DEPARTMENT OF TRANSPORTATION

COAST GUARD

MARINE CASUALTY REPORT

SS SANSINENA (LIBERIAN) EXPLOSION AND FIRE IN LOS ANGELES HARBOR, CALIFORNIA ON 17 DECEMBER 1976 WITH LOSS OF LIFE

U.S. COAST GUARD
MARINE BOARD OF INVESTIGATION REPORT

AND

COMMANDANT'S ACTION

REPORT NO. USCG 16732/71895

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
USCG 16732/71895		

4. Title and Subtitle	5. Report Date
Marine Board Casualty Report SS SANSINENA (Liberian); Explosion and Fire in Los Angeles Harbor, California on 17 December 1976 with loss of life	25 November 1977
	6. Performing Organization Code G-MMI-1/83
7. Author(s)	8. Performing Organization Report No.
9. Performing Organization Name and Address U. S. Coast Guard Washington, D.C. 20590	10. Work Unit No.
	11. Contract or Grant No.
	13. Type of Report and Period Covered MARINE CASUALTY REPORT 17 December 1976
12. Sponsoring Agency Name and Address Commandant (G-MMI-1) U. S. Coast Guard Washington, D.C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract - On 17 December 1976 the Liberian tanker SANSINENA, moored at berth 46, Union Oil Terminal, Los Angeles Harbor, California, exploded and burned while taking on ballast and bunkers. The casualty resulted in six members of the SANSINENA's crew known dead, and 22 injured. Two crewmembers and one terminal security guard are missing and presumed dead. Also approximately 36 personal injuries were suffered by the general public.

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

The Commandant concurred with the Marine Board that the probable cause of the casualty was the ignition of a hydrocarbon vapor cloud over the afterdeck of the SANSINENA. The source of ignition cannot be positively identified; however, it was most probably located in the vicinity of the midship deckhouse.

17. Key Words	18. Distribution Statement
Foreign; tankship; ballasting; terminal; pumping; explosion; fire; pollution; wind; inert gas systems; ventilation system; vapors; inspection	This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-69)

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ON 17 DECEMBER 1976 WITH LOSS OF LIFE

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DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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16732/ S/S SANSINENA
A-11Bd

Commandant's Action 25 NOV 1977

on

The Marine Board of Investigation convened to investigate the circumstances surrounding the explosion and fire on board the S/S SANSINENA (Liberian tanker) in Los Angeles Harbor, California on 17 December 1976 with loss of life.

REMARKS

1. Concurring with the Marine Board of Investigation, the probable cause of the casualty was the ignition of a hydrocarbon vapor cloud over the afterdeck of the SANSINENA. The source of ignition cannot be positively identified; however, it was most probably located in the vicinity of the midship deckhouse.

2. It is evident that this casualty resulted from poor operating procedures and design features on the SANSINENA. At the time of the casualty all pressure-vacuum (P/V) relief valves were in the hand-opened position and all ullage covers were open. It was customary on the SANSINENA to have all the P/V valves in the hand-opened position at all times except when the ship was loaded with cargo and to have all ullage covers open during ballasting. The chief officer believed that this was necessary to insure against pressure build-up in the tanks being ballasted or in any other cargo tanks in the event of either valve or internal bulkhead leakage or inadvertent opening of the wrong valves. Although the venting system was capable of providing the tank venting requirements during ballasting with all the ullage covers closed this would not have been practicable or safe since the vessel was not equipped with a closed gauging system and weighted ullage caps. With all of the ullage covers closed the crew could not ascertain the level of ballast. Therefore another unsafe condition would exist since the cargo tanks could be overfilled and the resulting overpressure could cause rupture of the bulkhead, side shell and main deck plating in way of the tanks.

Nevertheless, conventional systems such as that of the SANSINENA are poor arrangements because they allow hydrocarbon vapors to be vented at the main deck level in way of the cargo tanks, where all possible sources of ignition cannot be positively and totally eliminated.

This hazardous practice was further aggravated by vapor-emitting operations such as ballasting during periods of little air movement. At the time of the casualty the wind shifted from two points abaft the beam to practically dead astern. The reported wind velocity of eight knots was probably reduced to a velocity of five knots or less over the tank deck area because of the shielding effect of the after deckhouse. This slight airflow was not sufficient to dissipate the hydrocarbon vapor cloud which had formed between the midship and after deckhouses. This practice is contrary to the recommendations in the Tanker Safety Guide (Petroleum) and the International Oil Tanker and Terminal Safety Guide. The Tanker Safety Guide states, "Although most petroleum vapors are heavier than air, usually they will be dissipated rapidly by a breeze in excess of 10 mph, even when in rich concentration. If there is little air movement--winds of 5 mph or less--the risk from vapors is at its greatest and flammable mixtures may persist for some distance from the point of emission. Even when there is movement in the open air, flammable concentrations should always be suspected in or near enclosed or partially enclosed spaces where air circulation may be restricted. Additionally, where even strong wind crosses a deck structure an area of relatively low pressure can be created on the lee side, causing eddy currents that can trap gas or carry back gas through any openings in that area." The Tanker Safety Guide also states that it may be desirable to stop loading, ballasting, gas freeing or tank cleaning while the aforementioned wind conditions persist.

The integrity of the cargo vent system was compromised by numerous wastage holes on the underside of the cargo vent piping, a missing washout nipple cap, and a missing drain plug. The lack of integrity in the cargo vent piping further negated the dissipating effect of the weather head vent stacks at the top of the kingposts and contributed to the accumulation of hydrocarbon vapors on deck in the cargo tank area. The inspection procedures of the cargo vent system by the shipboard personnel, classification society inspectors, inspectors for the Government of Liberia, and company inspectors were inadequate to detect the relatively extensive deterioration that existed on the underside sections of the cargo vent piping. Furthermore, this lack of integrity allowed the vent piping to serve as a path of transmission for a flame to enter the cargo tanks.

The expansion hatches for the No. 5 wing tanks, which were converted in 1962 from segregated ballast to cargo tanks, were located under the bridge deck of the midship house. During ballasting or loading operations hydrocarbon vapors would vent out of the opened ullage holes and become trapped in this sheltered space. On the date of the casualty, the No. 5 wing cargo tanks were being ballasted with the ullage covers open.

Since a hydrocarbon vapor cloud had formed, due to the aforementioned discrepancies (the cargo venting system, ballasting in low wind conditions, wastage holes in cargo vent piping, and the conversion of the No. 5 wing tanks from ballast to cargo tanks), in the vicinity of the midship deckhouse, any source of ignition could result in a deflagration. One of the possible sources of ignition was the electrical equipment in the machinery compartment in the shelter-deck level of the midship deckhouse. The location of the two natural ventilation supply intakes for this machinery compartment was a serious design defect. The one supply intake originated on the port side of the upper bridge deck and was approximately 24 feet above the main deck. The other natural supply intake was located on the after end of the port bridge deck and was approximately 14 feet above the main deck. The location of these natural ventilation intakes could have provided the path for the hydrocarbon vapor cloud into this compartment.

COMMENTS ON CONCLUSIONS

1. Conclusion 16, which states that in this instance there probably would have been no casualty had there been no midship house, is concurred with. The shielding effects of the midship and after deckhouses, with the wind from dead astern, reduced the velocity of the wind to a negligible amount. This lack of air movement, combined with the procedure of ballasting cargo tanks with the P/V valves and ullage covers open, resulted in the formation of a stationary hydrocarbon vapor cloud in the vicinity of the afterdeck. The presence of the midship house, besides entrapping the hydrocarbon vapor cloud, also contained some of the possible sources of ignition.

2. Conclusion 31, that mild steel vent piping, either uncoated or metal coated, will deteriorate at a rate that will be a cause for concern after an initial period of about 10 years is not concurred with. The rate of deterioration varies with the type of cargo. The SANSINENA had previously carried sour crudes for an extended period, then switched out of that trade. Sour crudes are known to be corrosive

and if the vessel had continued in that trade, holing of the vent piping might have occurred much earlier.

ACTION CONCERNING THE RECOMMENDATIONS

1. The recommendation that regulatory action be initiated to require inerting of all tankers carrying flammable cargo which call in U.S. ports is concurred with in part. A Notice of Proposed Rulemaking has been published in Federal Register, Volume 42, Number 94, dated May 16, 1977 which would extend inerting requirements. The present regulations apply to new tank vessels of 100,000 deadweight tons or more and to new combination carriers of 50,000 deadweight tons or more that have a keel laying date after December 31, 1974. The proposed regulations would extend this requirement to tankships or combination carriers of 20,000 deadweight tons or more as follows: 1) Each United States flag tankship that is certificated to carry Grades A, B, C, and D liquids; and 2) each foreign flag tank vessel engaged in the trade of carrying flammable or combustible liquids to or from a U.S. port or place. Foreign tank vessels which carry cargo that has a flash point of 65.50°C (150°F) or higher by an open cup test (Grade E) would not be required to have an inerting system.

2. The recommendation that regulatory action be initiated to establish reasonable, practicable and enforceable restrictions on certain vapor-emitting operations on tankers, with responsibility defined for both tank vessel operators and terminal operators during periods of light airs or calms, to reduce the likelihood of flammable vapor clouds reaching a source of ignition, is under consideration. A task force composed of representatives of the Office of Marine Environment and Systems and the Office of Merchant Marine Safety has been established to investigate the feasibility of this recommendation.

3. The recommendation that the United States initiate an international effort, under IMCO, to seek a standardization of merchant marine qualifications with respect to training, examination and periodic re-examination, to assure that such personnel are kept current with changing technology is concurred with. The United States, through membership in the Intergovernmental Maritime Consultative Organization, has been an active participant on the Subcommittee on Standards of Training and Watchkeeping since its inception in 1971. The subcommittee was assigned the responsibility of drafting recommendations covering the qualifications of licensed officers and unlicensed ratings. A draft convention has been prepared for the Conference on Training

and Certification of Seafarers that is scheduled to meet in June 1978. The ratification of this convention by member governments should greatly enhance the professional standards of the officers and crews manning the merchant fleets of the world. The Subcommittee on Standards of Training and Watchkeeping has been designated as a permanent subcommittee and it will continue to review the qualifications of seamen after the 1978 Conference.

4. The recommendation that all tankers calling in United States ports, whether inerted or not, be required to install and use venting systems with high outlets, closed and/or restricted gauging systems, and weighted ullage caps, and to maintain the integrity of those systems, is concurred with in part. Vessels carrying Grade E and non-flammable cargoes such as sulfuric acid or caustic soda are tankers which should not be required to be fitted with this type of venting system on the basis of flammability. The Merchant Marine Technical Division will examine the need for these provisions in the context of pending regulatory improvements. Consideration will also be given to other systems of venting or processing of vapors which offer at least an equal degree of safety to that of high vent outlets.

5. The recommendation that the Coast Guard should continue its precautionary tanker boarding program is concurred with. The Merchant Vessel Inspection Division has initiated a program of boarding tank vessels for the examination of cargo venting and handling systems and other safety-related equipment and installations. The results of the boarding program to date have revealed that a large number of the tank vessels calling at United States ports have deficiencies in the aforementioned systems. In view of the results of the program, boarding of tank vessels by qualified inspectors will continue.

6. The recommendation that every cargo venting system at an age of 10 years be surveyed to determine its material condition, including the removal of all P/V valves and audiogauging of the underside of the piping directly under the P/V valves is concurred with in part. The Merchant Marine Technical Division will conduct a detailed physical and metallurgical examination on a representative number of tank vessels in various trades over the next 5 years to determine needed inspection intervals. In the interim the program of examining tanker venting systems, which was initiated as a result of this casualty, will be continued. Also, the scope and interval of examinations to be conducted aboard tankers is being thoroughly discussed at IMCO and a proposal will be presented at the Plenipotentiary Conference

on Tanker Safety and Pollution Prevention to be held in February 1978.

7. The recommendation that a study be conducted to determine the optimum period of continuous service for tanker personnel, particularly key personnel, is concurred with insofar as such a study would relate to the effect of continuous service on safety. The Coast Guard has an "umbrella" research and development project for personnel practices. The objective of this program is to identify practical methods by which human safety performance can be improved. As this project progresses, various aspects of "human error" will be developed. This study will cover lack of familiarity and self-confidence as well as complacency, biorhythmic and other factors related to given types and lengths of continuous service.

8. The recommendation that legislation be sought to impose substantial monetary penalties on a strict liability basis, against the owner/operator of any tank vessel who operates that vessel in a patently unsafe condition in United States waters or otherwise under United States jurisdiction, is not concurred with. Significant penalty powers already exist under the Tank Vessel Act, as amended, 46 U.S.C. 391a(11) and under the Federal Boat Safety Act of 1971, 46 U.S.C. 1461(d), and 1483, for operating a vessel in an unsafe condition in waters where the United States has jurisdiction. Other action besides penalty action may be appropriate when a vessel is found to be operating in an unsafe condition. Unsafe vessels can be required to make adequate repairs prior to the transfer of cargo or prior to departing a United States port. Recurring unsafe conditions on board a vessel would constitute grounds for denial of entry to United States ports.

9. The recommendation that the Commandant should evaluate the Coast Guard 41-foot UTB as to whether it is adequate as a firefighting platform, in view of the maneuvering difficulties experienced during the SANSINENA firefighting operation, is not concurred with. The original operating requirements for the 41-foot UTB specified that the firefighting capabilities shall consist of an installed fire/salvage pump system with a power take off on one engine. The mission of the 41-foot UTB is to provide search and rescue, law enforcement, port safety, aids to navigation, and logistics services in inshore, offshore and Great Lakes waters during moderate to heavy sea and weather conditions. The primary mission is to be search and rescue. The firefighting capability of the 41-foot UTB is considered adequate and within the context of the original operational requirements. The Coast Guard has developed a new 32-foot Ports and Waterways Boat (PWB) with an effective

firefighting capability. The 32-foot PWB has a separately driven fire pump rated at 500 gpm and 200 psi. This will allow full maneuverability of the boat while fighting fires.

10. The recommendation that a documentary film be produced to cover all aspects of tanker fire and explosion hazards is under consideration.

11. The recommendation that the evidence of Captain Bovone's violation of Liberian Maritime Regulations, with respect to lack of fire drills in the period of 4 November to 16 December, be forwarded to the Government of Liberia for appropriate disposition is concurred with. A copy of this report will be forwarded to the Government of Liberia.

[redacted]

O. W. SILER
Admiral, U. S. Coast Guard
Commandant

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
COMMANDANT (G-MMI-1)
U.S. Coast Guard
WASHINGTON, D.C. 205

16732/ S/S SANSINENA
1 April 1977

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

Subj: S/S SANSINENA, O.N. 1314 (Liberian tanker), explosion and fire in Los Angeles Harbor, California, on 17 December 1976, with loss of life.

FINDINGS OF FACT

1. At about 1938 PST on 17 December 1976 the Liberian tanker SANSINENA, moored at berth 46, Union Oil Terminal, Los Angeles Harbor, California, exploded and burned while taking on ballast and bunkers. The casualty resulted in six members of SANSINENA's crew known dead, and 22 injured. Two crewmembers and one terminal security guard are missing and presumed dead. Also approximately 36 personal injuries were suffered by the general public. The ship was a constructive total loss, and the total damages in all forms amounted to about $21.6 million.

2. Vessel Data:

Name:	SS SANSINENA
Official Number:	1314 (Liberian)
Service:	Tankship
Built:	Newport News Shipbuilding and Drydock Co., Newport News, VA, 1958
Gross tons:	38,562
Net tons:	25,231
Deadweight tonnage:	70,630
Length:	810'0"
Breadth:	104'5"
Depth:	60'1"
Draft (Summer Load Line):	46'11 3/8"
Draft at time of casualty (approx.):	Fwd. 12' Aft. 26'
Propulsion:	Steam turbine
H.P.:	25,000
Home Port:	Monrovia, Liberia
Owners:	Barracuda Tanker Corporation P.O. Box 630 Hamilton, Bermuda

Agent for the owner:	Hendy International (by assignment from Pine Company, a Nevada Corporation)
Charterer:	Union Oil Company of California Union Oil Center Los Angeles, CA 90017
Operator:	Hendy International
Master:	Paulo Bovone Via San Fruttuoso 5221 Genoa, Italy
License:	Master, Oceans, any gross tons Italy and Liberia
Certificates:	
Cargo Ship Safety Construction Certificate	
Date Issued:	10 January 1973
By:	Lloyd's Register of Shipping
Expiration Date:	31 May 1977
Cargo Ship Safety Equipment Certificate	
Date Issued:	5 September 1975
By:	Lloyd's Register of Shipping
Expiration Date:	23 July 1977
Load Line Certificate:	
Date Issued:	19 May 1972
By:	Lloyd's Register of Shipping
Expiration date:	18 May 1977
Inspections:	
Load Line:	
Date:	23 June 1976
Port:	Los Angeles, Calif.
Classification:	On continuing survey, by Lloyd's Register of Shipping
Last Inspected:	23 January 1976
Safety:	
By:	National Cargo Bureau, Inc.
Date:	16 January 1976
At:	Los Angeles, CA
Cargo Capacity:	514,244 bbls (98% full)
Grade:	"A" (Grade "B" in tank #4 only)

3. Cargo and Fuel Data

Type Cargo (last load):	
Attaka Crude:	Grade C
Amount:	212,656 bbls
API Gravity:	35.1
Reid Vapor Pressure 100°F	7.9 psia
Flash Point Tag Closed Cup:	28°F
Sepinggan Crude:	Grade C

Amount:	302,244 bbls
API Gravity:	43.0
Reid Vapor Pressure 100°F	3.9 psia
Flash Point Tag closed cup:	31°F

Bunker Fuel Oil:

Bunker "C" Capacity (98%):	60,188 bbls
API Gravity:	7.9
Flash Point (Pensky Martens Closed Cup):	184°F

4. Record of Dead and Injured

a. The following persons lost their lives as a result of this casualty:

Dead	Occupation	Address (nok)
Orazio D'Amico Age [redacted]	A.B.	[redacted] (Wife) [redacted] Trapani, Italy
Calogero D'Asaro Age [redacted]	A.B.	[redacted] Wife) Sciacca, Italy
Emanuele Orgioli Age [redacted]	Pumpman	[redacted] (Wife) [redacted] Gela, Italy
Umberto Scarogni Age [redacted]	Chief Fireman	[redacted] (Wife) [redacted] Ponza, Italy
Felice Tridente Age [redacted]	Radio Officer	[redacted] (Father) [redacted] Molfetta, Italy
Rocco Di Maio Age [redacted]	Wiper	[redacted] (Father) [redacted] Genoa, Italy Injured; dead in Genoa, Italy on 3/8/77; death certificate not available)

Missing and Presumed Dead

[redacted] Security Guard [redacted] wife)
Age [redacted]
Hawthorne, CA
(remains not found)

[redacted] 2nd Officer [redacted] (Father)
Age [redacted]
Riposto, Italy
(Listed as John Doe;
remains unidentifiable)

[redacted] 3rd Officer [redacted] (Wife)
Age [redacted]
Meta di Sorrento, Italy
(Listed as John Doe;
remains unidentifiable)

b. The following crewmembers were injured and incapacitated more than 72 hours as a result of this casualty:

[redacted] Fireman
Steward
Cook
Fireman

c. The following non-crewmembers were injured and incapacitated more than 72 hours as a result of this casualty:

[redacted] (terminal employee)
(2-month-old baby)
(terminal employee)

d. A total of 36 additional persons ashore suffered injuries that required medical treatment but not hospitalization.

5. Weather and Tide

a. The weather at the time of the casualty was a cloudless sky with good visibility, estimated at ten miles. Sunset was at 1648 PST. Air and water temperatures were 62° and 67°F, respectively. The humidity was 84%. High tide had been at 1856. Currents in the area of the SANSINENA were weak. (Pacific Standard Time is used throughout this report.)

b. There was no actual measurement of the wind at the ship. An anemometer was located at the pilot station, bearing 020° true, distant 950 yards from the SANSINENA's midship house, and at an elevation of 100 feet above mean sea level. Its recorder chart showed the wind from 195° true at eight to ten knots for several hours prior to the casualty. Then at about 1850 the wind began to back (counterclockwise) slowly but steadily, with the velocity stabilized at eight knots. At about 1938, when the wind indication was from 128° true at 8 knots, the recorder showed a sharp swing of the stylus and the instrument suffered a power failure.

c. Testimony from various persons in the vicinity agreed generally with the wind direction recorded at the pilot station, but indicated velocity as being somewhat less.

d. A representative of the National Weather Service testified that 3 1/2 weeks after the casualty he checked the pilot station anemometer and found it to have a directional error of 32° easterly.

e. Log entries on the USCGC VENTUROUS were consistent with the pilot station recording prior to the time of the SANSINENA explosion.

6. Vessel Description

a. The steam tankship SANSINENA was a typically-configured tanker for its date of build (1958), having a raised forecastle head, a midship house with enclosed shelter deck (not extending to the ship's sides) and an after deckhouse. The first level of the midship deckhouse (the centercastle) contained an enclosed shelter-deck space used for storing cargo-handling, tank-cleaning and gas-freeing equipment. Boatswain's stores were also located within the shelter-deck space. A raised fan and machinery compartment was located in the aft port side of the centercastle with personnel access only from the bridge deck, inside the officers' quarters. The midship deckhouse had four deck levels above the main deck. The first was the bridge deck, on which were located the staterooms of the

deck officers and radio officer, the radio room, and the battery room. The next deck, the upper bridge deck, contained the master's cabin and guest rooms; this was also the midship boat deck. The next deck held the pilothouse, chartroom, gyro room and a pilot cabin. Above this was the flying bridge on which was mounted the radar mast.

b. An elevated catwalk connected the midship house, at the bridge deck level, with the after deckhouse. The remainder of SANSINENA's crew lived in the after house.

c. SANSINENA had two pumprooms. A main cargo pumproom was located on the center line just forward of the after house, accessed through a raised enclosure extending between the main deck and the catwalk level. A bunker transfer pumproom was located under the aftermost part of the forecastle head, just forward of cargo tank #1 center.

d. There were four lifeboats, two amidships and two aft. The only motorboat was #1, with a hand-cranked diesel engine. The use of its electric starter and battery had long since been discontinued, although the battery was still in the boat after the casualty.

e. This 18-year-old tanker had been neither rebulkheaded nor rebuilt. The cargo tank bottoms had been coated to a height of five or six feet with vinyl-epoxy since July 1975. Although highly subdivided--unusual for a crude carrier--the SANSINENA had been in the crude oil trade exclusively since built. Part of that time was in the carriage of sour crudes (with hydrogen sulphide content). The vessel had no anodes inside the cargo spaces, nor was there any impressed-current cathodic protection of the hull. Cathodic protection of the hull was achieved by externally fitted zincs.

f. The SANSINENA did not have an inert gas system, nor did she have a closed or restricted gauging system. There was no bonding cable between ship and shore.

7. Cargo and Ballast Systems

a. SANSINENA had 36 tanks in her cargo tank body, numbered from #1 through #12, with three tanks across (port, center, and starboard). The #6 wings were segregated-ballast tanks. There were four 6,000 gpm steam turbine-driven main cargo centrifugal pumps located in the after pumproom (numbered from #1 through #4, from starboard to port). For each main cargo pump there was a suction line serving certain tanks and a discharge line rising to deck level in the pumproom and running forward along the deck, terminating at manifolds abaft the midship house. Each fore-and-aft deck line had a drop line connecting it

directly to its corresponding suction line, each drop having a gate valve near its juncture with the deck line. The #1 suction line served tanks #1 across, #2 across, and #3 starboard; suction line #2 served tanks #3 port, #3 center, #4 across, #5 across, #6 center, and #7 wings; suction line #3 served tanks #7 center, #8 across, #9 across, and #10 across; and suction line #4 served tanks #11 across and #12 across.

b. The suction lines were interconnected by double-valved crossover lines located as follows: line #1 to line #2, in #2 center tank; line #2 to line #3, in #6 center tank; line #3 to line #4, in #11 center tank. During the ballasting operation, at the time of the casualty, all these crossovers were open, forming, in effect, one system throughout the cargo tanks. At the time of the casualty ballast was being pumped from sea up to the deck lines and down through the deck drops to the bottom lines and into the selected tanks.

c. There were two steam reciprocating stripping pumps, each with a capacity of 1,500 gpm. The starboard stripping pump served tanks #1 port, #3 across, #5 across, #11 across and #12 across. The port stripping pump served all other cargo tanks. The stripping suction line crossover was located in #6 center tank. The stripping system was not in operation at the time of the casualty.

d. There were no heating coils in SANSINENA's tanks; during her shipyard availability in June-July 1975 at Sasebo, Japan, the steam supply and return lines had been cut off a short distance below the deck in each tank and were blocked off at their manifolds (underneath the catwalk in the case of those on the afterdeck) when the heating coils were removed.

e. The expansion trunks for #5 wing tanks (which had originally been intended for segregated ballast) were located underneath the after portion of the bridge deck extension to port and starboard of the midship deckhouse centercastle bulkheads.

f. There was a Golar vent system installed with a blower located in the after pumproom. This system consisted of a steam turbine-driven blower which could be connected to the cargo discharge pipe risers at about the maindeck level. The purpose of this blower was to inject air into the cargo tanks through the main cargo suction piping for gas-freeing. Not having proved satisfactory, this system had not been utilized recently. When not in use the Golar blower was segregated from the cargo piping with Hamer line-blind spectacle flanges.

8. Cargo Tank Venting

a. SANSINENA had five common-header cargo tank venting systems to which all cargo tanks were connected, except that #4 wing spaces had independent pressure-vacuum (P/V) valves. (Tank #4 across was one tank, each longitudinal bulkhead having one opening at its bottom.) At the time of the casualty all P/V valves were in the hand-opened position. According to the testimony of the chief officer this was the custom on this ship at all times except when the ship was loaded, i.e., between loading and discharge ports. The P/V valves were Fig. No. 130 by Mechanical Marine Co., USCG Approval No. 162.017/67/4, six-inch size, weighted to open at 2.0 psig pressure or at 0.5 psig vacuum. Each was fitted with a rising-stem handwheel control which, when open (stem up) allowed a free flow, and when closed (stem down) allowed the valve to operate at its designed pressure rating. (They could not be positively closed.) The common headers for the afterdeck terminated with weather head vent stacks mounted on top of flame arresters at the tops of the midship kingposts, two risers on each side, one external and one utilizing the kingpost itself. The weather heads, which exhausted the vapors upward, were a relatively recent installation, replacing the "stove-top" type which exhaust horizontally. On the port midship kingpost the external riser served #6 wing ballast tanks; the kingpost itself served cargo tanks #10 center, #11 across and #12 across. Both risers on the starboard midship kingpost served cargo tanks. All tanks on the foredeck were vented at the forward kingposts located on the forecastle head, port and starboard, except the #4 wing spaces as mentioned above.

b. The SANSINENA was originally constructed with #4 center and #5 and #7 wing tanks dedicated to and piped for segregated ballast. In order to gain more cargo cubic, in 1960 or 1961 center tank #4 was altered to carry oil. In 1962, in order to eliminate excessive trim by the head in the fully loaded condition, #4 and #6 wing tanks were altered to be segregated-ballast tanks, and #5 and #7 wing tanks were in turn altered to be in cargo service. Cargo vent branch pipes for #7 wing tanks were connected to the starboard after vent header in place of the #6 wing tank vent piping. The vent branch pipes for #5 wing tanks were connected to the starboard vent header serving the tanks immediately abaft the midship house. The #4 wing tanks were returned to cargo service with the entry into force of the International Convention on Load Lines, 1966, which permitted a freeboard reduction. All these changes had the approval of Lloyd's Register of Shipping, the classification society under whose rules the vessel was built and which also issued the load line certificate on behalf of the Government of Liberia. Only the "as-built" drawings were

available with none of these changes shown. Thus it was ascertained that #10 center tank vent line was connected to the port-side after header which also had #11 and #12 across connected farther aft, as shown on the as-built drawing, and no changes had been made to this portion of the vent header system.

9. As noted earlier, within the confines of the shelter-deck level of the midship house there was a raised machinery room containing air conditioning equipment, ventilation supply and exhaust blowers, and an automatic pressure-activated water pump driven by an induction motor. This space had no doors opening into the shelter-deck space. An inclined ladder led up to the officer's area on the bridge deck. Although the air conditioning was not running at the time of the casualty, the ventilation blowers were. The supply blower took its air from the machinery compartment, which was supplied by two natural ventilation supply ducts. One supply duct originated on the port side of the upper bridge (boat deck) through a mushroom head and terminated near the fan's suction. The other natural supply duct had a large trainable intake cowling located on the after end of the port bridge deck extension (figure 1) and terminated near the after port corner of the machinery compartment. The electric water pump was located midway between the two duct terminations, at deck level. This pump cut in and out frequently, being controlled by a pressure switch and a motor controller, the contacts of which were inside a louvered metal box. The supply fan was of about twice the capacity of the exhaust fan, thereby maintaining a slight "pressurization" on the midship deckhouse living spaces served by the ventilation system.

10. The SANSINENA arrived at Los Angeles Harbor at 0016 on 16 December 1976, from Santan, Indonesia, moored starboard side to the Union Oil Company terminal, Berth 46, at San Pedro, and discharged its entire cargo ashore. Cargo discharging was completed at 1645 on 17 December, and cargo lines were blown. At 1845 all cargo Chicksan arms were disconnected, leaving only the Bunker "C" arm connected. Upon her arrival at the terminal she had been boarded by two gaugers; one took temperatures, thievages and samples of the cargo tanks while the other took ullages, accompanied by the chief officer, Clemente Gugliotta. One gauger and the chief officer completed the Declaration of Inspection form. An inspector from the Los Angeles Fire Department came on board at 1145 on 16 December and conducted an inspection to determine compliance with the Los Angeles Municipal Fire Code, finding no discrepancies.

11. The loading of Bunker "C" for ship's fuel was started at 0925, 17 December 1976, first into the after bunker

tanks, and later, at 1655, when all cargo stripping was finished, the after bunkers were shut off (about 18,000 bbls having been loaded) and the bunkering of #2 center forward deep tank was begun. By 1938 about 9,000 bbls of bunkers had been loaded into #2 center deep tank--a tank with a capacity of 10,142 bbls. The bunkering rate was about 2,300 bbls/hour at 100-110 psig with the oil at 108°F. At about 1625 the bunkering pumps in the tank farm stopped automatically, apparently due to excessive back-pressure. Lamar White, dock foreman, left the control shack and, at 1630, went on board SANSINENA to confer with the chief fireman about the pump stoppage. He was told that a fuel line valve had been closed inadvertently while switching from one tank to another. He then went back to the control shack, rejoining his assistant, [redacted] and had the bunkering pumps restarted. A routine operation continued. The bunkering operation was under the supervision of the chief engineer, with the chief fireman in charge on deck at the time of the casualty.

12. Deck stores were taken on board in the afternoon of 17 December and were temporarily stowed under the bridge deck extension, starboard side, on the main deck. These stores included paint. This was completed at 1600.

13. During the day welding was being done on a small boat hull on the property adjacent to the oil terminal, at a distance of about 200 yards from the ship. This was discontinued at about 1700, with the approach of darkness, and was not resumed.

14. After the discharging of cargo was completed, the shore gauger checked all cargo tanks and took innages on those having a little oil on the bottom. He prepared a Dry Certificate which the chief officer signed, showing 400 bbls of cargo remaining on board. Chief Officer [redacted] then lined up the cargo piping system for ballasting. (The #6 port and starboard segregated-ballast tanks had already been filled.) He interconnected all cargo tank suction-loading systems by opening the crossovers, and at 1725 put all four main cargo pumps on the line, ballasting tanks #3 wings, #5 wings, #7 center, #8 wings and #10 wings. All main valves to those tanks were opened fully. At the time of the explosion all these tanks were approximately half full, with about 11,000 of the planned 23,000 long tons on board. The total ballast loading rate was about 34,000 bbls/hour (8,500 per pump). All ullage caps were open and all cargo tank P/V valves were in the fully open position. The chief officer testified that this was necessary to insure against pressure buildup in the tanks being ballasted or in any other cargo tanks in the event of either leakage or inadvertent opening of the wrong valves. He also testified that the large

starboard after door giving access from the main deck to the midship shelter-deck space was open.

15. The personnel who were on watch in the engineroom testified that everything was stable there, just prior to the explosion, that four main cargo pumps were on the line, and that there was no blowing of boiler tubes going on.

16. Having been relieved on deck by Third Mate [redacted], as was customary for the evening meal, Chief Mate [redacted] went to his cabin in the midship house at about 1910. At about 1915 he went to the master's cabin and told Captain Bovone that it was time to eat.

17. Captain [redacted], Assistant General Manager of Hendy International, operators of SANSINENA, had come on board at 1830 in the course of his agent-type duties, for a routine pre-sailing visit with the master. He had gone directly to the master's cabin. When the chief mate came by, Captain Bovone invited Captain Hood to dinner, and the three of them went aft to eat.

18. On watch with Mr. [redacted], on deck, were able seamen Calogero D'Asaro and Orazio D'Amico, the pumpman, [redacted]. Also on deck was the chief fireman, Umberto Scarogni, who was taking bunkers. In the midship house were the second officer, [redacted], and the radio officer, Felice Tridente.

19. Mr. [redacted] was on duty and is believed to have been in the terminal guard shack, located about 200 feet from the loading rack.

20. At 1938 a tremendous shock ran through the ship, knocking most of the crew down. Chief Officer [redacted] and First Assistant Engineer [redacted], who were dining together in the officer's salon, ran out the starboard side door. Looking forward and seeing a wall of flames forward of the after deckhouse, they both went aft on to the fantail and jumped overboard, swimming first to a small pier nearby, and then to the rocks on the bank.

21. Captain Bovone and Captain [redacted] went out onto the poop deck from the officer's salon, via the galley, then went up on the after boat deck and walked most of the way forward on that deck. All they could see ahead of the after deckhouse was flame and smoke. They then went to organize an effort to lower away the #4 (port) lifeboat, but gave up on that when they saw flames on the water approaching the boat's location. The #3 lifeboat was hanging from the after fall, the forward fall having parted. They then returned to the

poop deck and tried to calm the excited crew who were milling about. As the ship was moving outward from the dock, putting a great strain on the mooring lines, Captain [redacted] concentrated on keeping the crew clear of these in case they should part. Captain Bovone had a line hung from the rail to the water so that the men could climb down. Within 16 minutes all hands had left the stern section, followed by Captain Bovone.

22. At the time of the explosion [redacted] was sitting in the terminal control room, where he could see only the after part of the vessel--nothing forward of the after deckhouse. [redacted] was in the rear of the control room. Just prior to the explosion everything was normal. Something attracted White's attention on the dock itself, he looked out and saw a blast--a "heat wave"--coming toward him (the appearance of air and dust). [redacted] was knocked out of his chair and onto the floor, as all the windows were blown in. Before he could get up, a second "blast" was heard as the roof fell in. [redacted] helped [redacted] up and they both ran out of the control room and away from the vessel.

23. Summary of Eyewitness Testimony

a. Eyewitnesses observed various stages of the explosion from several locations, including the nearby boatyard, two private aircraft at an altitude of 1800 feet and a range of 5 miles, the Coast Guard cutter VENTUROUS in the Los Angeles entrance channel, a small boat in the harbor at a range of 400 yards, a roadway a half-mile across the harbor, and from various homes within a distance of 1 to 3 miles. These eyewitnesses generally saw two explosions, the second being of much greater intensity. Only two of the eyewitnesses interviewed actually observed large portions of the vessel traveling through the air. Several witnesses observed an initial flash occurring over the tank deck abaft the midship deckhouse. Several witnesses reported seeing a fire at the instant of or just before the second larger explosion. Two witnesses testified to seeing, before the explosion, what they thought was a vapor cloud or smoke over the midship house and the port bow area. One nearby witness observed two crewmembers running from abaft the midship house, on the starboard side, diagonally aft toward the catwalk, immediately prior to the explosion.

b. In March 1977 additional testimony was received after the media reported the possibility of a bomb having made a hole in #3 port cargo tank. One witness testified that he had observed what he thought was a flare fired from a small aircraft carrier (the ex-USS HANCOCK) being dismantled at Berth 53, a half-mile from the SANSINENA. He said the flare went in the general direction of the

SANSINENA immediately prior to the explosion. A woman standing on a patio approximately 2 3/4 miles from the SANSINENA observed a "ribbon of light" extending from left to right towards the tanker, not in motion, immediately preceding the explosion. Another witness, a seaman on the bow of the Coast Guard Cutter VENTUROUS, testified that he observed a fire in the vicinity of the loading arm, which appeared to move toward the vessel, until he lost sight of it at the deck edge at which time, he said, he saw the explosion occur. An airline pilot 1 1/2 miles away at an altitude of 7,000 feet was looking in the direction of the SANSINENA at the time of the explosion. He saw no flare or rockets. Other witnesses on board the VENTUROUS looking in the direction of the small aircraft carrier saw no flares. Other witnesses from the VENTUROUS looking toward the SANSINENA saw no fire traveling from the dock to the tanker.

c. At about 1938 a large light-colored flash explosion occurred over the after tank deck, described by some witnesses as very similar to the discharge of a camera flashbulb. Fires over the after tank deck were observed as the ship blew apart, with the entire tank deck and midship deckhouse rising an estimated 750 feet in the air. The tank deck was observed to land on the terminal property. The deckhouse was aflame. The remainder of the vessel was aflame throughout the cargo tank area. The bow inclined aft and the stern section settled slowly in the water. Bunker oil and cargo residue entered the water and burned extensively.

d. The midship deckhouse landed on top of the terminal guard shack.

e. Debris consisting of piping and fittings fell onto the terminal and adjoining property, including the nearby boatyard.

24. Summary of Firefighting and Lifesaving Efforts

a. The Los Angeles Fire Department initially responded to the SANSINENA explosion with two task forces, four engine companies and five fireboats, followed up by three more engine companies and three more task forces. The first units arrived on scene at 1945.

b. FIREBOAT #5, stationed at Fort McArthur, approximately one-half mile from Berth 46, responded immediately. By 1954 this boat had picked up 18 survivors, some from SANSINENA's stern and some from the water.

c. Land units, hampered in approaching the tanker's berth due to the scattered debris, had to hand-lay about 700

feet of fire hose. One task force was assigned to prevent extension of the fire into the San Pedro Boat Works just west of Berth 46. Various fire department units fought the fire on the tanker, on the dock, and at a broken pipeline on the terminal property where the deck and midship house had fallen.

d. Altogether, the Los Angeles Fire Department utilized 10 task forces, 7 single-engine companies, 5 foam apparatus, 5 fireboats, 9 rescue ambulances, two helicopters, 2 tankers, 2 light utility units, and various miscellaneous equipment. Five task forces and 2 single-engine companies were held in reserve. Some 240 uniformed firefighting persons were actively engaged in the operation.

e. Water, aqueous film-forming foam, high expansion foam, and liquid protein foam were used to control and extinguish the fire, which was accomplished at 2220, except for continued flare-ups on the dock due to oil supplied by the broken pipeline.

f. At 1945 COTP (LA-LB) contacted Chief Petty Officer [redacted], Coast Guard Reserve Firefighter Coordinator, who arrived on scene at 2115, and was assigned as coordinator between the Coast Guard and the Los Angeles Fire Department. He boarded CG-41377 where he coordinated communications between land units, fireboats, and the Coast Guard on-scene commander. The Fire Department reports indicate that coordination and cooperation with the Coast Guard were excellent. Chief [redacted] report, noted the maneuvering difficulties experienced by the Coast Guard 41-foot boats and a problem in the use of Coast Guard helicopters over a fire.

g. The USCGC VENTUROUS (WMEC 625) was standing into Los Angeles Harbor when the SANSINENA casualty occurred. The explosion was witnessed by several of her crew members, from a position about 150° relative from the SANSINENA, distant 2000 yards. She proceeded immediately to the scene and assumed on-scene command at 1955. Several other Coast Guard units responded, some almost immediately, and others within two hours. These were: POINTS ADAMS, POINT BRIDGE, POINT CAMDEN, CG-41377, CG-40603, CG-21346, CG-205411, and HH52A's 1408 and 1442. The Coast Guard units assisted in firefighting; survivor and body search; evacuation of survivors; the picking up, laying and patrolling of oil booms; traffic control; pollution surveys; and in providing transportation to concerned agencies as needed. The three 82-foot cutters and one 41-foot utility boat, the CG-41377, were directed by the on-scene commander to assist in the firafighting. The VENTUROUS, being on one engine, was

unable to maneuver adequately to be involved in the firefighting.

h. One survivor was retrieved from the water by the CG-41377 and another was received from Los Angeles FIREBOAT #3. A private sailboat, the SPRITE III, underway and about 400 yards from the SANSINENA at the time of the casualty, approached the seawall near SANSINENA's stern and picked up three of the tanker's crewmen (the chief officer, first assistant engineer and one other) who were urged to swim out from the rocks, to which they had swum after jumping overboard. These survivors were transferred to the VENTUROUS. The SPRITE III was disabled while maneuvering in the oily waters to pick up these men, and was towed to Base Terminal Island by the small boat of the USCGC VENTUROUS.

i. The 18 survivors picked up by FIREBOAT #5 were taken to Berth 55 and were transported to neighboring hospitals by Fire Department ambulances. The two survivors aboard CG-41377 were evacuated to a hospital by Coast Guard helicopter HH52A 1442. The three survivors aboard the USCGC VENTUROUS, taken off the SPRITE III, were transferred to FIREBOAT #3 for further transfer to hospitals. A total of 23 crewmembers were picked up and all were taken to hospitals; of these, two were uninjured and required neither medical treatment nor hospitalization.

25. Summary of Damages Resulting From SANSINENA Explosion

a. The S/S SANSINENA was a constructive total loss; its insured value was $7,300,000.

b. The Union Oil Terminal, Berth 46, suffered extensive damage; the cost of rebuilding the facility has been estimated at $3,500,000.

c. Claims indicate damage to some 260 other vessels, mostly pleasure craft. The bulk of this damage, primarily from debris, was sustained by boats in San Pedro Boat Works, located immediately adjacent to Berth 46. Boats in three marinas in Watchorn Basin, up to one-half mile north of Berth 46, sustained blown-out windows. Several vessels suffered minor oil-coating on their hulls. The total for such boat damage claims is about $275,000.

d. Damage to property ashore beyond the Union Oil Terminal ranged from severe to scattered, depending on the proximity and degree of exposure to the explosion, and to the vagaries of the concussion wave. Definitions of damage are: (1) severe--major structural damage, large areas of broken glass, blown-in doors, etc.; (2) heavy--damage to plate glass windows, shades and screens; and (3) scattered--

broken windows, interior furnishings such as tables, mirrors, etc.

e. Severe damage occurred in the Fort McArthur (lower reservation) area, the Cabrillo Beach area, and the San Pedro Boat Works.

f. Heavy damage occurred at distances ranging from 1 1/16 miles to the west, Gaffey Street and Paseo del Mar, to 1 1/2 miles to the north, or approximately Seventh Street and Harbor Boulevard. This area is generally bounded on the west by a line running along Gaffey Street to Seventh Street, and easterly to the Main Channel.

g. Scattered damage occurred in a westerly direction as far as 3 1/16 miles from Berth 46, then in an easterly arc to a point two miles north, where an extension of O'Farrell Street would intersect the main channel, thence across the channel to include the Fish Harbor area. Damage was generally uniform in all areas.

h. Damage was also reported in the cities of Carson, to the north, and Long Beach, to the east. The city limits of these two cities are approximately 6 and 3 miles, respectively, from Berth 46. This damage was minor in nature.

i. There have been about 100 non-crew personal injury claims, mostly for injury from flying glass fragments. As of 11 January 1977, approximately 6,000 claims for property damage had been filed with Underwriters Adjusting Company, of Tustin, California, who were appointed by the Union Oil Company to handle such claims. The total costs for non-crew personal injury claims and damage to residential and commercial property is estimated to be $2.5 million.

j. The cost of salvage involved in the removal of the SANSINENA wreckage is estimated at $5 million.

k. The cost of pollution cleanup and associated services is estimated at $1 million.

l. The estimated cost of claims arising from crew injuries and deaths is between one and two million dollars.

m. The total estimate of damage costs in all forms is about $21.6 million.

26. Pollution

a. At approximately 2030 COTP Long Beach began contacting pollution clean-up companies. Crowley

Environmental Services, the first to respond, immediately deployed a boom around the vessel. Crosby and Overton, Wm. Hutchinson and Son, and Crowley then deployed approximately two miles of boom in an attempt to contain the oil. Pollution abatement efforts closed the Los Angeles Main Channnel and Entrance until noon the following day.

b. An estimated 22,000 barrels of bunker fuel oil entered the harbor from the vessel and from a broken pipeline ashore. Oil settled on the bottom around the stern of the vessel within about twenty to thirty yards, located in patches up to nine feet thick. It tapered down to a thickness of one inch out to a distance of 100 yards from the vessel. By 11 January 1977 approximately 20,000 barrels of oil had been recovered.

27. Coroner's Report

a. At approximately 2200 on 17 December 1976 personnel from the County of Los Angeles Coroner's Office located the remains of crewmembers Emanuele Orgioli, Umberto Scarogni, and Calogero D'Asaro on the dockside area of Berth 46. The remains of crewmember Orazio D'Amico were found floating in the water between the seawall and the bow section of the SANSINENA.

b. During dismantling of the wreckage on 30 December 1976 the remains of Felice Tridente were located.

c. On 31 December 1976 and 10 January 1977, after further dismantling of the midship wreckage, the remains of portions of two bodies were located. Because the Italian government does not require the recordation of blood types or fingerprints of merchant seaman, the remains could not be identified.

d. On 11 January 1977 a piece of human flesh weighing five pounds was found in the wreckage near the bosun's locker on the main deck in the midship house. Due to insufficient evidence this flesh was not catagorized as that of a person separate from those previously identified or discovered.

28. By contractual arrangement, the Italian crewmembers of SANSINENA and one other tanker, the S/S LAKE PALOURDE, were provided by [redacted] SpA, an agency in Italy. Under the existing arrangement the agency is responsible to provide experienced and qualified personnel, relative to the position being filled. Hendy International normally interviews the candidates for the key positions (master, chief officer, chief engineer, and first assistant engineer). In the case of the SANSINENA, however, the key officers were already employed and serving satisfactorily in

1969 when Hendy's involvement with these ships commenced, so this was not done in their case.

29. The company policy is that the maximum stay on board is six months. With its run in the Pacific and an Italian crew, this means that each man is away from home generally for six months at a stretch. It was also noted that after a period of leave a man rarely would return to the same ship. As an illustration of this point, when Mr. [redacted], the chief officer, joined the ship this time, he had been away for 18 months; during that interval there had been five different chief officers on board. CAPT [redacted], [redacted], general manager of Hendy International, testified that in some instances some of the new crew members have been to training schools in Italy, such as a firefighting school, but for the most part training is done on the job. When a new seaman arrives on board, he said, he immediately assumes his watch, whether he has had previous tanker experience or not. On the day of the casualty six new men had reported on board; one of these, able seamen Calogero D'Asaro, was on watch on deck at the time of the casualty. D'Asaro was not experienced on tankers, but was an experienced seaman; he had served only on trawlers and held an Italian license as coastwise master.

30. Contractual Relationships

a. The SANSINENA was built by Newport News Shipbuilding and Drydock Company for Barracuda Tanker Corp. and was time-chartered for 20 years to the Union Oil Company of California. Union acknowledged that Barracuda Tanker Corp. was a lease-back firm created solely to serve Union Oil. Though not owned by Union, Barracuda was set up to build a fleet of oil tankers for charter to Union.

b. Barracuda was formed with only a $20,000 investment by a group of employees, stockholders and relatives associated with Dillon, Read and Company, Union's investment banker. Barracuda's ability to borrow millions of dollars from Metropolitan Life Insurance Company Funding, with a working capital of only $20,000, rested largely on its time charter with Union. Under the charter Union made payments on Barracuda's ship construction loan, paid owner's costs, insurance fees, and operating expenses, and agreed to pay off the loan if the ship were lost or destroyed. After the casualty Union paid off more than $6 million remaining on the construction mortgage.

c. The original 20-year time charter was amended in April 1965 to run another 20 years.

d. By a "management of the vessel" agreement with Barracuda, the Pine Company was, among other things, to provide for ordinary maintenance of the vessel, which rights and obligations were further contracted out, in toto, to Hendy International Company. As mentioned in paragraph 28 above, Fratelli Cosulich, SpA. was responsible for providing the crewmembers.

31. Marine Board's Material Findings In Its Investigation of the Wreckage of the S/S SANSINENA

a. SANSINENA's after deckhouse and bow section in way of the forecastle head were relatively undamaged except in their forward and after ends, respectively. (See figure 2.) The entire cargo tank deck, from the forward end of #1 cargo tank back to the forward end of the after deckhouse, was blown away forward and to starboard, end-for-ending and landing inverted, except where curled around the midship deckhouse, which landed diagonally upright, turned 115 degrees counterclockwise from its original orientation on the ship, falling on top of the terminal guard shack. (See figures 3 and 4). One piece of deck from over #1 and #2 center cargo tanks broke away from the rest and landed near the south end of the terminal property, about 75 feet from the water. The deck ripped out along the longitudinal riveted seams, one located eight feet inboard of the the starboard gunwale, at the inboard edge of the stringer plate, and the other at the inboard edge of the port riveted deck strap, some 24 feet inboard of the port gunwale. The largest piece that landed ashore contained the starboard and center cargo tank expansion trunks. All bulkheads in the tank section were knocked down, at least at their tops. The sides were blown outward and down, more to port than to starboard, as the ship's starboard side was close alongside a reinforced concrete wharf. The 24-foot-wide strip of decking, including the port cargo tank expansion trunks, was blown to port. The 8-foot-wide strip of the deck stringer plate from the port side was not immediately found, either by the Marine Board or by the the divers. The port midship kingpost fell with the port edge of the center deck section, over the north end of the terminal control room, breaking in two, with its upper end near the water's edge. The starboard midship kingpost fell under its adjacent deck plating on the terminal area. The after pumproom ventilator trunks fell onto the after boat deck, the port trunk to port of and the starboard trunk into the swimming pool. The paint was largely intact in the after pumproom, with no evidence of a fire having occurred within that space.

b. The Board's examination of the inverted deck plating revealed small pieces of bulkhead on all cargo tank transverse bulkhead lines. All such pieces forward of #10

tank were bent forward, all abaft #10 tank were bent aft. (Figure 5.) There were no bits of the #10 longitudinal bulkheads left attached. However, a close examination of the broken continuous fillet welds along those bulkhead lines revealed that on the outboard sides the remaining welds were lower on average and were beveled outward from the bulkhead's former postion, while the opposite broken fillets were higher and were slightly "hooked" toward where the bulkhead had been. (Figure 6 typical.) The bulkhead fragments indicated clearly the direction of bulkhead displacement. There were consistent findings that the beveled fillets were on the side toward which the bulkhead fragments were bent, with the slightly "hooked" edge higher on the opposite fillets.

c. Examination of the deck from #10 center tank showed that the four tank-washing plates, studs and gaskets were intact and in excellent condition. Three steam pipes, about 1 1/4" i.d., and four smaller steam pipes, all of which had previously served the cargo tank heating coils, had been cut off inside the tank but had been left intact on the top-deck side. As the deck plating was cut away and turned over, these pipes were inspected. All were broken off. One of the previous steam supply pipes was bent and ruptured. A close scrutiny of the ruptured area revealed that the metal there was "paper-thin." A fresh break could not be discerned.

d. Examination of pieces of the cargo tank vent piping, including the branch lines and the common header revealed numerous areas of localized wastage. Several pieces were found with holes wasted through on their undersides. (See figures 7 through 8 for examples.) Examination of the area surrounding these holes revealed that the holes were primarily the result of internal corrosion. Much of this piping had a very heavy buildup of exterior paint, as much as 1/8-inch thickness in places. Various samples of the cargo vent piping and a typical P/V valve were analyzed by the Aerospace Corporation in an effort to characterize the corrosion behavior. Generally, uniform corrosion of the bottom portion of the vent piping was noted to be at least twice and at some places up to four times the normally expected corrosion rate for galvanized steel in a marine environment. Further, localized deeper pits and holes in the vent header pipes in the vicinity of P/V valve connections were attributed to either galvanic action between the steel pipes and copper products from the P/V valves or action of a hydrochloric acid solution in areas of initial breakdown of the protective zinc coating. The analysis also concluded that the corrosion holes studied were covered by a thick external paint coating prior to the explosion.

e. The blank on the end of one vertical riser, which had been attached to the exterior of one of the midship kingposts, had a threaded hole in it of about 1 3/4 inch i.d. There was no nipple or plug in it and the inside threads were intact and rusted and appeared not to have been used recently. One washout nipple on a transverse branch vent line, found underneath #11 center tank, had no cap on it.

f. Nearly all branch lines were broken off from the common header pipes, and most of the P/V valves found had their tops broken off.

g. A number of ullage screens were found with various degrees of damage. All those observed had 20-mesh wire screens (20 x 20 wires per inch). The screens were covered by a 4-mesh protective wire screen.

h. All P/V valve housings and vent line relief valve housings had 20-mesh wire screens, most being single layer but a few were double-layered.

i. The screen from one vent header pressure relief valve was badly corroded and appeared to have fallen out from corrosion, not from tearing loose.

j. When the deck plating in way of #10 center cargo tank was cut up and turned over, the wheelstand for the #10 center stripping suction valve was crushed too badly to indicate the valve's position. The wheelstand for the #10 center main cargo suction valve, however, was only slightly damaged and its pointer was in the closed (down) position. Another piece of the #10 center deck plating, when turned over, had a mooring winch with wire drum and one valve wheelstand with no stem.

k. Portions of the midship deckhouse and the main tank deck had penetrated approximately 16 feet into the earth, severing a 30-inch pipeline near the terminal manifold. The fuel from the broken oil pipeline fed the fire which burned throughout the deckhouse off and on for several days. This break was plugged with drilling mud on Tuesday, 21 December. An inspection of various parts of the midship deckhouse, because of the severe physical and/or fire damage, failed to reveal any evidence of a positive source of ignition.

l. Pieces of deck piping, catwalk structure, etc., were strewn about over an extensive area. Most of the material found adjacent to and on the premises of the San Pedro Boat Works appeared upon close examination to have come from the afterdeck area. Most of the piping from the foredeck area,

which landed on shore, was found in the area generally to southward of the midship house location.

32. Possible Ignition Sources

Having established to its satisfaction that the deflagration and detonation inside the ship had started in #10 center tank and had travelled longitudinally and outboard from there, the Board considered the following possible sources of ignition, internal and external to that tank:

a. Possible internal sources include such things as:

- Falling object, e.g., ladder, reach rod, piece of bulkhead, flashlight, tool, or other object
- Static electricity
- Auto-ignition
- Breaking and striking together of any metal part within or in the periphery of #10 center tank including structural members, ladders and bulkheads.
- Chemical action

b. Possible external ignition sources included those adjacent to as well as those remote from #10 center tank. A preponderance of eyewitness testimony indicated a vapor cloud flash over the after tank deck. The probability of such vapor cloud forming from the ballasting of tanks #10 wings, #8 wings, #7 center and #5 wings was established, considering the weather conditions prevailing immediately preceding the explosion of the SANSINENA.

(1) External ignition sources adjacent to tank #10 center:

- Smoking by crew member, or other open flame (match, cigarette lighter)
- Static electricity from polyester clothing
- Dropping of a steel tool
- Breaking of a flashlight bulb by dropping flashlight on deck.

(2) External ignition sources from the vicinity of the midship deckhouse that possibly could have ignited a vapor cloud over the deck.

- Gangway telephone
- Loose-fitting light globes on the deckhouse or in the shelter-deck area
- Dropping of steel tool
- Polyester clothing worn by crew

- Pressure switch and/or the motor controller of the fresh water pump in machinery compartment located inside the midship deckhouse.
- Smoking of crewmember
- Electric spark from dockside Chicksan assembly
- Breaking of a flashlight bulb by dropping of a flashlight.
- Friction source
- Hot particle as from stack soot
- Static discharge between ship and shore

(3) Possible external ignition sources included those adjacent to and remote from #10 center tank. Any remote source of ignition would require some path of transmission into #10 center tank, either through a closed conduit of some sort or through the atmosphere itself.

(4) It was reasoned that after the vapor cloud flashed over the after tank deck the flame transmission into #10 center tank could easily have been effected through either the compromised vent system or the old and wasted heating coil supply pipe. A further possibility was that of flame transmission directly into the tank through the ullage screens, or through the ullage opening if the screen to #10 center was not in place.

33. Inspections

a. Liberian Maritime Regulations provide that various classification societies are authorized to act as agents of the Government of Liberia. Such agents are authorized to survey vessels and issue necessary certificates on behalf of the Republic of Liberia as may be required by any International Convention to which Liberia is a party. In the case of the SANSINENA, this classification society was Lloyd's Register of Shipping.

b. The SANSINENA was designed and constructed in conformance with Lloyd's Register Rules and Regulations for the Construction and Classification of Steel Ships in effect at the time. The vessel was maintained continually in class, which by definition in the Liberian Maritime Regulations is to be accepted as evidence that the vessel is in seaworthy condition. Accordingly the required certificates (Cargo Ship Safety Construction Certificate, Cargo Ship Safety Equipment Certificate, and International Load Line Certificate) were issued.

c. Lloyd's Register, as does other classification societies, requires inspections of the material conditions of the hull and machinery at periodic intervals, with the scope of the inspection increasing as the vessel ages. An

option available to owners, which was exercised in this case, is that of placing the vessel on a scheduled maintenance and inspection program known as a continuous survey. Each survey item is scheduled well in advance. The result is that a surveyor visits the vessel more frequently but with a smaller scope of inspection being conducted on each visit than would be the case with a special survey program. Surveyors only visit a vessel on the specific invitation of the owner or master.

d. In any event, the vessel must be surveyed annually, as was the SANSINENA, in order to renew or endorse the International Load Line Certificate. This inspection consists of general examination of the hull and all potential sources of flooding, such as hatches, doors and vents. The SANSINENA was so inspected on 22 and 23 January 1976 and the Load Line Certificate was endorsed.

e. As a normal practice, repairs recommended in the course of a survey would be submitted to the vessel's owner via the master. The recourse available to the society, should the owner elect not to follow the recommendations, is to drop the vessel from classification.

f. The cost of this service is defrayed by direct reimbursement of the society by the vessel's owner.

g. Liberian vessels are also subject to another annual inspection. Nautical Inspectors, appointed by the Government of Liberia, conduct a safety inspection upon request of the owner or master. This inspection generally involves the operational readiness of the vessel; e.g., required publications, charts, logbooks, oil record books, etc., and the particulars of licenses of the crew, and navigation equipment maintenance and calibration. The inspector is also authorized to spot check lifesaving, firefighting and general safety conditions covered by the International Convention for the Safety of Life at Sea, 1960, and to conduct fire and boat drills. Costs of the service are borne by the Government of Liberia, which in turn charges the shipowners a set fee.

h. The last safety inspection of the SANSINENA was conducted at Los Angeles, CA, on 16 January 1976 by an inspector of the National Cargo Bureau, Inc. Deficiencies in crew qualifications were resolved prior to the vessel's sailing. Generally, corrective action for material deficiencies noted during an inspection would be limited to bringing these deficiencies to the attention of the master and classification society representatives.

i. Liberian Maritime Regulations also require the master to conduct fire and boat drills once a week. No fire drill had been conducted on board the SANSINENA from 4 November 1976 to the time of the casualty.

34. Maintenance and Repairs

a. By all accounts the SANSINENA was a generally well-maintained ship. Company maintenance supervisors and surveyors from Lloyd's Register of Shipping and the National Cargo Bureau, Inc., all testified as to the satisfactory status of maintenance and repair of the vessel. Close examination of the cargo vent piping after the casualty, however, showed that considerable wastage in this critical system had gone uncorrected, if not undetected. None of those who testified had looked closely and specifically at the entire cargo vent system. The master and chief officer, both of whom had been aboard about six weeks, also disavowed any knowledge of the wastage of the vent piping.

b. Deck maintenance and repair items beyond the capability of the crew were informally noted by the ship's officers for review by the Hendy International shore staff. The deck officers had maintained a rough log of maintenance accomplished by the crew. This maintenance record book was lost in the fire. For its part, the company had promulgated no written instructions to masters concerning the scope and frequency of deck maintenance and inspection to be accomplished by the crew.

c. In order to remain in class, the SANSINENA had been routinely subjected to scheduled repair periods, roughly annually. For the past several years, except for extraordinary items, the annual hull and machinery repairs had averaged approximately a quarter-million dollars. In 1975, over one million dollars was expended in removal of steam heating coils and in applying vinyl-epoxy coating to the bottom portions of all cargo tanks to arrest internal corrosion. Many continuous survey items were scheduled for calendar year 1977 and accordingly the repair budget had been projected to be nearly one-half million dollars.

d. Review of previous shipyard worklists disclosed that only one short section of 6-inch branch vent line had been renewed in the past several years. Maintenance had been extensive in repairs to various and numerous small cargo tank bulkhead cracks, some of which were in existence at the time of the explosion.

35. Vapor-Emitting Operations Policy

a. Chief officer Gugliotta testified that it was the policy on the SANSINENA to carry out vapor-emitting operations such as loading or ballasting in the same manner, regardless of the condition of the wind. This practice is not in keeping with the advice in the two books on tanker safety which are required to be carried on all Liberian-flag tankers. English versions of the Tanker Safety Guide (Petroleum), published by the International Chamber of Shipping, and the International Oil Tanker and Terminal Safety Guide were on board, and the ship's key officers appeared to have a sufficient facility in the English language to read and understand them.

b. The Hendy manual on Ship's Business had no advice for shipboard personnel in this regard, but it did point up the importance of saving ship's time.

c. When questioned about the company policy with regard to a shipboard decision to stop operations because of low-wind conditions, CAPT Erikson testified that no action would be taken against a master or mate who made such a decision. Upon further inquiry, however, he said that the shipmasters are not told this. He said that they have the books on board which advise them on safety matters, and that it is up to them to make their own decisions. He also testified that he had not briefed them very specifically on safety matters, reasoning that shipmasters, because of their position, are required to exercise independent judgment.

d. The Union Oil terminal, for its part, had no established rules or procedures for limiting or controlling vapor-emitting operations by tankers berthed there.

36. Terminal Security Practice.

a. Security at Berth 46 was provided by Shield Security, Inc. of Los Angeles, upon request, when a ship was in. The guard customarily stood an 8- to 12-hour watch, primarily in the guard shack at the main gate.

b. According to the established terminal rules, the only visitors allowed onto the terminal property were those authorized by the berth supervisor or the wharf foreman. The ship's master and agent were authorized to provide a written pass for shipboard visitors.

c. At about 1700 on 17 December 1976, Mr. [redacted] visited the SANSINENA to pick up his friend, crewmember [redacted]. They departed the vessel, went to [redacted] home, and returned to the ship at approximately 1915. [redacted] testified that he had the master's permission to go on board the vessel. [redacted]

said that when he went on board the last time he noticed two seamen on the deck watch. There was no evidence that he was challenged by them. In any case, [redacted] was on board, in the crew's messroom, when the casualty occurred, and got off the vessel with the crew.

d. Captain Bovone testified that he did not authorize any visitors other than Captain [redacted] that evening.

37. Expert Witness Testimony

a. [redacted], Ph.D., associate professor of chemical engineering, University of Arkansas, presently on leave and acting as technical advisor to the U.S. Coast Guard Hazardous Materials Division, Washington, D.C., testified as an expert witness on fire and explosion phenomena. Dr. Havens' doctoral and postdoctoral work was in the Flame Dynamics Laboratory at the University of Oklahoma, primarily associated with flame phenomena. He is a consultant in fire and explosion phenomena, is Vice Chairman of Committee E27 of the American Society for Testing and Materials, which is a committee on the hazard potential of chemicals.

b. Dr. [redacted] described the function of a flame screen, such as an ullage screen, as working basically on a cooling principle, designed to stop a low-velocity flame front by absorbing heat from the flame. He explained that if the heat absorption is sufficiently high, the flame will be cooled down to the point where it will not propagate through the screen. In order for the flame screen to fulfill its design function there is a limit to the size of the holes in the screen, above which the screen will not stop the passage of even a low-velocity flame, this limiting hole size being on the order of about 1/20 inch (0.050 inch). He said that a 20-mesh flame screen actually has holes of about 0.035-inch, after the size of the wires is taken into account. He further stated that a one-tenth-inch hole would pass a low-velocity flame.

c. As to the question of what velocities of flame would be stopped by a proper flame screen, he stated that tests have indicated that a flame velocity of 5 ft/sec would be stopped, but one of 50 ft/sec would not, and that between these velocities data are lacking. He expressed an opinion that it is possible that a flame of 20 or 30 ft/sec (such as might occur in an unconfined vapor cloud at a distance of 20 or 30 feet from the point of ignition), impinging directly on a flame screen, would penetrate a 20-mesh screen.

d. Concerning the nature of flame fronts in a hydrocarbon vapor cloud, Dr. [redacted] testified that the flame

velocities in the open air depend upon the fuel mixture, its composition, the degree of mixing, and on other factors such as the temperature and size of the flammable cloud. He said that a flame front will travel out in all directions from the point of ignition, and that it will seek to expend the mixture that it is using as its source. If the flame reaches an over-lean region it will stop; however, if it contacts an over-rich region then usually it will continue to burn through the over-rich region because air will be entrained into the flame area and will make that a combustible mixture. As to flame velocities in an unconfined hydrocarbon vapor cloud, he said that "there is evidence of measured flame speeds ranging up to about 30 feet per second for propane-air clouds, and somewhat lower for methane clouds." Although these are relatively low flame velocities, he said, they are approaching the point where stoppage by a 20-mesh flame screen is questionable. He did, however, state that a well-designed [ullage] flame screen, properly in place, should stop a flame that originates next to a tank hatch.

e. With respect to confined hydrocarbon vapors, Dr. Havens stated that ignited light hydrocarbon vapors in a confined space can achieve supersonic speeds, i.e., velocities in excess of about 1100 ft/sec.

f. In a discussion of the energies required for vapor ignition, he said that energies equivalent to about 0.3 millijoule will ignite hydrocarbon vapors. He said that tests indicate, for example, that a hot filament of a flashlight bulb, if the flashlight is broken, might be sufficient for ignition, whereas the switching of a flashlight on and off apparently is not.

g. With regard to dispersion of a vapor cloud, Dr. Havens said that ". . . normally we would characterize a condition in which we expect very little dispersion of vapors as being one where the wind velocity was less than, say, 5 miles per hour." As to the height of the vapor such as might have existed over the SANSINENA's decks, he said that with the vapors venting only at the ullage holes, he would not expect vapor to be found to the height of the top of the midship house, but that with venting both from the ullage holes and the vent header stacks he would expect to find vapors throughout that height.

h. Corrugated-plate-type flame arresters, such as those provided on the tops of common-header vent stacks, were described as working on the same basic (cooling) principle as flame screens, but as being able to stop flames of much higher velocities than a screen, by providing a considerably longer contact time. Neither flame screens nor flame

arresters, he said, would stop a flame of detonation velocity, which velocities produce pressures in the hundreds of pounds per square inch, and sometimes higher.

i. When questioned as to the appearance of a hydrocarbon vapor cloud, Dr. [redacted] said that it would only be discernible as a light-refraction phenomena, similar to heat waves off a highway . . . that it would not be visible as condensed materials in the sense of a cloud in the sky.

38. In late February, during the removal of cut-up sunken sections of the cargo tank area of the SANSINENA, an externally caused hole was discovered in #3 port wing tank. Allegations of sabotage were made. Examination by Board members and explosion experts of the Los Angeles Police Department, the U.S. Treasury Department's Alcohol, Tobacco and Firearms Division, and the U.S. Navy, established that no external explosion had occurred, but rather that the damage was caused by contact with a hard object. Divers, hired by the Board, subsequently discovered the stringer plate from the area of #4 port wing tank embedded in the harbor floor beneath the position of the shell-plating hole. Divers who had been in #3 port tank during the wreck-removal operation subsequently identified the piece of deck plating from #4 cargo tank as having been present in the hole.

39. Wreck removal operations continue at the date of this report and are expected to be completed in late April 1977.

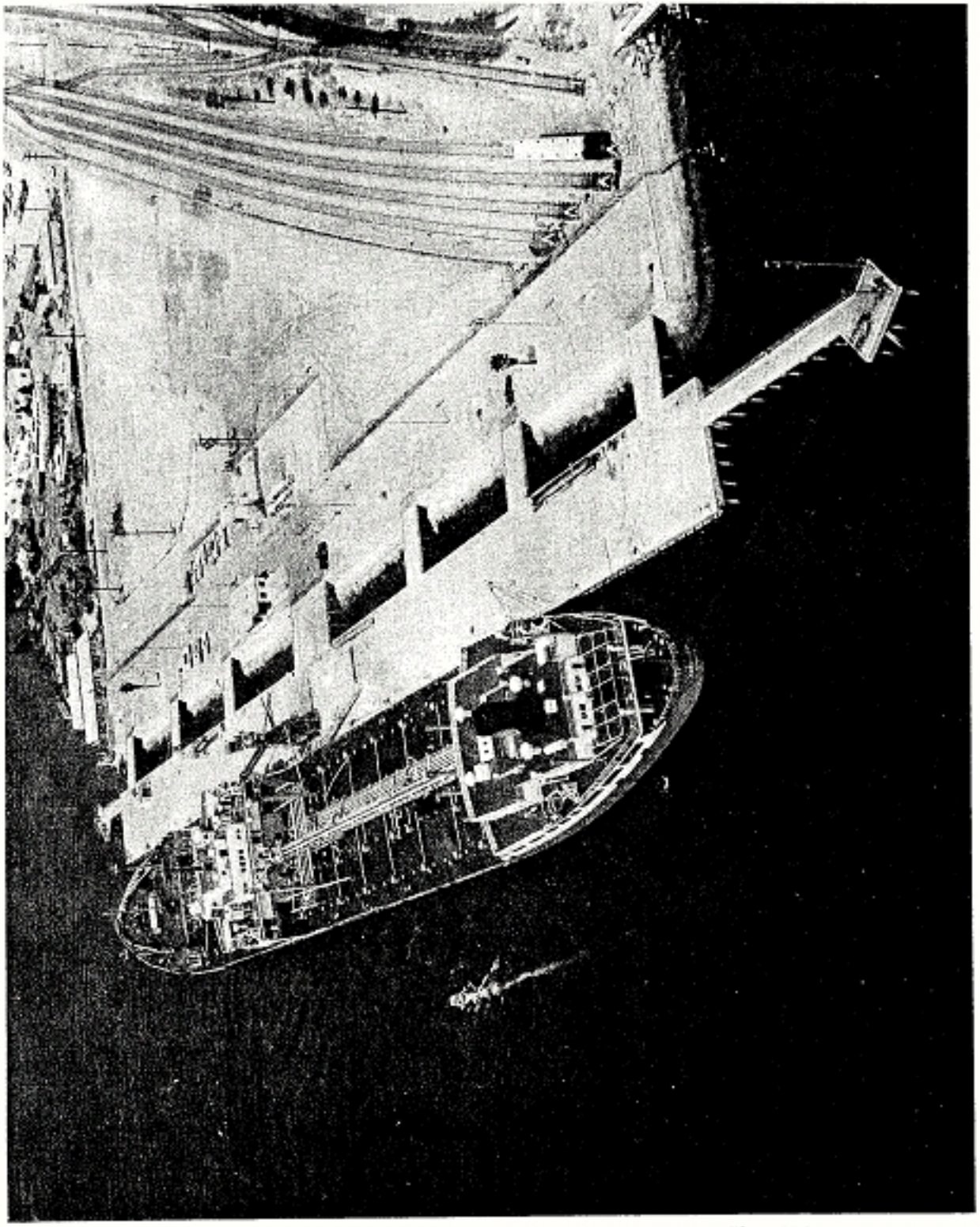

Figure 1

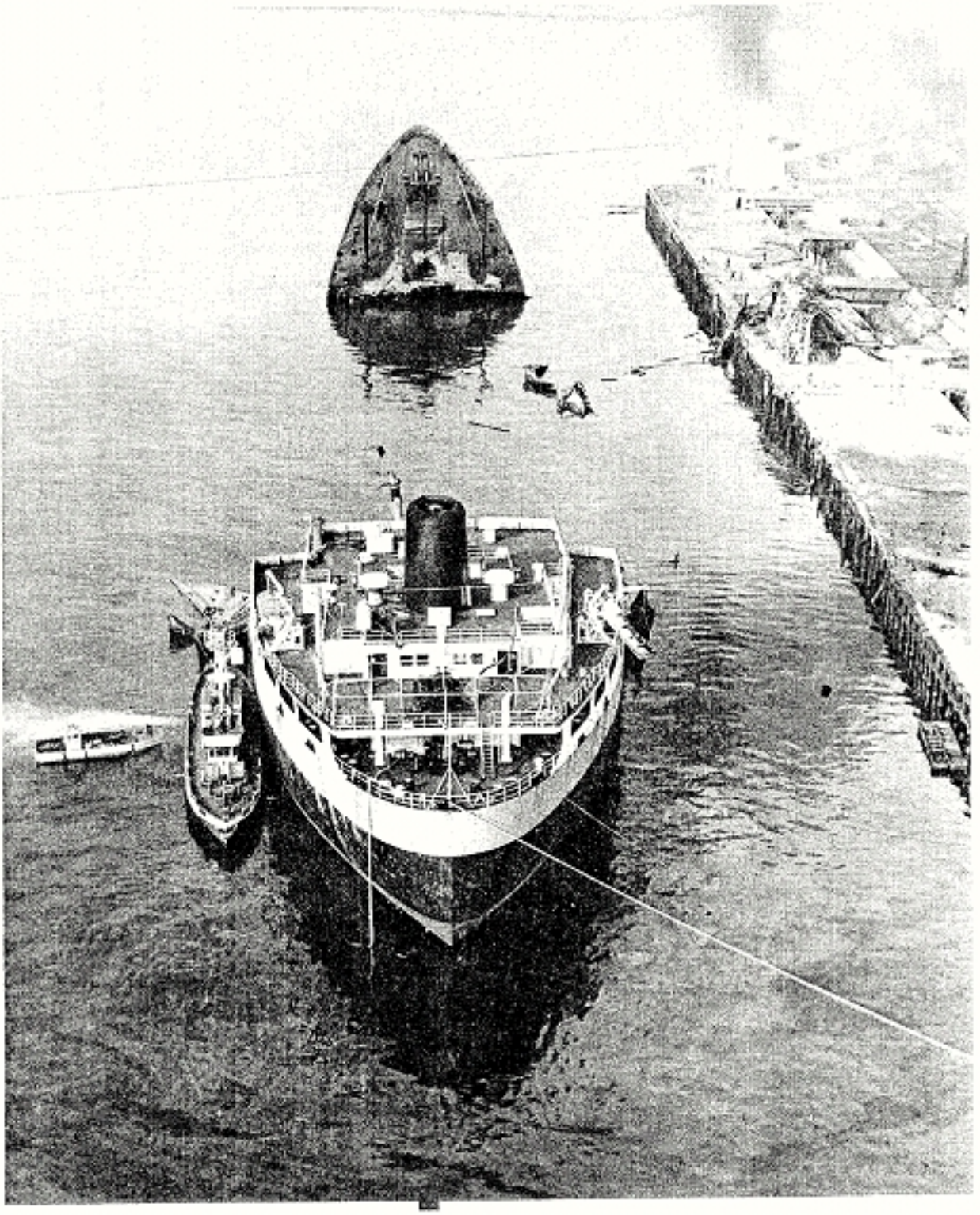

Figure 2

Figure 3

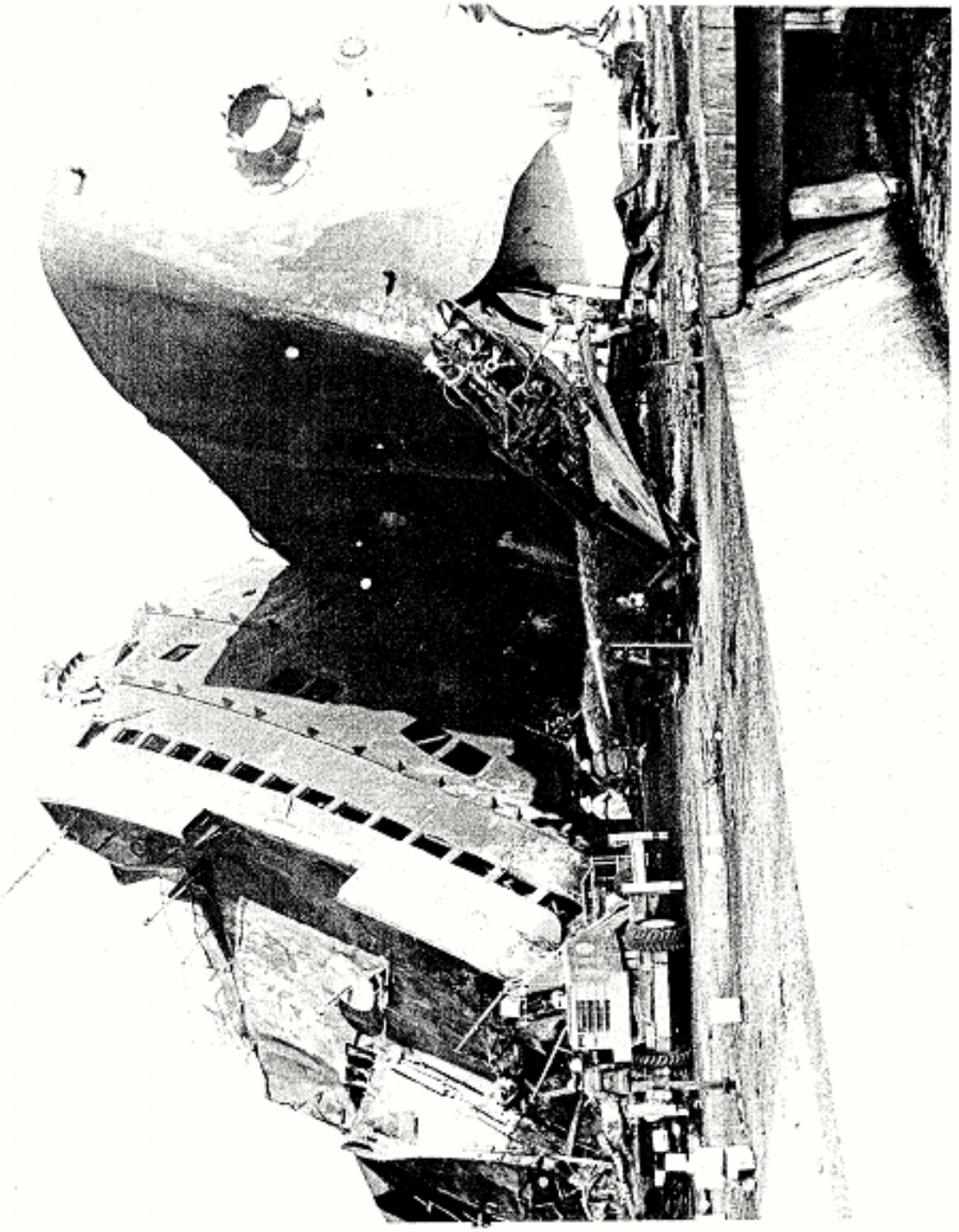

Figure 4

Figure 5

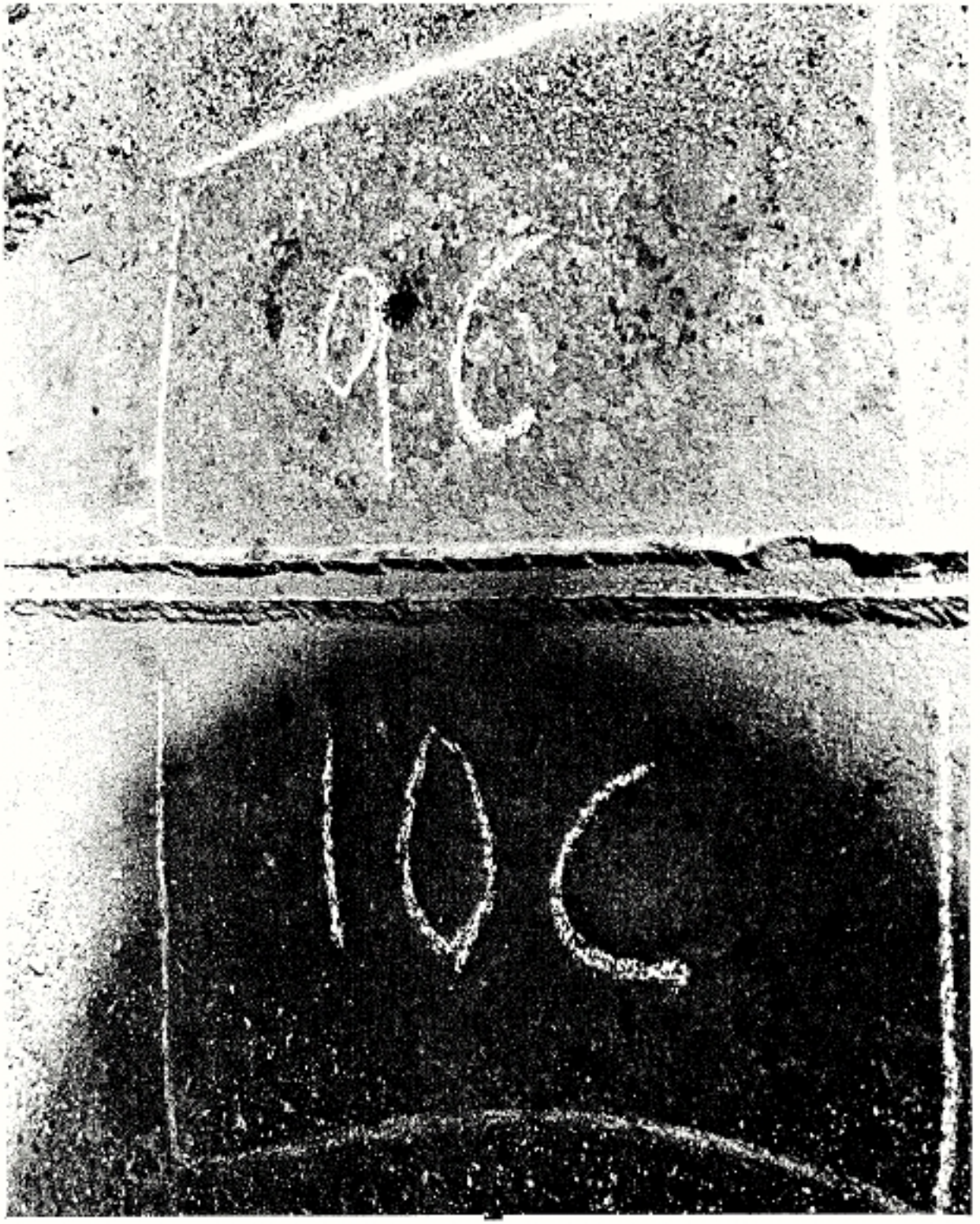

Figure 6

Figure 7

CONCLUSIONS

1. That the exact source of ignition could not be positively determined, but that more than one possible source existed.

2. That the most probable cause of this casualty was the ignition of a hydrocarbon vapor cloud over the afterdeck.

3. That the ensuing internal explosion was initiated by the vapor-cloud deflagration, which developed into a detonation in No. 10 center cargo tank, proceeding forward, aft and outboard, throughout the tank body, as a high-velocity pressure wave and flame front.

4. That the hydrocarbon vapor cloud was created by the ballasting of seven tanks in the afterdeck area under a light-wind condition which was not adequate for natural dispersion of the vapor, particularly that emitting from the ullage holes.

5. That the source of the vapor-cloud ignition was most probably in the vicinity of the midship deckhouse, but not inside that portion of the deckhouse in which a positive atmospheric pressure was maintained.

6. That the most probable point of ignition was in the midship fan room, and the ignition occurred when the wind shifted from about two points abaft the port beam to practically dead astern. The reported wind velocity of eight knots was probably reduced to a velocity of five knots or less over the tank deck area, with eddy currents, by the masking effect of the after deckhouse. This slight airflow moved the vapor cloud over the afterdeck in the direction of one or both of the fan room natural supply intakes, blanketing the vent cowling(s) with flammable vapors long enough for the flammable cloud to be drawn undiluted into the fan room and into contact with a source of ignition.

7. That the most likely source of ignition in the fan room was the motor controller of the fresh water pump, which cut in and out automatically.

8. That the following alternative possible external sources of ignition could not be entirely ruled out, but were of a lesser probability:

   a. Hot particle, such as stack soot
   b. Loose or missing vapor globes on lights outside the midship deckhouse or in the centercastle space
   c. Broken flashlight bulb
   d. Spontaneous combustion

e. Smoking or open flame on deck
f. Spark at loading arm and on the deck

9. That the speculation concerning a possible flare having been fired from the small aircraft carrier at Berth 53 was based on uncorroborated, delayed, and unreliable eyewitness testimony which was probably a result of sensory perceptions of reflections of the initial vapor-cloud flash as seen from a shadowed point of view which was not in a clear line of sight to the SANSINENA. The "ribbon of light" is evaluated as having been a glimpse of the very end of the initial vapor-cloud flash phenomena as seen by an observer who was not looking directly at the event as it initiated. The account of one observer of having seen a flame moving from dock to ship is evaluated as having been either a reversal of remembered perception as to the direction of movement of the initial vapor-cloud flash, or a mistaken impression as to its location relative to the wharf and the ship's deck. In any case it was not corroborated by other eyewitnesses from the same vantage point, and it too was delayed testimony.

10. That all of the internal ignition source possibilities have a lower probability, no supporting evidence, and are incompatible with the eyewitness testimony indicating that ignition started external to the tanks.

11. That the most probable path of transmission of the flame into No. 10 center tank was through the cargo vent system. Since no tanks connected to this portion of the vent header system were being ballasted, there would have been little or no velocity of the hydrocarbon/air mixture in this piping and the presence of a flammable mixture was highly probable. Thus it is also highly probable that the flammable mixture inside the piping was ignited through an opening in the vent system piping. (The P/V valve being in the open position, there would have been no obstacle to the movement of a flame to the tank.)

12. That alternative possible paths of a flame into No. 10 center tank were through the wasted steam heating coil pipe, which was open-ended under the deck, or directly through the ullage screen by impingement of the vapor cloud flame front directly onto the screen. These paths are considered less likely, however, because of an absence of a vapor cloud over No. 10 center tank hatch.

13. That at the time of the casualty two basic hazardous conditions existed: (a) a flammable fuel-air mixture inside the cargo tanks, without which there would have been no destruction of the vessel, and (b) the flammable vapor cloud

over the deck, without which there would have been no initial deflagration.

14. That had the cargo tanks been inerted, a vapor cloud might have been formed and probably would have been ignited as in this instance, but destruction of the ship is unlikely to have resulted therefrom.

15. That the flammable vapor cloud could have been avoided through (a) adequate dilution or dispersion, either natural or induced, (b) emission of all vapors high enough off the decks to prevent contact between the flammable vapor cloud and a source of ignition, or (c) by cessation of ballasting when the wind was not sufficient to disperse the vapors.

16. That in this instance there probably would have been no casualty had there been no midship house.

17. That had the vent system not been compromised--e.g., by wastage holes, which may or may not have been sealed by paint, or by missing drain plug and missing washout nipple cap--it could not have served as a path of transmission of the flame into #10 center cargo tank.

18. That the procedures followed in the inspection of the cargo vent systems by responsible personnel, including shipboard personnel, classification society inspectors, inspectors for the Government of Liberia, and company inspectors, were inadequate to timely detect wastage holes and failed to insure the integrity of the cargo vent system. The integrity of the cargo vent system was compromised by a missing cap and a missing plug which were detectable and by wastage holes which may or may not have been detectable. The nature of the wastage makes it extremely unlikely that timely visual inspection alone is sufficient to enable early detection and repair and thus to insure the integrity of the system.

19. That the location of the fan room air supply intake so near to the cargo deck was a serious design fault.

20. That had the shelter-deck doors not been open, another possible source of ignition might have been eliminated.

21. That because it is practically impossible to avoid compromise of the cargo containment system at all times when the hydrocarbon-air mixture inside the tanks is within the flammable range, a non-inerted tanker in volatile cargo trade is inherently hazardous during certain phases of its operation.

22. That the operating personnel on board the SANSINENA were not sufficiently knowledgeable in the subject of tanker safety, particularly with regard to the nature of the various hazards, e.g., understanding the function of vents and screens, the behavior of hydrocarbon vapors, and the relationship between loading rates and the resultant induced air pressure with known venting setups and vapor emission velocities. Key personnel on board the SANSINENA lacked sufficient theoretical background to make intelligent operational decisions. Simple do's and dont's are not a sufficient basis for proper decision-making by men carrying such responsibilities as do tanker officers; they need a thorough understanding of the elements with which they deal in order that they may intelligently choose the safest of the alternative practicable courses of action open to them in any given situation.

23. That the power failure suffered by the Pilot Station anemometer recorder and the directional error later found on that instrument both resulted from the concussion wave from the SANSINENA explosion.

24. That the company policy of rotating its shipboard personnel, particularly key personnel such as the chief officer, was detrimental to an effective shipboard maintenance system and was therefore contributory to this casualty.

25. That the testimony of CAPT [redacted] implied strongly that even though the company might not act against a master or deck officer for electing to suspend operations under low-wind conditions, it was not intended that a master know this for certain and that therefore any such decision would be made without knowledge of company support for it and would, in the mind of the person making such a decision, be balanced against the risk of losing his job.

26. That the following entities and persons are worthy of special recognition:

a. The Los Angeles Fire Department FIREBOAT No. 5, for its immediate response to the explosion of the SANSINENA and its rescue of 18 persons from the burning tanker.

b. The Los Angeles Fire Department, for extinguishment of the fire on the tanker and the adjacent dockside area.

c. BM2 [redacted], USCG, coxwain of the COTP Long Beach UTB CG-41377, for diving into the water to rescue an injured SANSINENA crewmember.

d. The crew of the COTP Long Beach UTB CG-41377, for rescuing an injured SANSINENA crewmwmber from the water and for assisting FIREBOAT No. 5 while it rescued 18 persons from the burning tanker.

27. That each tanker terminal might play a useful role in the field of ports and waterways safety by establishing restrictions on vapor-emitting operations by tank vessels during periods of low wind volocities, particularly with respect to vessels which are not inerted or provided with closed or restricted gauging, common header venting, and weighted ullage caps.

28. That the lack of regulations governing vapor-emitting operations can be considered a factor in this casualty.

29. That on the SANSINENA and other vessels with similar ullage arrangements, the practice of leaving the ullage caps in the open position and thereby allowing the vapors to vent at the cargo hatch level is a poor one. It is recognized, however, that vessels not equipped with a closed gauging system must periodically open the caps to determine the liquid level, and that without weighted caps it might not be practicable to keep them closed when loading or ballasting.

30. That the lack of fire drills is indicative of a general lack of training on board the SANSINENA and, further, that the lack of fire drills was a violation of Liberian regulations, although it was not pertinent to this casualty.

31. That mild steel vent piping, either uncoated or metal-coated, will deteriorate at a rate that will be a cause for concern after an initial period of about 10 years.

32. That the forward fall of #3 lifeboat parted as a result of the explosion concussion forces.

33. That classification society surveyors performing a dual role on behalf of the government and the shipowners, as in this case, are placed in a position of inherent conflict of interest.

34. That the Coast Guard 41-foot utility boat proved to be ineffective as a firefighting platform.

35. That there is no evidence that any personnel of the U.S. Coast Guard or of any other government agency contributed to this casualty.

RECOMMENDATIONS

1. That regulatory action be initiated to require inerting of all tankers carrying flammable cargo which call in U.S. ports.

2. That regulatory action be initiated to establish reasonable, practicable and enforceable restrictions on certain vapor-emmitting operations on tankers, with responsibilities defined for both tank vessel operators and terminal operators during periods of light airs or calms, to reduce the likelihood of flammable vapor clouds reaching a source of ignition.

3. That the United States initiate an international effort, under IMCO, to seek a standardization of merchant marine qualifications with respect to training, examination and periodic re-examination, to assure that such personnel are kept current with changing technology. This could best be facilitated through the establishment of a continuing permanent body within IMCO whose function would be to gather and evaluate technical and professional information and disseminate it in all the appropriate languages.

4. That all tankers calling in U.S. ports, whether inerted or not, be required to install and use venting systems with high outlets, closed and/or restricted gauging systems, and weighted ullage caps . . . and to maintain the integrity of these systems.

5. That as an interim measure until all tank vessels are inerted, and until there is international agreement on the scope and frequency of inspections of tank vessels, the Coast Guard should continue its precautionary tanker boarding program, paying particular attention to the integrity and condition of cargo tank vent systems, and to the ventilation systems, especially those of midship deckhouses, and that to this end an adequate Coast Guard-wide training program be developed to insure that the inspectors involved know how to conduct such operational boardings, and to keep them current through continuing training. Due to the comprehensive nature of these inspections, qualified marine inspectors should be utilized in conjunction with COTP personnel whenever possible.

6. That every cargo venting system at an age of 10 years be surveyed to determine its material condition, including removal of all P/V valves and audiogauging of the underside of the piping directly under the P/V valves.

7. That a study be conducted to determine the optimum period of continuous service for tanker personnel, particularly key personnel.

8. That legislation be sought to impose substantial monetary penalties on a strict-liability basis, against the owner/operator of any tank vessel who operates that vessel in a patently unsafe condition (for which guidelines should

be provided) in U.S. waters or otherwise under U.S. jurisdiction.

9. That the Commandant should evaluate the Coast Guard 41-foot UTB as to whether it is adequate as a firefighting platform, in view of the maneuvering difficulties experienced during the SANSINENA firefighting operation.

10. That a documentary film be produced to cover all aspects of tanker fire and explosion hazards, to be made widely available to Coast Guard, industry and international bodies, with solicitation to IMCO to produce versions with subscripts or dubbing in other languages as needed.

11. That the evidence of CAPT Bovone's violation of Liberian Maritime Regulations, with respect to the lack of fire drills in the period 4 November to 16 December, be forwarded to the Government of Liberia for appropriate disposition.

[redacted]

JAMES W. MOREAU
Rear Admiral, U.S. Coast Guard
Chairman

[redacted]

JAMES A. ATKINSON
Captain, U.S. Coast Guard
Member

[redacted]

RICHARD A. SUTHERLAND
Commander, U.S. Coast Guard
Member

[redacted]

RENE N. ROUSSEL
Lieutenant Commander
U.S. Coast Guard
Member and Recorder

[redacted]