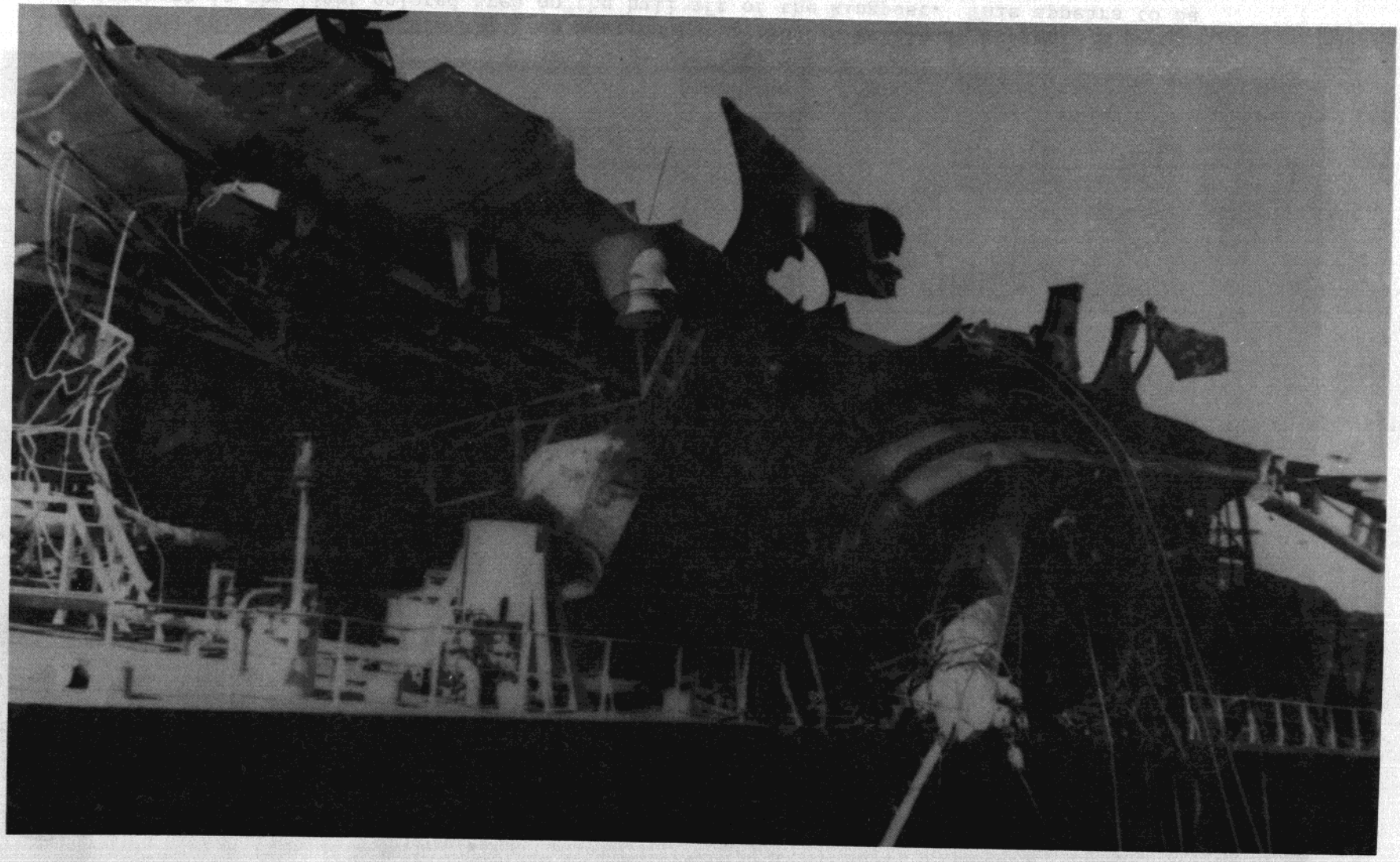


Figure 6. Schematic showing caustic soda solution and Alkane 60 in 6CV shortly before the casualty.

(FaAA Drawing)

PHOTOGRAPH #1: The S.S. PUERTO RICAN on September 11, 1984 in Portland, Oregon. A point of interest is the light colored area on the hull aft of the kingpost. This appears to be in way of the number 4 port wing tanks. The Board could not determine the reason for this discoloration. (LAARS Photography Photo)



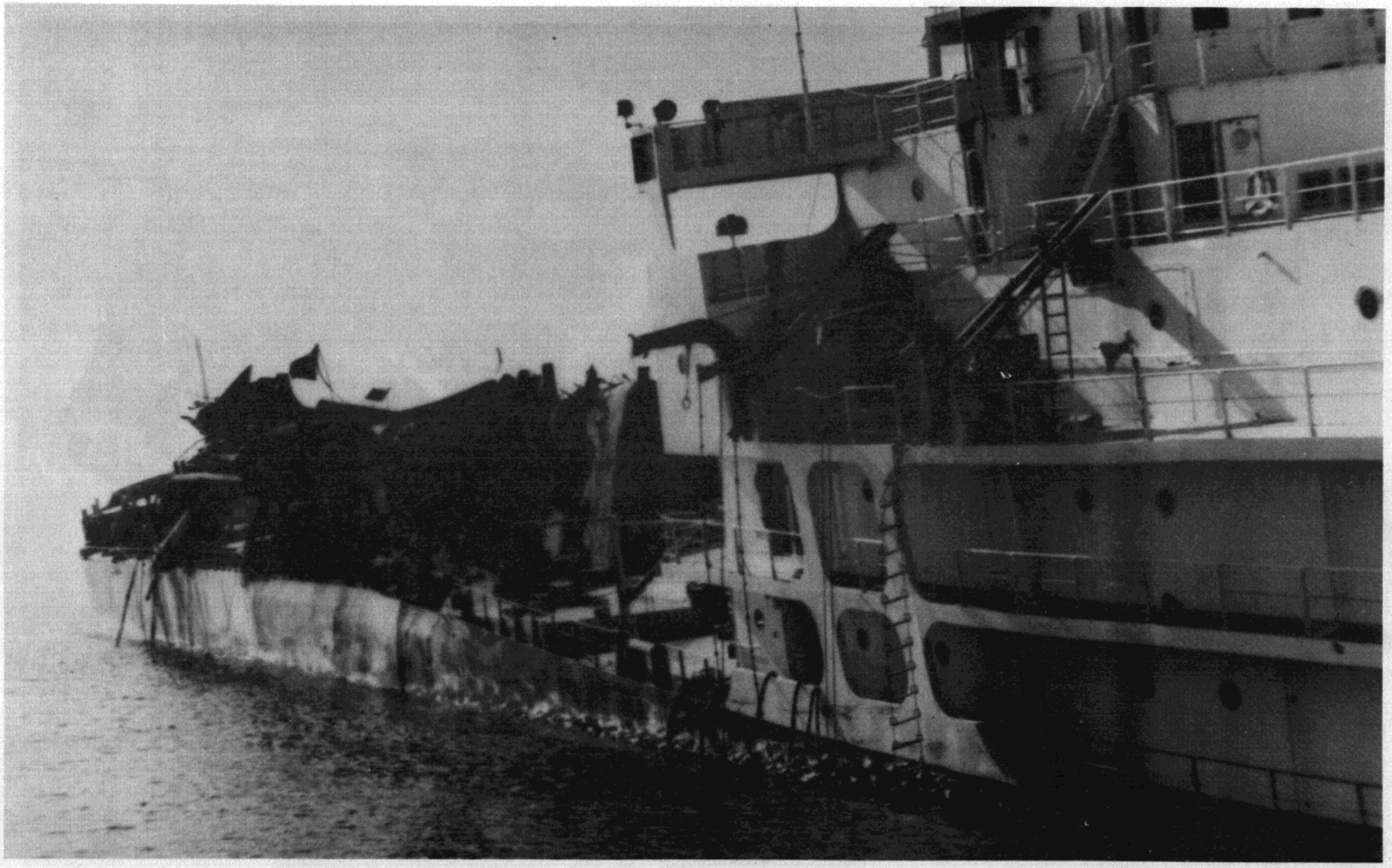
PHOTOGRAPH #2: Port-side view showing inverted deck and the pilot ladder which had been located over 4PF. The fore-and-aft tear in the inverted deck corresponds to the area of weld between the main deck and the longitudinal bulkhead separating 6CV and 4PA. Taken at approximately 0930 on November 1, 1984.(USCG Photo)

PHOTOGRAPH #3: PUERTO RICAN under tow on October 31, 1984 at approximately 1030 in position approximately 15.5 miles and 250°T from Point Bonita. (USCG Photo)

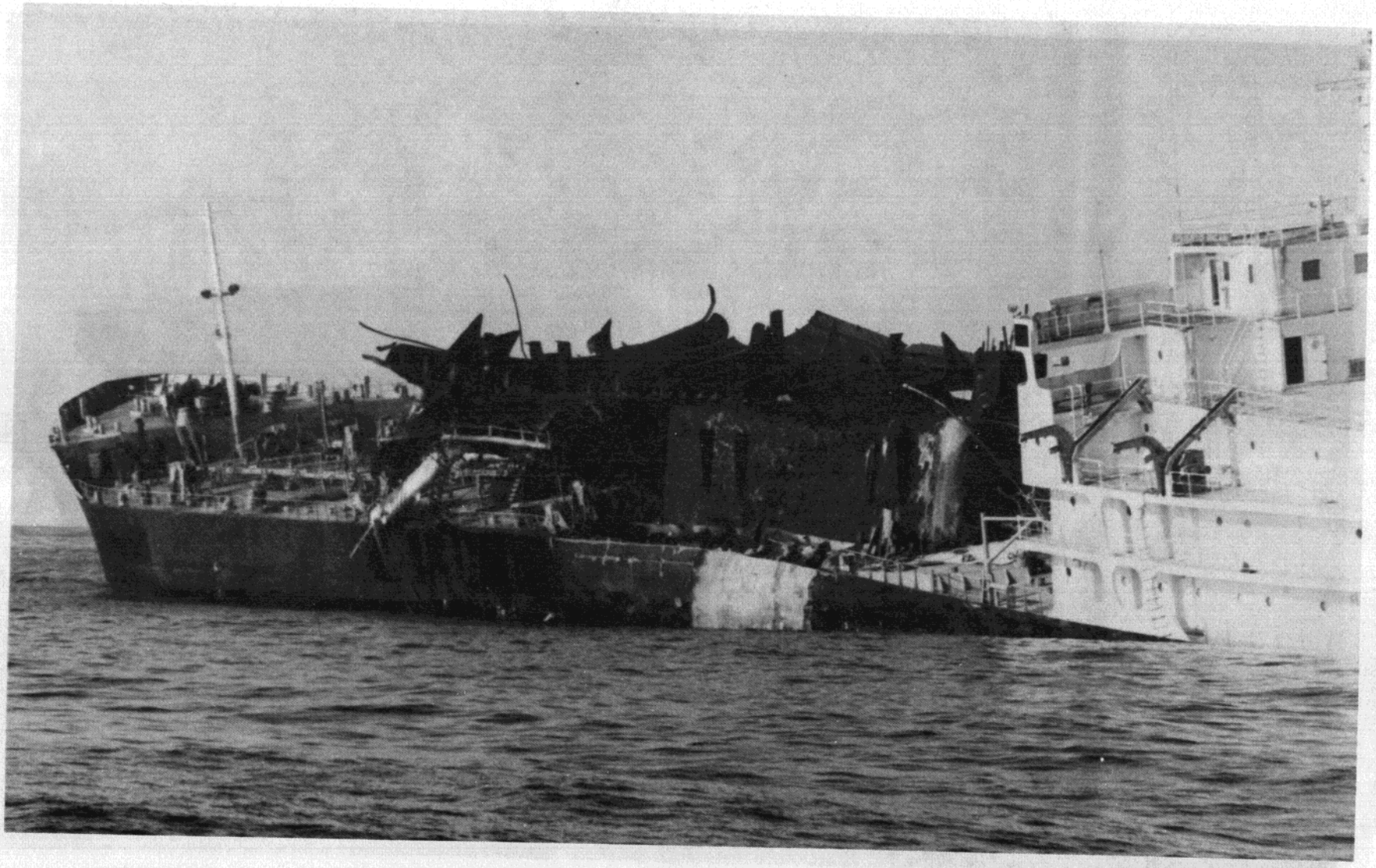
PHOTOGRAPH #4: PUERTO RICAN under tow on October 31, 1984 at approximately 1030 in position approximately 15.5 miles and 250°T from Point Bonita. (USCG Photo)

PHOTOGRAPH #5: View of forebody of PUERTO RICAN showing 6C independent tank and the inverted deck taken at approximately 1230 on November 1, **1984.** This photograph shows, among other things, the concave shape of the deck over the number 4 starboard wing tanks and the convex shape over the 4 port wing tanks. The area indicated by the letter "A" is the end of a web frame, which acts as part of a "hold-down" system to limit upward flotation of the tank. It meets a member attached to the tank as indicated by letter "B". (USCG Photo)

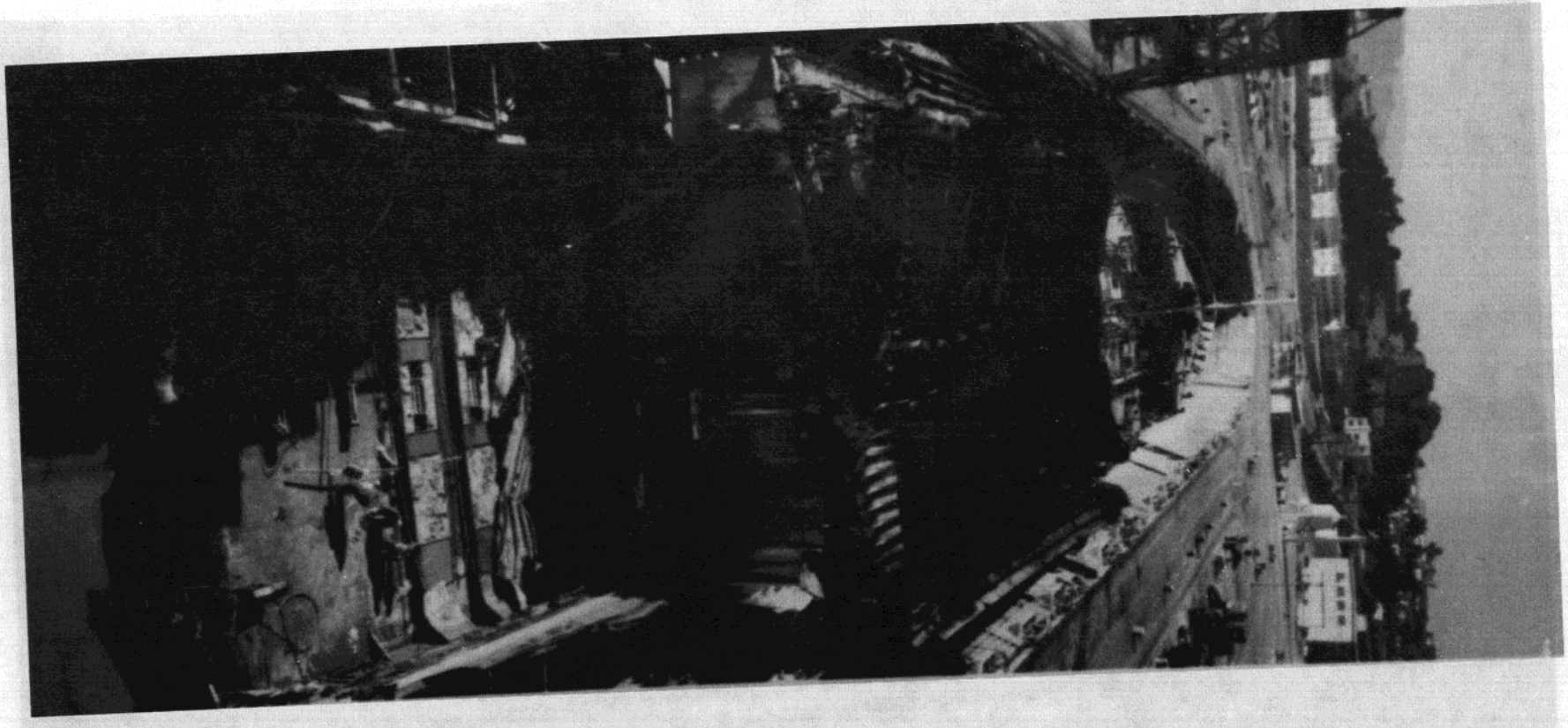
PHOTOGRAPH #6: PUERTO RICAN under tow on November 1, 1984 at approximately 1000 in position approximately 35.5 miles and 215°T from Point Bonita. (USCG Photo)



PHOTOGRAPH #7: PUERTO RICAN November 1, 1984 at approximately 0930 in position approximately 35.5 miles at 215°T from Point Bonita. (USCG Photo)

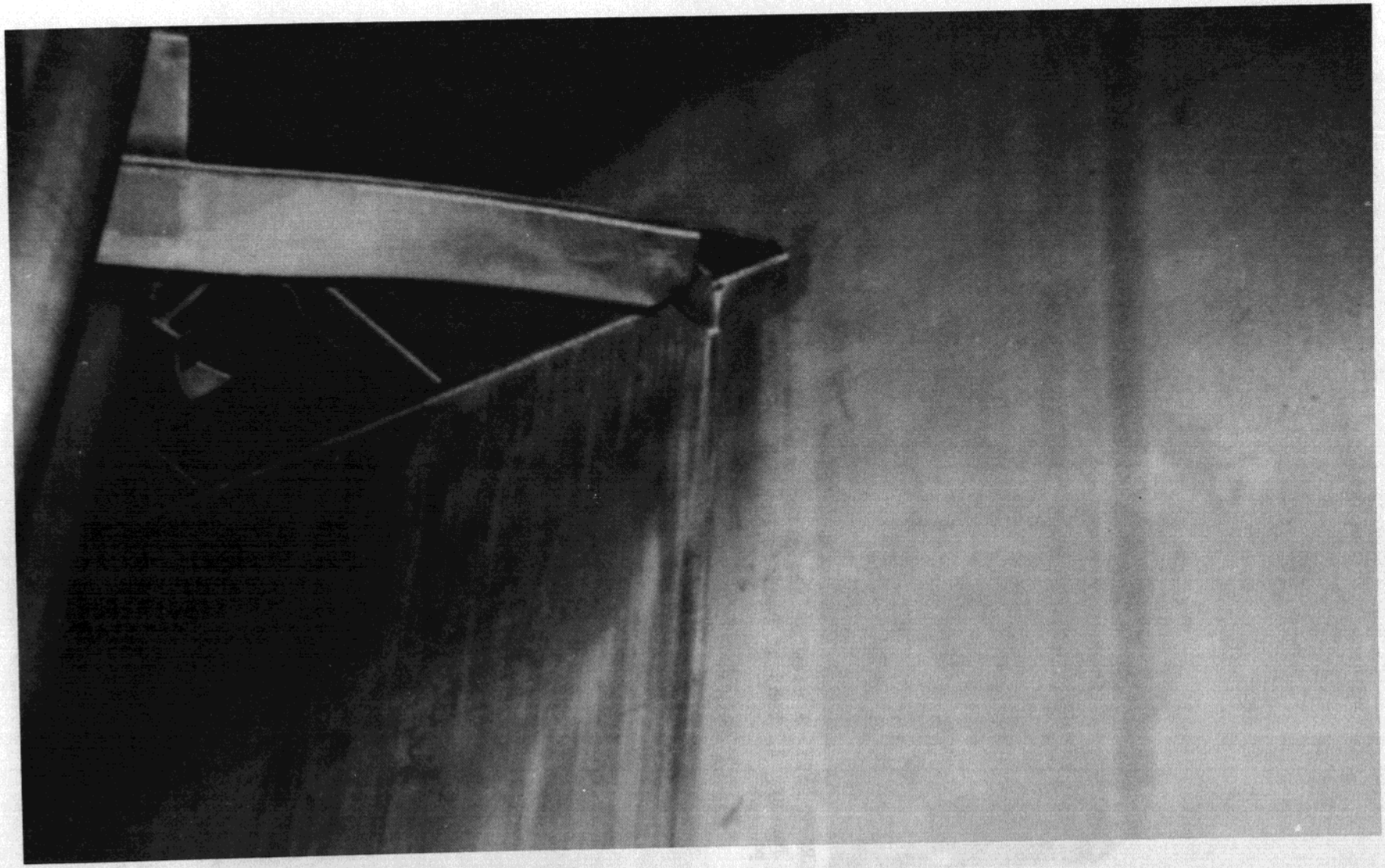


PHOTOGRAPH #8: PUERTO RICAN under tow on November 1, 1984 at approximately 0930 in position approximately 35.5 miles at 215°T from Point Bonita. The swell in the foreground gives the illusion that the stern is awash. The angular difference at the gunwale shows the area where the forebody separated from the stern on the port side at the main deck. (USCG Photo)



PHOTOGRAPH #9: View of forebody taken January 16, 1985 in Triple A Shipyard, San Francisco, California showing 6CV and the inverted deck. The man in the approximate center of the photograph shown standing at the forward end of 6CV on the second transverse bulkhead stiffener is at the location of the hole found between 5CP and 6CV. (Fa AA Photo)

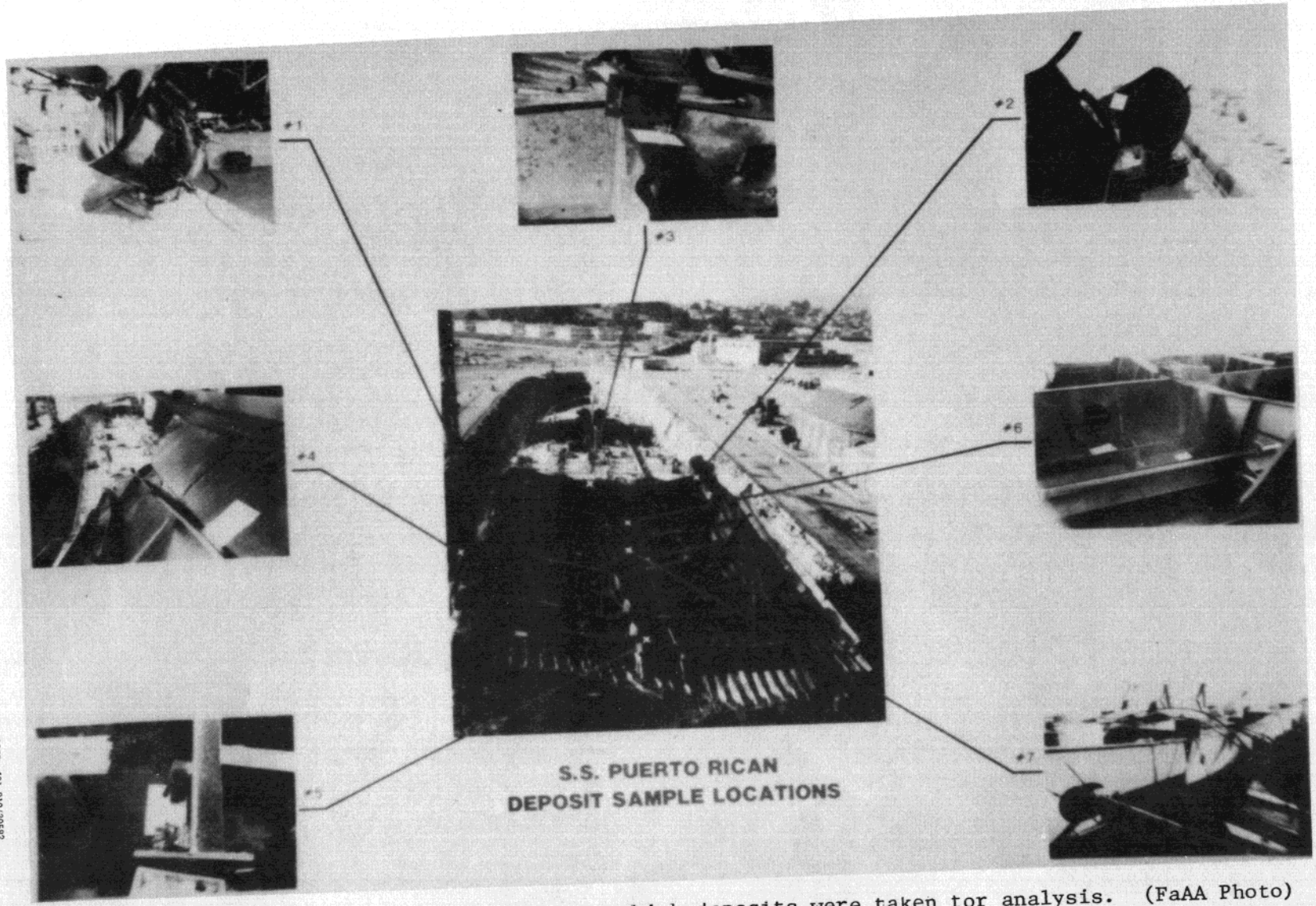
PHOTOGRAPH #10: View in 5CP looking aft at the bulkhead between 5CP and 6CV where it joins the centerline bulkhead. The hole is located just inboard of the end of the second horizontal corner bracket, which is 16'6" from the deck, and outboard of the center longitudinal bulkhead. This location is shown by letter "A". Note the fire effected zone on the bulkhead approximately 18' above the deck. (Fa AA Photo taken November 19, 1984)



PHOTOGRAPH #11: A detailed view showing the hole from the 5CP side. It is located below a horizontal stiffener plate and behind a cutout in a vertical gusset plate which are part of a horizontal corner bracket. (FaAA Photo taken November 19, 1985)

PHOTOGRAPH #12: A view of the after end and starboard side of 6C; taken January 2, 1985 at Pacific Drydock Co., Oakland, CA. (FaAA Photo)

PHOTOGRAPH #13: A view of the forward end of 6C; taken January 2, 1985 at Pacific Drydock Co., Oakland, CA. (FaAA Photo)



PHOTOGRAPH #14: The seven locations from which deposits were taken for analysis. (FaAA Photo)

*U.S. GOVERNMENT PRINTING OFFICE: 1985--491-810/20582