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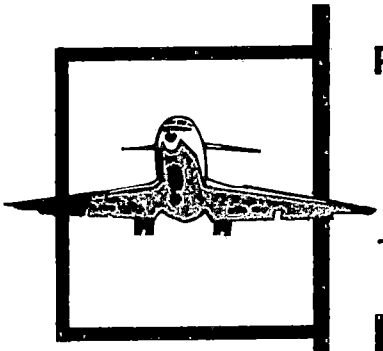

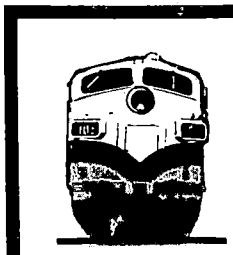

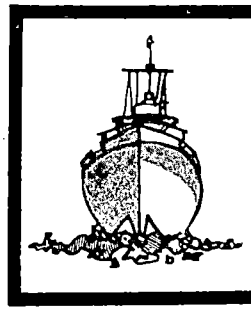

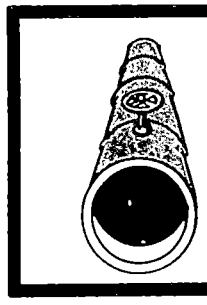

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

FIRE ABOARD THE BAHAMIAN PASSENGER SHIP M/V SCANDINAVIAN SUN PORT OF MIAMI MIAMI, FLORIDA AUGUST 20, 1984

NTSB/MAR-85/08

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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15. Supplementary Notes

16. Abstract

About 2300, on August 20, 1984, a fire erupted in the auxiliary machinery (generator) room and spread to adjoining spaces of the Bahamian registered passenger ship SCANDINAVIAN SUN shortly after it docked at the Port of Miami Terminal, Miami, Florida. It had just completed a daily 14-hour round trip cruise to Freeport, Bahamas, with 530 passengers and 201 crewmembers on board. One passenger and one crewmember died as a result of smoke inhalation, 4 persons received minor injuries, and 58 persons were treated for smoke inhalation. Damage and repair cost was estimated to be $2.3 million.

The National Transportation Safety Board determines that the probable cause of the fire on board the SCANDINAVIAN SUN was the crew's failure to tighten a threaded pipe fitting on the No. 1 diesel generator's lubricating oil line adequately which allowed the fitting to vibrate free and oil to spray from the line which ignited when it contacted the hot exhaust manifold of the engine. Contributing to the spread of the fire outside the auxiliary machinery (generator) room was the failure of the crew of the SCANDINAVIAN SUN to keep closed the watertight door and the self-closing fire door between the engineering spaces and the accommodation spaces. Also contributing to the spread of the fire was a delay in closing the automatic fire doors and stopping the ventilation system because a watch was not maintained in the pilothouse where the alarms and fire detection cabinets were located.

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CONTENTS

INTRODUCTION 1

SYNOPSIS 1

INVESTIGATION 2
The Accident 2
Emergency Response 6
Injuries to Persons 9
Vessel Damage 9
Crew Information 10
Vessel Information 10
General 10
Method of Operation 11
Fire Detection/Suppression Equipment 14
Overhaul of the No. 1 Diesel Generator 14
Port and Waterway Information 17
Meteorological Information 17
Medical and Pathological Information 17
Propagation of Fire 18
Survival Aspects 19
Test and Research 19
Analysis and Test of Pipe Fitting 19
Analysis of Lubricating Oil 19
Oil Consumed 20
Other Information 20
SOLAS Regulations 20
USCG Control Verification Examinations 20

ANALYSIS 21
Fire 21
Vessel Design and Construction 22
Communications 24
USCG Control Verification Program 24
Emergency Drills 24
Contingency Planning 25
Smoke Production and Movement 25

CONCLUSIONS 26
Findings 26
Probable Cause 27

RECOMMENDATIONS 27

APPENDIXES 29
Appendix A--Personnel Information 29
Appendix B--Effects of Carboxyhemoglobin and Hydrogen Cyanide 31

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

Adopted: July 9, 1985

FIRE ABOARD THE BAHAMIAN PASSENGER SHIP M/V SCANDINAVIAN SUN PORT OF MIAMI, MIAMI, FLORIDA AUGUST 20, 1984

INTRODUCTION

This accident was investigated jointly by the National Transportation Safety Board and the U.S. Coast Guard. The Safety Board conducted an on scene investigation between August 22 and August 25, 1984. No public hearing was convened. This report is based upon evidence developed in the investigation. The Safety Board has considered all facts pertinent to its statutory responsibility to determine the cause or probable cause of the accident and to make recommendations.

The Safety Board's analysis and recommendations are made independently of the U.S. Coast Guard. To insure public awareness of all Safety Board recommendations and responses, a notice of all recommendations and responses is published in the Federal Register.

SYNOPSIS

About 2300, on August 20, 1984, a fire erupted in the auxiliary machinery (generator) room and spread to adjoining spaces of the Bahamian registered passenger ship SCANDINAVIAN SUN shortly after it docked at the Port of Miami, Miami, Florida. It had just completed a daily 14-hour round trip cruise to Freeport, Bahamas, with 530 passenge rs and 201 crewmembers on board. One passenger and one crewmember died as a result of smoke inhalation, 4 persons received minor injuries, and 58 persons were treated for smoke inhalation. The cost to repair damage was estimated to be $2.3 million.

The National Transportation Safety Board determines that the probable cause of the fire on board the SCANDINAVIAN SUN was the crew's failure to tighten a threaded pipe fitting on the No. 1 diesel generator's lubricating oil line adequately which allowed the fitting to vibrate free and oil to spray from the line which ignited when it contacted the hot exhaust manifold of the engine. Contributing to the spread of the fire outside the auxiliary machinery (generator) room was the failure of the crew of the SCANDINAVIAN SUN to keep closed the watertight door and the self-closing fire door between the engineering spaces and the accommodation spaces. Also contributing to the spread of the fire was a delay in closing the automatic fire doors and stopping the ventilation system because a watch was not maintained in the pilothouse where the alarms and fire detection cabinets were located.

INVESTIGATION

The Accident

At 0830, 1/ on August 20, 1984, the Bahamian registered passenger ship SCANDINAVIAN SUN (see figure 1) departed the Port of Miami on Dodge Island, Miami, Florida, on its daily round trip cruise to Freeport, Bahamas. The ship arrived in Freeport at 1350 and departed at 1652. It returned to the Port of Miami Terminal at 2255 and moored starboard side to berth 7. Aboard the ship were 530 passengers and 201 crewmembers.

Shortly afterward, the second engineer, who had the watch in the engineering spaces, told the motorman, who was on watch in the engineroom, to move four cylinder liners from the tween deck (upper level) in the generator room to the vehicle area on the Bimini Deck. The second engineer then went into the generator room and secured a waterline located near the after bulkhead of the tank top deck (lower level) of the generator room. Shortly afterward, he saw oil spraying on the overhead above generator No. 1. The second engineer proceeded forward toward the watertight door (WTD) at frame No. 52, leading to the tank top level in the main engineroom to reach the engineer's control room on the tween deck (upper level) of the engineroom, and to shut down generator No. 1. However, before reaching the WTD, he heard a small explosion and saw flames above generator No. 1. (See figure 2.) The second engineer then proceeded to the control room where he secured the generator and activated the engineer's alarm which sounded in the deck and engineering officers' passageways and in the engineroom. The second engineer also ordered the repairman on watch, who was taking readings in the engineroom, to start the fire pumps. Meanwhile, the motorman had planned to carry all the liners from the tween deck in the generator room up to the Bimini Deck port trunk space, then down to the tween deck in the engineroom, through the control room, up the ladder on the starboard side of the engineroom to the starboard trunk space on the Bimini Deck, then through the vestibule and into the vehicle area. He had just completed carrying the fourth cylinder liner to the port trunk space on the Bimini Deck when he saw smoke. He immediately "ran" forward and down the ladder to the control room.

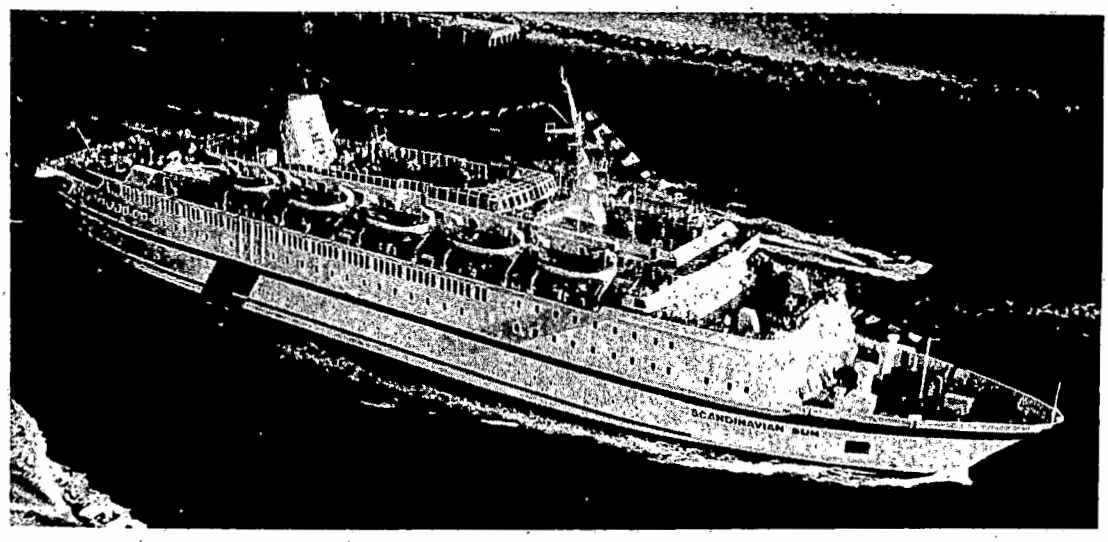

Figure 1.--The M/V SCANDINAVIAN SUN.

1/ All times are eastern daylight savings and based on the 24-hour clock.

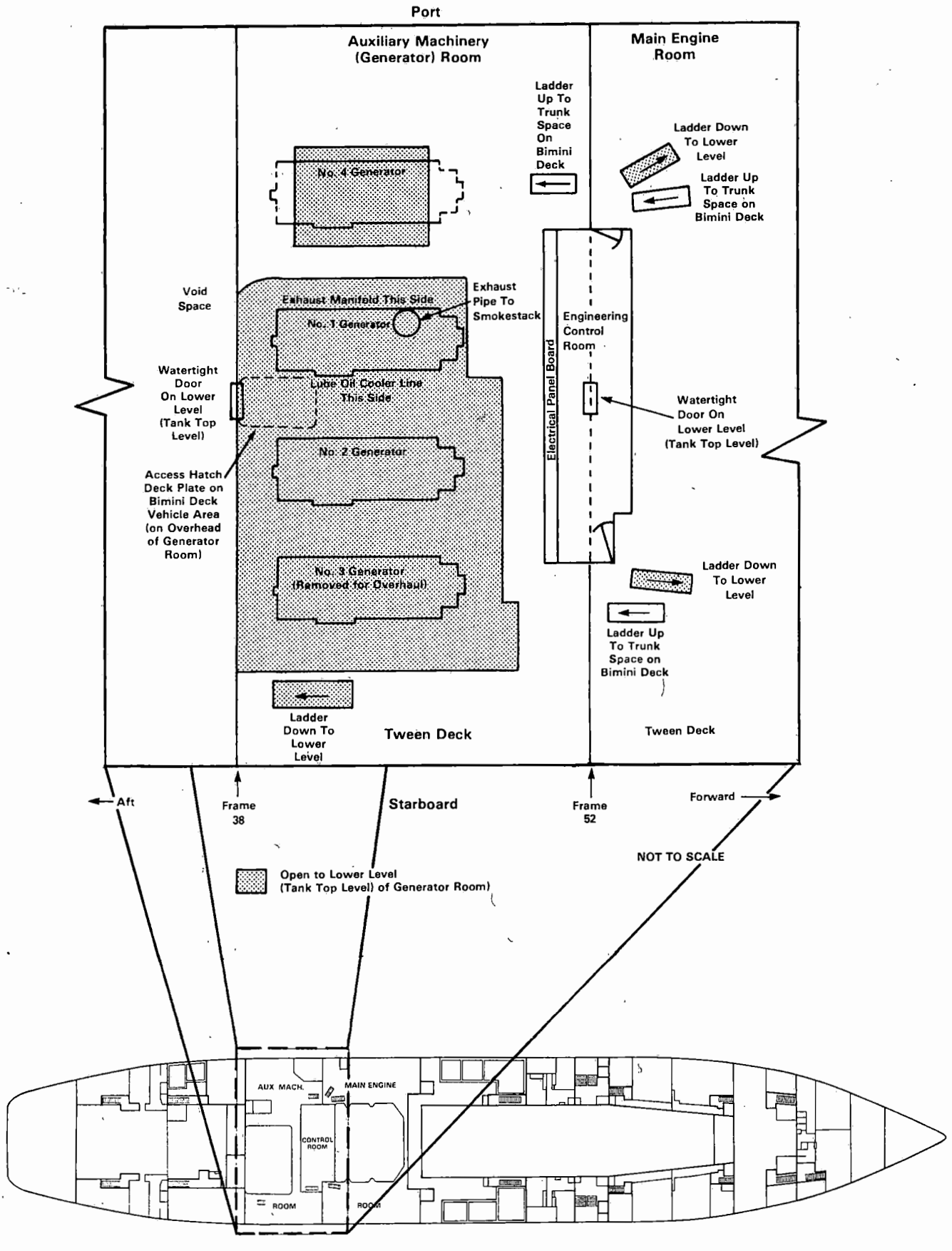

Figure 2.--Plan view of generator room.

The master was in his room which is below the pilothouse and on the Exuma Deck when he heard the engineer's alarm. He immediately proceeded to the pilothouse where he saw that the fire detection panel indicator lights were flashing for the generator room; Bimini Deck-port side aft and vehicle area; Andros Deck-port side aft and amidships; Nassau Deck-aft, port and starboard, and lobby; Bahamas Deck-Lucaya West dining room and casino; Exuma Deck-Hideaway Lounge, Castaway Lounge, smokestack, and starboard circular stairway; and Bridge Deck-circular stairway and Discotheque. (See figure 3.) The lights indicated that at least one fire detector in each zone had been activated.

As the ship entered port, passengers gathered in the passageways adjacent to the lobby on the Nassau Deck in anticipation of disembarking. The lobby was kept clear of passengers and crew while U.S. Customs and U.S. Immigration personnel examined the ship's documents to clear the ship to allow it legal entry into the United States. The ship received clearance from the authorities about 2300, 2/ and the passengers began to disembark using the starboard gangway which leads to the upper level of the terminal for their individual Customs clearance. Shortly afterward, passengers and crewmembers saw smoke coming from overhead ventilation ducts in the lobby and the after port stair tower. At 2305, all four of the fire doors in the lobby were closed by crewmembers using the local release buttons next to the doors. About 2308, the chief purser closed the door to the gangway, and passengers no longer were allowed to disembark because the purser feared that they might become trapped on the gangway. At the time, between 100 and 150 passengers had disembarked. Between 380 and 430 passengers still remained aboard the vessel.

About 2312, the master closed all automatic fire doors, stopped all ventilation fans, and sounded the crew fire alarm. About 1 minute later, he sounded the abandon ship signal 3/ on the ship's general alarm in both crew and passenger areas. Passengers were advised of the fire over the public address system by the cruise director and were directed by crewmembers to move to the forward weather (outside) decks. Some passengers and crewmembers located throughout the ship and Customs agents later reported that they did not hear the alarm or the public address announcement.

At 2314, 2315, and 2319, the master attempted to contact the U. S. Coast Guard (USCG) on VHF-FM radio channels 13 and 16 but he did not receive any answer. His transmissions did not include an urgency identifier or other indications of urgency. The USCG radioman on watch in the USCG Group Miami Communications Center (Group Miami) 4/ stated that it was a busy watch period and that although he heard transmissions from the SCANDINAVIAN SUN he did not hear to whom the transmissions were directed. At 2320, the USCG radioman called the SCANDINAVIAN SUN and asked if they were calling the Coast Guard, but he did not receive an answer.

Meanwhile, about 2313, the staff captain 5/ was on the Bimini Deck vehicle area, preparing to receive supplies when "someone noticed fire" in the area of the partially

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2/ The times used are the best available as obtained from interviews, master's notes, chief engineer's notes, fire department logs, and the ship's log which was written the morning after the fire. The exact timing of all events was not available as there is no ship's data recorder or similiar device to automatically record significant events. No ship data recorder was required by existing regulations.

3/ 7 short and 1 long blast.

4/ The USCG Group Miami Office is located on Causeway Island, approximately 2 miles east of Dodge Island's Berth 7.

5/ The officer next in line of responsibility for the ship after the master.

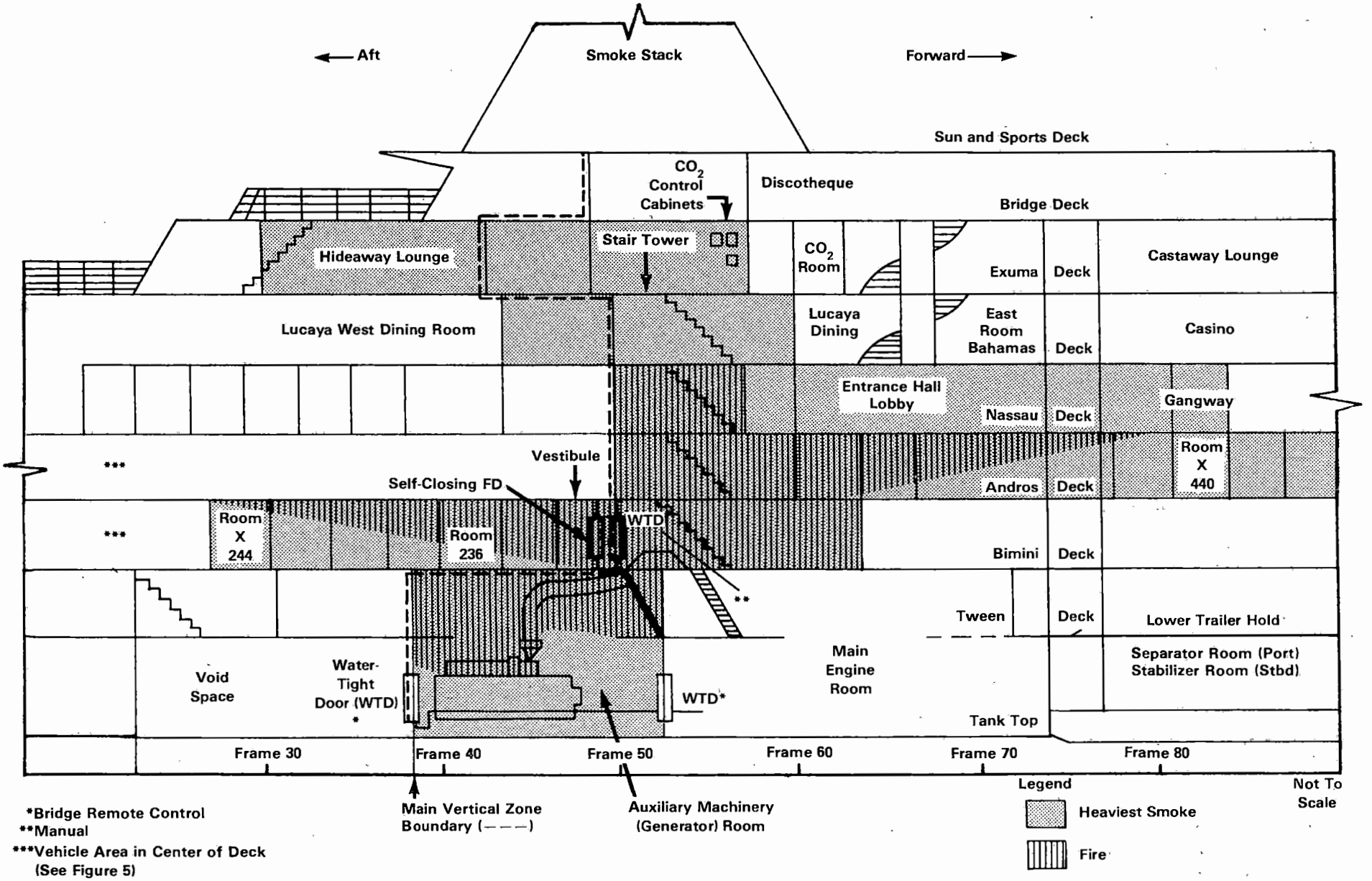


Figure 3.--Inboard profile, portside.

closed sliding fire door No. 8. (See figure 4.) The staff captain, who, according to the ship's emergency plan, was in-charge of on-scene firefighting,immediately formed two firefighting teams and a backup team consisting of the crewmembers who were in the vehicle area. A firehose was rigged from the starboard side of the vehicle area and water was sprayed onto fire door No. 8 and on the fuel tank of an empty refrigerated trailer located next to the fire door. About 2315, longshoremen removed the trailer from the vehicle area and the ship's firefighters entered the vestibule through fire door No. 8. While attacking the fire in the vestibule and port passageway, the firefighters heard a banging noise from the second crew room aft of the vestibule. The staff captain and the first officer proceeded to crew room 236 where they rescued a crewmember. The crewmember had earlier attempted to exit his room, but flames in the passageway outside of his door blocked his escape. About 2321, the fire appeared to be extinguished in the passageway and vestibule.

The chief engineer who also was on the Bimini Deck said that about 2315 he saw smoke coming from the edges of the access hatch plate in the deck in the vehicle area above the generator room. He immediately started for the engineroom through the vestibule and trunk space on the starboard side of the Bimini Deck which gave access to the lower level of the engineroom. The chief engineer entered the generator room through the WTD at frame No. 52 at the after end of the lower level of the engineroom. He observed flames in the overhead and heavy black smoke. Meanwhile, the second engineer and first engineer had donned self-contained breathing apparatus and had begun to fight the fire through the WTD at frame No. 52 with two firehoses. Shortly afterward, the chief engineer concluded that the fire could not be extinguished with water and decided to energize the CO_2 system to the generator room. The WTD at frame No. 52 was closed by activating a local control switch next to the door. The Nos. 2 and 4 diesel generators were shut down, and the engineroom spaces were evacuated. The firefighters on the Bimini Deck were then ordered by the first officer to vacate the vestibule as CO_2 was going to be released into the generator room. When the chief engineer reached the Bimini Deck, he used the staff captain's hand-held radio to call the pilothouse and requested that the after WTD at frame No. 38 in the generator room be closed.

About 2324, the five remaining remotely controlled WTDs were closed from the bridge using the master control switch. Licensed engineers and the ship's electricians assembled at the three CO_2 control cabinets located on the port side of the Exuma Deck, forward of the stair tower. However, because the cabinets were locked and the chief engineer had left his keys in his room, the chief engineer had to obtain the spare key from the pilothouse. While the chief engineer went to the pilothouse, an electrician and a third engineer closed the vent covers on the smokestack on the Sun and Sports Deck. When the engineer returned, he proceeded to release CO_2 into what he thought was the generator room. Five days after the accident, investigators determined that the CO_2 actually had been released into the starboard stabilizer room, two compartments forward of the generator room, a compartment which was not involved in the fire.

Emergency Response

About 2316, the supervisor of the U.S. Custom's team assigned to the SCANDINAVIAN SUN saw smoke coming from the vessel and dialed the "911" emergency number from a telephone in the terminal building. Because of the high noise level in the terminal he did not hear the response and he was not sure whether or not his call for assistance was heard. At 2317, one of the Customs inspectors used the supervisor's hand-held radio, to call the U.S. Customs Sector Communication's Office and requested that it notify the Miami Fire Department (MFD). The three inspectors then proceeded to the

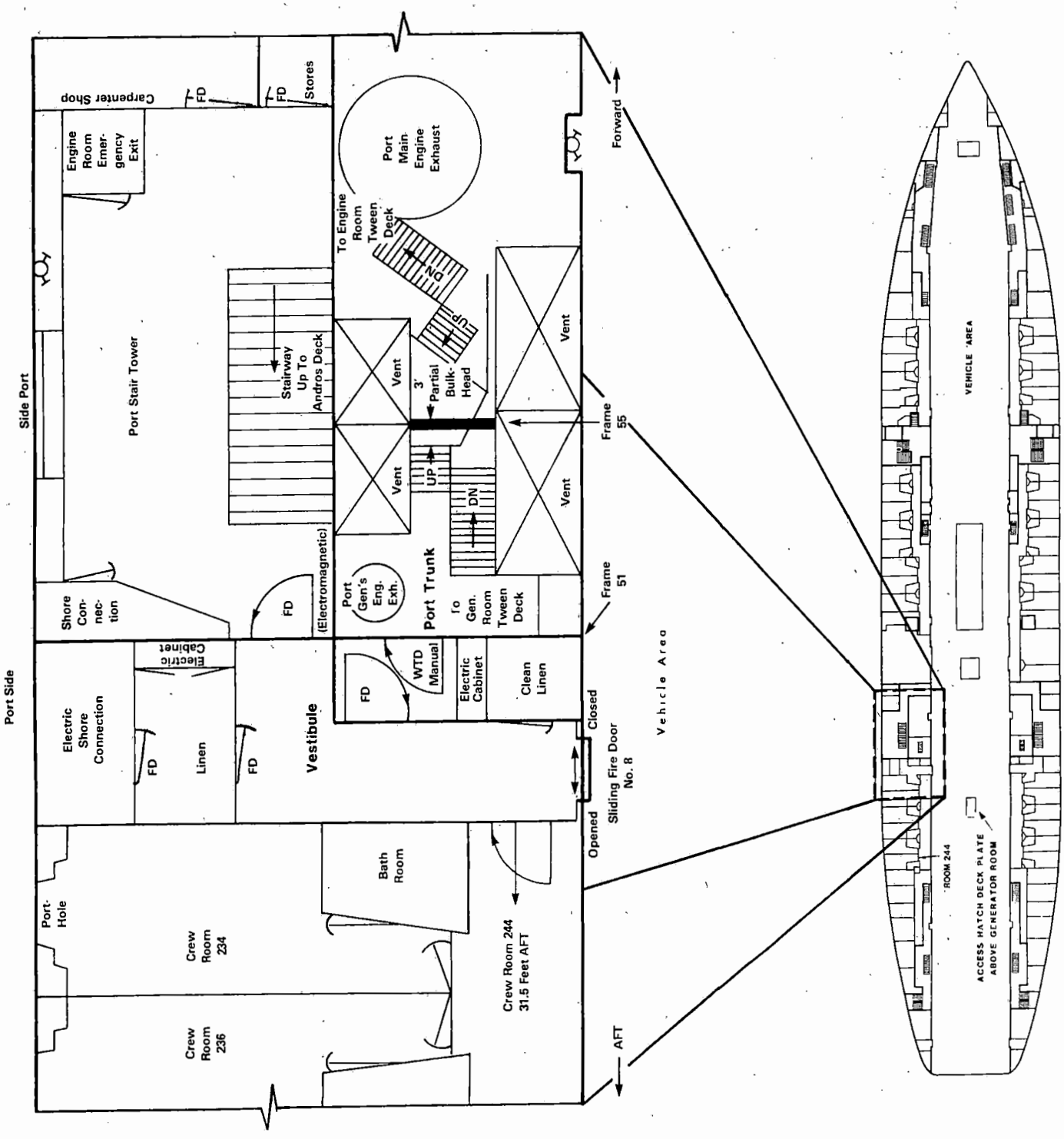


Figure 4.--Plan view of the Bimini Deck portside in the area of the stair tower.

upper level of the terminal to the lobby to assist the passengers. Two of these inspectors also entered the smoke filled lobby and rescued an elderly male passenger who had been overcome by smoke and had collapsed. After assisting the passenger ashore, the inspectors reentered the ship's lobby but did not find anyone else.

At 2317, the MFD dispatched firefighters and equipment from three fire stations and one medical unit from a Miami rescue station. The MFD units began arriving on scene at 2321. The MFD units attached hoses to shoreside hydrants and an aerial ladder truck was positioned near the forward part of the ship. The ladder was raised to the gangway on the Nassau Deck to allow firemen with self-contained breathing apparatus to search the lobby and adjoining passageway for persons overcome by smoke; none were found. The ladder was then repositioned to remove passengers who had gathered at the bow of the ship. About 75 passengers disembarked using the ladder. Some firemen remained on the forward weather decks with other passengers to reassure them of their safety and to prevent panic.

The District fire chief who had arrived on scene with the MFD units assumed command of the firefighting operations. He set up a command post on the dock between the ship's mid-section and the terminal building. The master of the SCANDINAVIAN SUN assisted the fire chief by assigning ship's personnel to guide shoreside firemen on board the ship. MFD firemen wearing self-contained breathing apparatus first started fighting the fire through fire door No. 8 on the Bimini Deck. They extinguished the flames at the base of the stair tower but were driven back by heat and steam which formed when water contacted the hot steel. The firefighters then moved the firehoses from fire door No. 8 to the starboard side of the Bimini Deck in order to enter the engineroom. However, they were unable to enter the generator room because the WTD at frame No. 52 was closed. The door could not be opened using the local control switch next to the door. About 0004, August 21, a SCANDINAVIAN SUN crewmember released pressure in the hydraulic cylinder closing mechanism and opened the WTD at frame No. 52. After the fire, the door was tested and functioned properly. The cause of the malfunction of the door mechanism could not be determined. When the firemen entered the generator room, they did not find any fire on the lower level and only small fires on the upper or tween deck level which they quickly extinguished with a minimum amount of water. The firefighters returned to the Bimini Deck port stair tower and after reaching the Andros Deck had to retreat to replace their air tanks. Before leaving, they lashed the firehose on the stairway railing with the nozzle in the open fog position directing water upward.

An MFD backup firefighting team arrived shortly afterward and continued efforts to extinguish the fire in the port stair tower. The fire was completely extinguished about 0035. In a telephone call at 0046, the Coast Guard Captain of the Port (COTP) established a 100-yard safety zone 6/ around the ship, and Group Miami provided a patrol boat to enforce the zone. At 0052, as the smoke began to clear, the remaining 305 to 355 passengers were directed aft and disembarked via the stern ramp on the Bimini Deck. At 0100, crewmembers on the forward decks were directed aft to disembark. At the same time, the COTP arrived on scene and met with the master of the ship and the MFD fire chief. The fire chief wanted to ventilate the ship to clear out the smoke but the master strongly advised against doing so. The master wanted to maintain the concentration of the CO_2 which he believed had been released to the generator room to prevent a reflash of the fire. The COTP also advised against ventilating the ship. The vice president for

6/ A safety zone is a water area, shore area, or water and shore area established for safety or environmental protection purposes; access is limited to authorized persons, vehicles, or vessels. USCG District Commanders and COTPs have been delegated authority to establish safety zones from the Commandant, USCG.

7/ Marine Accident Report--"Fire Aboard the Bahamian Passenger Vessel M/V SCANDINAVIAN SEA, Cape Canaveral, Florida, March 9, 1984" (NTSB/MAR-85/03).

operations for Scandinavian World Cruises who had arrived on scene about 2345 on August 20 also advised the MFD against ventilating in order to prevent a possible reflash of the fire which had occurred on a similar ship 7/ belonging to the company. The fire chief accepted this advice and did not ventilate the ship. After overhauling the fire 8/ and extinguishing some spot fires, the MFD declared the fire out at 0106.

At 0333, the fire chief turned over firefighting responsibilities to the ship's master, and the master set a reflash fire watch. A hose was charged from a shoreside hydrant and led onto the Bimini Deck near fire door No. 8. A USCG command post trailer on the dock received fire patrol reports every 30 minutes. At 0900, the USCG command post was secured.

At 0130, the command post received a report from members of an excursion group that one of its members was missing. A check of the passenger list confirmed that the group had rented room 440 on the Andros Deck to store personal belongings and for use in the event a group member became sick or required rest. Search parties were formed with the staff captain, other members of the crew, and the MFD. Self-contained breathing apparatus were worn because of the heavy concentrations of smoke. Searches of room 440 were conducted at 0200, 0220, and 0400 by ship's crew and fire department search teams, but the missing female passenger was not located. The room was dark and smoke filled with about 1-foot of visibility. A search also was made of the upper decks and the lifeboats. Between 0305 and 0325, a Coast Guard patrol boat conducted a water search for the missing passenger in case she had jumped over board. The search had negative results and the safety zone was cancelled at the end of the search. About 1300, the passenger was found fully clothed in the shower of room 440 by members of the Miami Police Department who were investigating her disappearance.

A muster was held for all crewmembers at 0130 in the terminal building. The names were called out from the crew list and checked off as each person responded to their name. Due to similar sounding names an incorrect response was made to a name called, and consequently one crewmember was not determined to be missing until he failed to report to the chief chef for work later that morning. About 1145 the chief chef and the first officer found him dead in his room.

Injuries to Persons

	Crew	Passengers	MFD+ Rescue Units	U.S. Customs	Total
Fatal	1	1	0	0	2
Non-Fatal Injuries	2	0	2	0	4
Smoke Inhalation	5	49	3	1	58
None	193	480	53	8	734
Total	201	530	58	9	798

Vessel Damage

The fire damage in the generator room was minor. The vestibule, aft of the port trunk space, and the crew passageway aft of the vestibule sustained extensive damage. Fire damage in the stair tower on the Bimini and Andros Deck levels was extensive. On the Nassau Deck, the after portion of the stairtower was burned severely and the damage in the forward portion was limited mainly to smoke and heat damage. Burning carpeting

8/ The process of moving and separating burned material to locate any hot or smoldering debris and to cool or wet it down to prevent any reflash of the fire.

on the decks and insulation in the overhead in the areas of severe fire caused heavy smoke during the fire. The ship was repaired and returned to service on October 22, 1984. Total cost of repairs was estimated at $2.3 million.

Crew Information

The SCANDINAVIAN SUN was manned in accordance with Bahamian Law. The master and licensed officers were Danish nationals and held Certificates of Competency from Denmark and the Bahamas. (See appendix A.)

Personnel in the deck department, the engineering department, hotel staff, entertainers, and the cruise staff were employed by Scandinavian World Cruises. Personnel in the catering, concession, and casino operations were employed by independent contractors. However, all persons employed on the SCANDINAVIAN SUN were considered ship's crew and, therefore, subject to the master's lawful orders.

While the SCANDINAVIAN SUN is moored, the watch shifts to the gangway and the pilothouse is left unattended. The deck watch consists of the mate, a quartermaster at the gangway, and a roving fire patrolman. The mate on watch is responsible for the ship's business and can be contacted by telephone in his room or by hand-held portable radio during his assigned 24-hour watch. The quartermaster and the roving fire patrolman each stand a 6-hour watch. The roving fire patrolman must make hourly rounds to all accessible parts of the ship, except the machinery spaces where there is a watch, between 2300 and 0700. The rounds are recorded on a key-type recording clock.

The engineering watch consists of an engineering officer and two unlicensed persons. They carry out normal watch routine and maintenance of equipment throughout the machinery spaces. No one stands watch in the engineering control room, which is left unattended, except for an occasional check of the space or when a watchstander enters to use the intraship telephone.

Vessel Information

General.--The SCANDINAVIAN SUN, originally named the FREEPORT, was built in September 1968 by the Orenstein and Kappel Shipyard, Lubeck, Federal Republic of Germany, as a combination passenger and roll-on/roll-off vehicle carrier. (See figure 5.) It is constructed of welded steel, and it was built according to the rules and regulations of the West German classification society Germanischer Lloyd (GL). The vessel has retained GL classification for its hull and machinery.

The vessel's principal characteristics are:

Length	441.1 feet
Breadth	70.5 feet
Depth	41.3 feet
Draft	18.1 feet
Gross Tons	9,902.9
Net Tons	4,660.1
Displacement Tons	8,286
Horsepower	16,000

The SCANDINAVIAN SUN is a twin-screw motor vessel with controllable pitch propellers, bow thruster, and stabilizer fins. It is powered with two 16-cylinder Ottensener Eisenwerk (Hamburg, Germany) diesel engines and has a cruising speed of 20 knots.

Four diesel generators, numbered 4, 1, 2, and 3 from port to starboard, are located in the auxiliary machinery room aft of the engineroom. The Nos. 1, 2, and 3 generators were installed as original equipment when the ship was built, and the No. 4 generator was installed in 1976. At the time of the accident, the No. 3 generator had been removed temporarily for overhauling.

The vessel is divided into five main vertical fire zones by fire-resistant bulkheads and insulated steel decks. International regulations require that the distance between these boundaries generally should not exceed 40 meters (131 feet). Where bulkheads had paneling installed, the paneling was generally 3/4-inch thick consisting of a 9/16-inch asbestos-type cement mineral board laminated between a melamine veneer 9/ and a fire-resistant backing board.

In the passageways and stair towers, aluminum panels are suspended overhead about 8 inches below the deck above. Within this space are electrical cables, ventilation and air conditioning ducts, and other utilities. Combustible material in this space consisted of electrical insulation and pipe covering. The steel decks in the passenger area generally are covered with fire resistant carpet consisting of 80 percent wool and 20 percent nylon, and other areas were covered by ceramic or vinyl tile.

Fire doors are installed throughout the ship within the fire zones and in the zone boundaries. There are 37 sliding self-closing, 165 hinged self-closing, and 65 hinged automatic fire doors. The hinged automatic fire doors can be closed locally by depressing a switch near the top of the door or remotely using a master control switch in the pilothouse. There is no provision to close the doors selectively from the pilothouse either zone by zone or within each zone.

An emergency diesel generator is located in the emergency generator room at the after end of the bridge deck. Power to the automatic fire doors, the public address system, the general alarm bells, and other emergency systems was supplied by batteries in the battery room located above the CO_2 room on the starboard side of the Bridge Deck.

Method of Operation.--From 1968 until 1981, the FREEPORT operated on 3- and 4-day cruises out of Miami, Florida, to Nassau and Freeport, Bahamas. In 1981, the vessel operated on 7-day cruises in the Caribbean during the winter months, and it operated between ports in the northeast United States and Nova Scotia, Canada, during the summer months. After completing its 1981 summer season, the ship was sold to DFDS 10/ Seaways, Bahamas and was operated by Scandinavian World Cruises. It underwent overhaul and conversion in Hamburg, West Germany, from October 1981 to January 1982 to adapt it for daily cruise service. It was registered in the Commonwealth of the Bahamas on January 25, 1982, and renamed the SCANDINAVIAN SUN. On February 19, 1982, the SCANDINAVIAN SUN commenced daily cruise operations between Miami, Florida, and Freeport, Bahamas.

Scandinavian World Cruises daily prepares a manifest of passengers and a current crew list. Copies of the lists are kept on the ship and in the main office on Dodge Island. Between August 1 and August 20, 1984, the SCANDINAVIAN SUN carried a total of 15,369 passengers, averaging 768 passengers per day.

Passenger and crew rooms are located outboard of the vehicle area along the port and starboard sides on the Andros and Bimini Decks respectively. Passenger rooms also are located on the Nassau and Bahamas Decks.

9/ A pressure laminated plastic sheet formed from melamine resins.
10/ Det Forenede Dampskibs-Selskab or The United Steamship Company.

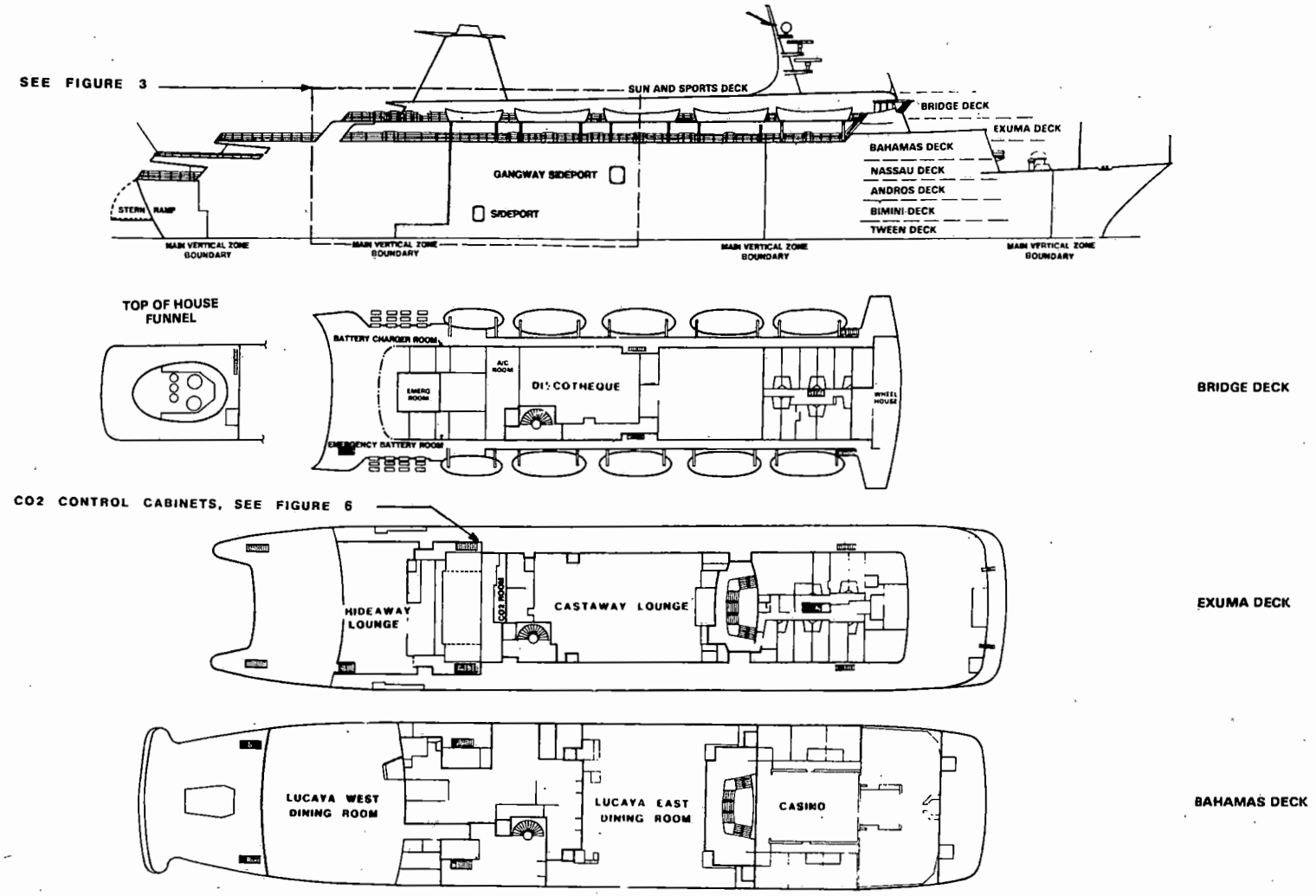


Figure 5.--General arrangement of SCANDINAVIAN SUN. (Sheet 1)

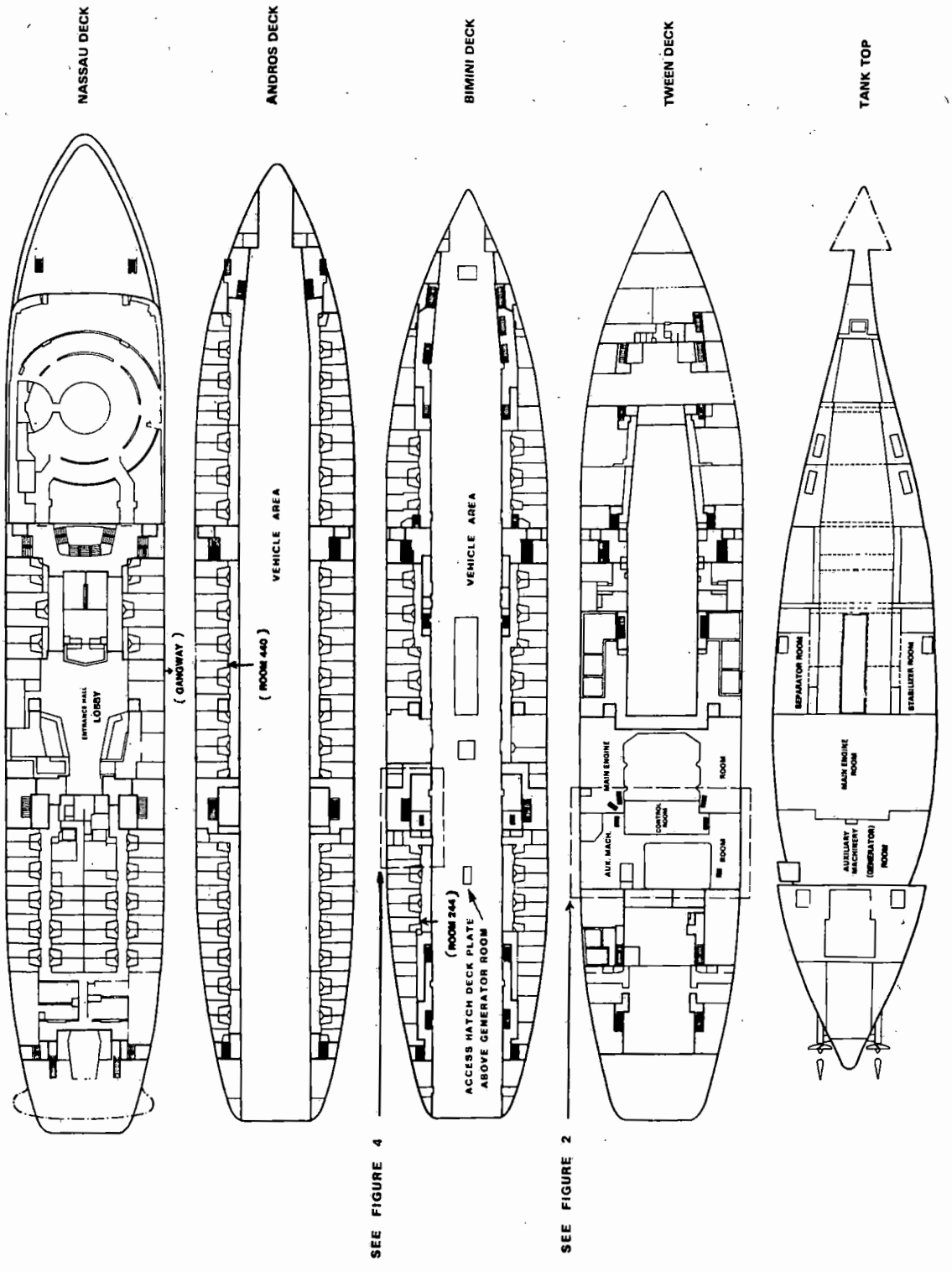


Figure 5.--General arrangement of SCANDINAVIAN SUN. (Sheet 2)

Fire Detection/Suppression Equipment.--The SCANDINAVIAN SUN is equipped with a heat detection system and two smoke detection systems. There is a smoke sampling detection system in the lower trailer hold on the Tank Top deck terminating in its own smoke detection cabinet in the pilothouse. The presence of smoke will activate an aural and visual alarm in the cabinet. The engineering spaces also are monitored by an ionization smoke detection system that terminates in the same cabinet in the pilothouse as the heat sensors. Throughout the vessel there are 685 heat sensing detectors grouped into 45 zones with at least one sensor in every compartment. The fusible-link sensors in the machinery spaces are activated when the temperature exceeds 68° Celsius (154° F) and in accommodation spaces when the temperature exceeds 48° Celsius (118° F). If a sensor is activated, a light in a cabinet on the bridge will indicate the location and an aural alarm will sound.

A two-position switch on the pilothouse console next to the general alarm buttons operates the fire control system. When the switch is in the automatic position, it will automatically release all of the fire doors so they will close, shut down all the ventilation, and sound the crew fire alarm whenever any heat or ionization smoke detector is activated. When the switch is in the manual position, a person in the pilothouse must activate the individual controls for automatic fire door closure, ventilation shutdown, and general alarms. It was the ship's unwritten policy to routinely place the switch in the automatic position after all passengers had disembarked. On the night of the fire, the switch was still in the manual position.

There are separate locally controlled fixed CO_2 systems for the paint room, lamp room, and the emergency generator room. The major fixed CO_2 extinguishing system services the main engineroom, the generator room, the stabilizer room (starboard side forward of the engineroom), the separator room (port side forward of the engine room), and the lower trailer hold. The major fixed CO_2 extinguishing system has 55 cylinders, each containing 45 kilograms (99 pounds) of CO_2 which are located in a separate compartment just forward of the port stair tower on the Exuma Deck. The CO_2 release control for the lower trailer hold is located in a cabinet on the after bulkhead in the pilothouse. The CO_2 release controls for the engineering spaces are located in three 14- by 14-inch cabinets on the exterior of the port stair tower on the Exuma Deck, just aft of the CO_2 cylinder compartment. The CO_2 release control cabinets are designated as follows: upper left cabinet is for the separator room, lower left cabinet is for the stabilizer room, and the upper right cabinet is for the engineroom and the generator room. (See figure 6.) The cabinets are kept locked at all times. One key for the cabinets is in the chief engineer's possession and a duplicate key is kept in the pilothouse.

Overhaul of the No. 1 Diesel Generator.--At 0001 on August 19, 1984, while the vessel was moored at the Port of Miami, the engineers on watch started to overhaul the No. 4 cylinder of the No. 1 diesel generator. The repair required removal of the cylinder head and an access plate located on the starboard side of the engine. A platform on the forward starboard side of the engine in the area of the five forward cylinders (the engine has 8 cylinders) provided a flat surface 2 1/2 feet wide by 4 1/2 feet long and 2 feet above the deck to gain access to the top of the engine. The platform was positioned over a 3-inch lubricating oil line and the lubricating oil cooler. A threaded 1/2-inch pipe fitting in the lubricating oil line which was plugged protruded about 1 to 2 inches through a 2- by 6-inch rectangular opening near the center of this platform, by the No. 4 cylinder access plate. (See figure 7.) During an interview with the second engineer, he stated that the pipe fitting was not removed. The repair of the No. 4 cylinder was completed by 1230, August 19, 1984, and the diesel generator was placed in operation at 1630 and was run continuously until the accident. A postaccident examination of the No. 1 diesel generator revealed that the pipe fitting was not in place in the generator's lubricating oil line; it was found on the engine access platform.

In Case of Fire in Separator Room

1. When Opening the Door of Release Station Fire Alarm Will Sound.
2. Make Sure That All Personnel Has Left the Burning Room.
3. Shut Off Ventilation, Oil and Fuel Oil Supply. Close All Openings.
4. Open CO2 Valve.
5. Break Glass of Control Box "CO2 Release" and Pull Out Handle.

In Case of Fire in Engine Room

1. When Opening the Door of Release Station Fire Alarm Will Sound.
2. Make Sure That All Personnel Has Left the Burning Room.
3. Shut Ventilation, Oil and Fuel Oil Supply. Close All Openings.
4. Open CO2 Valve.
5. Break Glass of Control Box "CO2 Release" and Pull Out Handle.

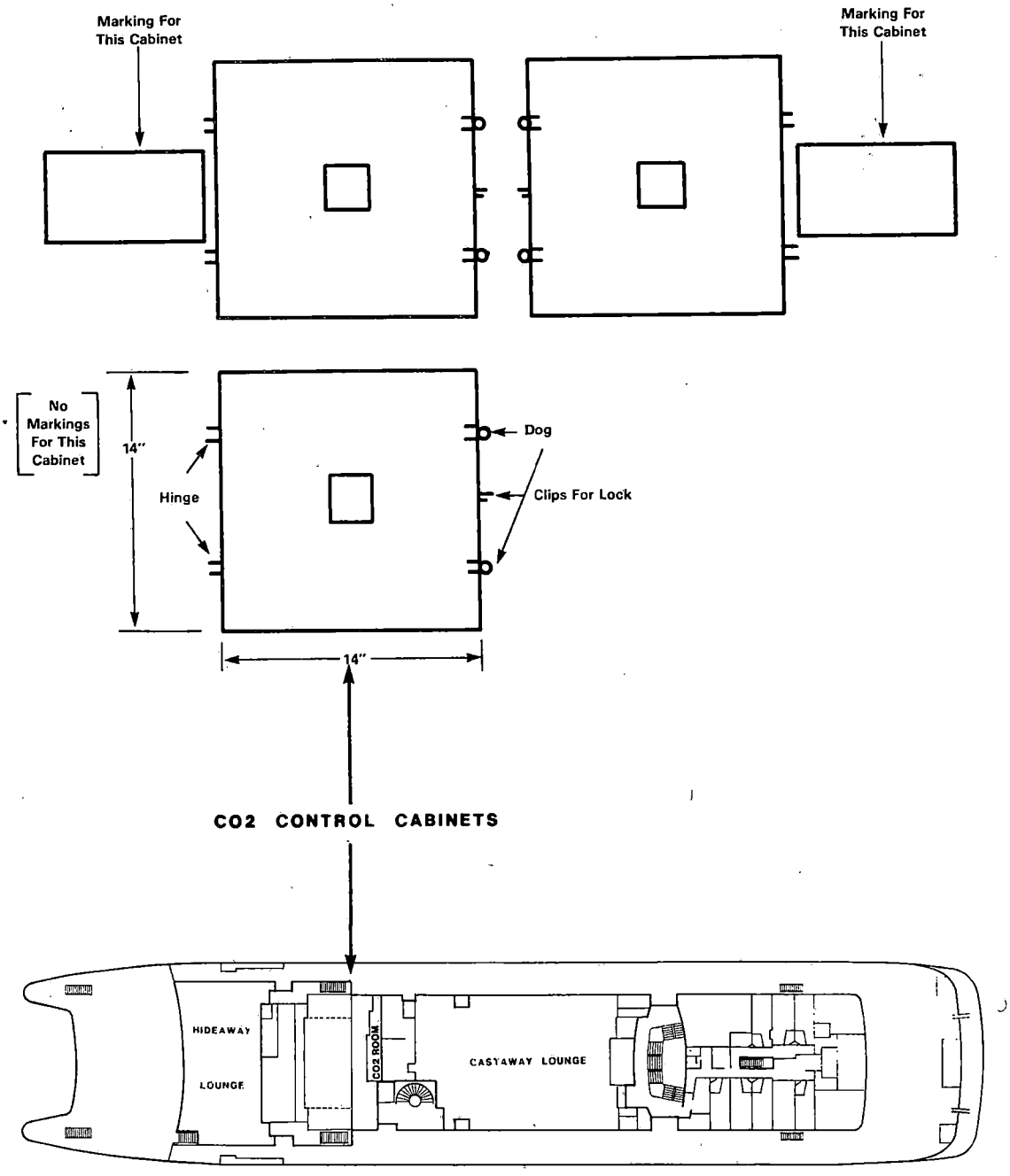
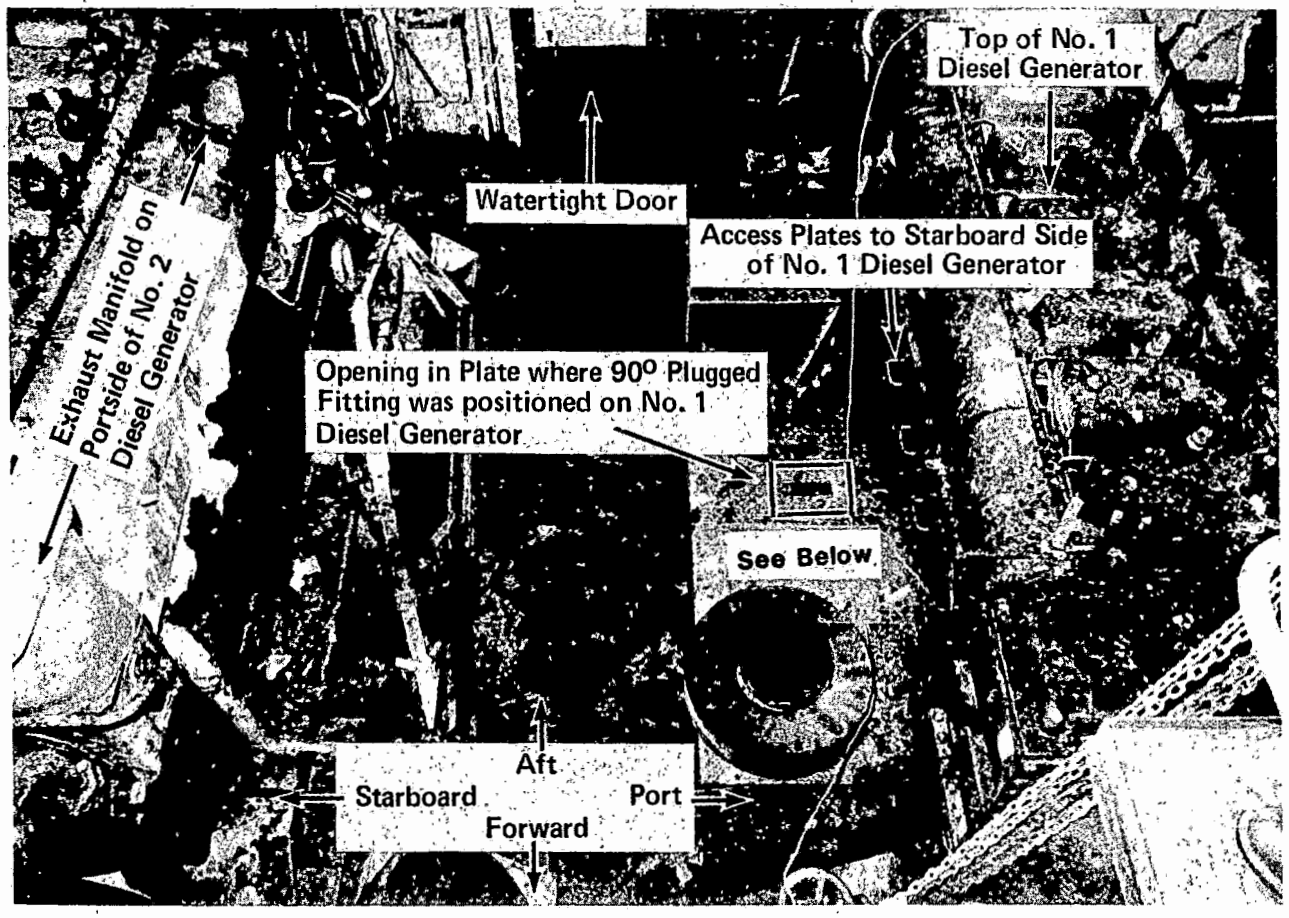


Figure 6.--Carbon dioxide cabinets.



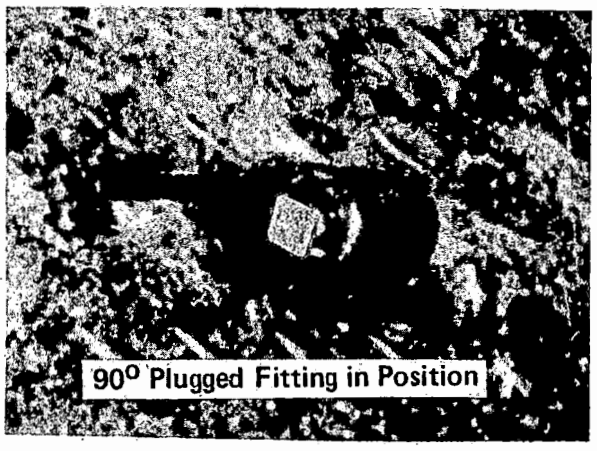


Figure 7.-- No. 1 diesel engine generator
(looking down and aft from the tween deck level).

Port and Waterway Information

The Port of Miami Terminal is located on the east coast of Florida, on Dodge Island, Miami, Florida, and has about 10,000 linear feet of dock space. The west side of the island is connected to the City of Miami by a highway-railway causeway with a bascule bridge over the Intracoastal Waterway. Dodge Island is almost rectangular in shape, approximately 1.2 miles long and 0.3 mile wide, and lies parallel to the main channel, about 2 miles from the Atlantic Ocean. The main channel is 400 feet wide, with a controlling depth of 37 feet. (See figure 8.)

The Port of Miami has facilities for general cargo, container, and cruise ships. Eighteen cruise ships routinely call at the port and 9 berths are reserved for their use. Eight cruise trade operators have offices on the island. Over 2 million cruise ship passengers passed through the Port of Miami in 1984.

Fire protection for Dodge Island is provided by the MFD under contract to Metropolitan Dade County Port Authority. The MFD has clearly written procedures for responding to a ship fire at Dodge Island. The USCG Marine Safety Office (MSO), Miami, Florida, had a "Shipboard Fire Contingency Plan and Vessel Requirements" manual which was published on December 2, 1979, and was in force on the day of the fire. It was distributed throughout the MSO zone to fire departments, harbor masters, and other maritime interests in the zone. Both the MFD and USCG plans state that all firefighting operations on board a ship docked at Dodge Island are under the control of the senior MFD representative on the scene. The plans state, however, that the presence of the MFD or the USCG at the scene of a shipboard fire does not relieve the master, officers, or crew of the vessel of their obligation and duty to assist in a firefighting operation.

A revised USCG MSO Miami contingency plan was published on November 16, 1984. The most significant change was a requirement that passenger ships maintain a continuous watch in the bridge and engineroom control rooms while passengers are on board. It specifies that the watch be staffed by qualified individuals who can initiate a prompt and effective response upon the detection of smoke or fire on board the vessel.

Meterological Information

On the day of the accident, the visibility was 7 miles with scattered clouds. The air temperature was 79° F. The barometer was at 30.02 inches of mercury, and the wind was from the west at 5 knots. Sea conditions at the dock were calm.

Medical and Pathological Information

One crewmember lacerated his hand when he attempted to break the porthole glass in his room. One crewmember on watch in the engineering spaces sustained a minor burn to his right elbow. Two firefighters sustained second and third degree burns on their ears when water being applied to the fire in the port stair tower turned to steam. Thirty-seven of the fifty-eight people who suffered smoke inhalation went to one of three Miami hospitals for further treatment or observation.

One passenger and one crewmember died in their rooms as a result of carbon monoxide poisoning from smoke inhalation. The pathological reports indicated that the passenger had a carboxyhemoglobin (COHb) of 79 percent saturation, blood cyanide of 0.90 mg/ml, and a small amount of alcohol (0.02 percent) in her blood. The crewmember had a COHb of 61 percent saturation, blood cyanide of 0.62 mg/ml, and no alcohol. No other drugs were detected in the two victims.

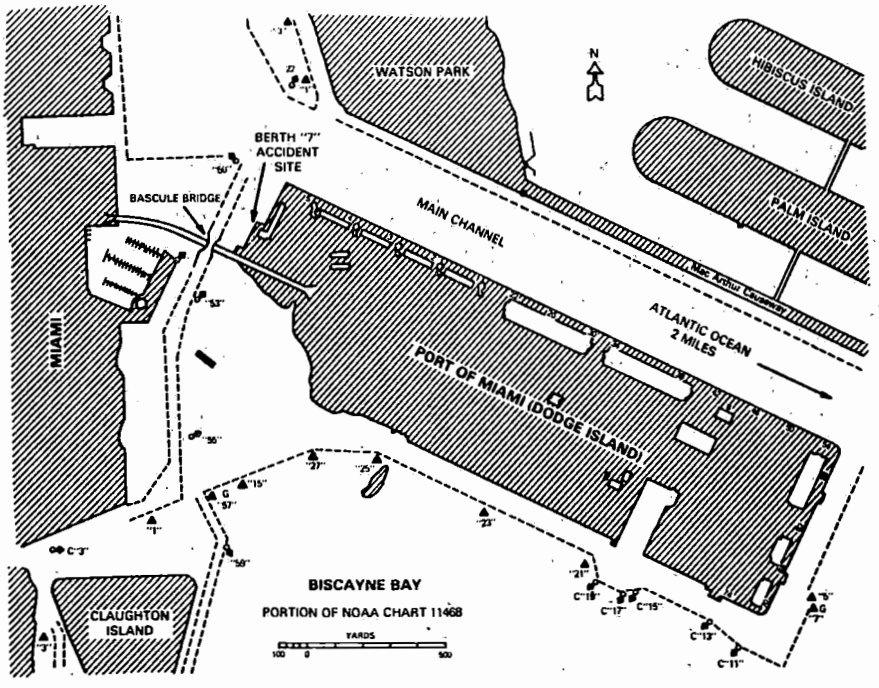


Figure 8.--Port of Miami (Dodge Island), Miami, Florida.

Smoke inhalation as the cause of death may involve many factors. For example, in a fire there generally are multiple factors that contribute to a lethal environment. These factors include: (1) toxic products in addition to carbon monoxide, such as hydrogen cyanide and hydrogen chloride, (2) oxygen depletion, (3) heat, and (4) particulate matter (soot). (See appendix B.)

Propagation of Fire

The fire at diesel generator No. 1 spread very rapidly upward and to port, toward an opening in the overhead above the escape ladder that leads from the generator room to a trunk space on the Bimini Deck common to the generator and the main engine rooms. The trunk space provides access down to the machinery rooms, up to the smokestack, and aft to a manually operated WTD. Aft of the WTD is a self-closing fire door which opens into a vestibule. From the trunk space, the fire spread in two directions: upward into the smokestack and aft through the open doors to the vestibule. The supply 11/ ventilation to the engineroom prevented the fire from spreading forward and down into the engineroom.

From the vestibule, the flames spread aft past the partially closed sliding fire door No. 8 and through an open door into a fore and aft passageway lined with crew rooms on the port side. Flames in the vestibule also spread to the port side passing through an open automatic fire door at the base of the port stair tower that led from the Bimini Deck to the Andros, Nassau, Bahamas and Exuma Deck levels.

On the Andros Deck, the flames spread forward on the port side through another open automatic fire door into a passageway in the passenger accommodations about 4 passenger rooms forward of the fire door, but the flames did not penetrate any of the closed doors. The fire continued upward to the Nassau Deck mainly in the after portion of the stair tower. Some flame, heat, and smoke damage was evident in the forward section

11/ A system in which fresh air is forced mechanically into ship spaces and displaced air is drawn off by uptake vents or exhausted through doors or other openings.

of the Nassau Deck stair tower level, including the lobby area. Above the Nassau Deck, smoke and heat spread upward in the stair tower to the Bahamas and Exuma Decks.

Survival Aspects

Passengers are provided with a boarding pass which is divided into three parts. Two parts are perforated to serve as boarding permits in Miami and Freeport. On the reverse side of the third part is a description of the emergency signal, the card holder's emergency muster station, and a description of how to don a life preserver.

Immediately after the SCANDINAVIAN SUN departed Miami, a public address announcement welcomed passengers aboard and directed their attention to the emergency instructions on the boarding pass. The emergency alarm signal was explained, and muster locations and locations of areas where the crew would dispense life preservers, if needed, were identified. Separate emergency instruction placards in three languages were posted in all passenger cabins, public locker rooms, and public toilets.

Because the SCANDINAVIAN SUN was on a short international voyage, 12/ it was not required by international regulations 13/ to conduct emergency drills when the ship left port. Neither is there any requirement to provide passengers with a safety orientation at any time during the cruise.

Fire and boat drills are conducted with the crew each Wednesday afternoon while the ship is in Freeport and the passengers are ashore. The ship's mobile firefighting group musters in a different part of the ship for each drill and training sessions are conducted by the officers. After the fire drill is completed, an abandon ship drill is held. Crew members are mustered at their emergency stations and boat crews are trained in lifeboat handling using a different boat at each drill.

Test and Research

Analysis and Test of Pipe Fitting.--On August 27, 1984, the USCG MSO Miami sent the plugged pipe fitting and its two brass washers to the Metropolitan Dade County Police Department's Crime Laboratory for analysis to determine if the fitting had been purposely loosened by a tool. Their findings indicated that there were no recent tool marks on the fitting, the threads were not damaged, and there were no tool marks on the washers.

On October 5, 1984, while the SCANDINAVIAN SUN was in drydock, a marine inspector from the USCG MSO Jacksonville, Florida, conducted a vibration test using the pipe fitting in the lubricating oil line on the No. 1 diesel generator. The results of the test indicated that it took 4 1/2 turns clockwise to hand tighten the fitting in the lubricating oil line and 100-inch pounds of torque to loosen the fitting after tightening. The fitting was reinstalled and torqued to 100-inch pounds, and the generator was run for 3 minutes at its operating speed of 900 rpm. The fitting did not loosen. It was then loosened one-fourth turn from its hand tight position, and, with the engine running, it immediately and readily rotated loose. After the elbow loosened one turn, the engine was stopped before the fitting backed out completely.

Analysis of Lubricating Oil.--Between August 29 and 31, lubricating oil was taken from the No. 1 diesel generator and analyzed by an independent laboratory. The analysis

12/ A voyage that is not more than 600 miles long from the port of departure to the termination of the voyage and in which a ship is never more than 200 miles from a port of safety. (SOLAS 1974, Chapter III, Regulation 3)
13/ SOLAS 1974, Chapter III, Regulation 18.

revealed that the oil had been diluted about 10 percent by diesel fuel. Its autoignition 14/ temperature was 670° F, its flash point 15/ was 390° F, and its fire point 16/ was 435° F. The Mobil Material Safety Data Bulletin for uncontaminated Mobilgard 324 lists the flash point as 425° F. It does not list autoignition or fire point temperatures. Although the exhaust manifold on the diesel engine was insulated, there were some exposed metal surfaces. The chief engineer estimated that the exhaust manifold temperatures are typically between 400° C and 450° C (752° F and 842° F).

Oil Consumed.--The lubricating oil's pressure was approximately 70 psi when the generator was operating. Normally, the lubricating oil reservoir held 700 liters; after the fire, the chief engineer determined that the reservoir contained 560 liters, a loss of 140 liters (about 37 gallons). The Safety Board calculated that at the lubricating oil's operating pressure, it would have taken approximately 1 minute for the engine to lose 37 gallons of oil based upon the viscosity of the oil, the diameter of the opening, and the coefficient of discharge.

Other Information

SOLAS Regulations.--When the SCANDINAVIAN SUN's keel was laid in October 1967, the rules in the Convention for the Safety of Life At Sea of 1960 (SOLAS 60), as developed by the International Maritime Consultative Organization (IMCO), now the International Maritime Organization (IMO), were in effect.

Germanischer Lloyd stated that the SCANDINAVIAN SUN was built to SOLAS 60 including part H. Chapter II of SOLAS 60 originally included Parts A through F dealing with vessel construction, as it pertains to subdivision and stability, machinery and electrical installations, fire protection, detection and extinguishment, and general fire precautions. Parts G and H were contained in the 1966 and 1967 Amendments to SOLAS 60 which were not ratified by sufficient countries to go into effect internationally. Nearly identical requirements were incorporated in SOLAS 74. The ship's 1981 conversion adhered to the regulations in SOLAS 74.

Part of the regulations in SOLAS 60 and 74 address the combustibility of materials used in construction but leave it to each government to determine the specifications regarding the combustibility of materials. Although there is an international fire test, there is no international standard for the acceptance or rejection of a material. An international standard for measuring smoke when materials and furnishings burn is under development, but it is not yet available.

USCG Control Verification Examinations.--The USCG examination of foreign passenger ships is conducted under the authority of Chapter I, Regulation 19, SOLAS 74, which allows signatories (countries) of the convention to verify that the conditions on the ship or its equipment correspond substantially to the ship's SOLAS safety certificate. The record of the examination of a foreign vessel by the USCG is contained in CG-840F, Control Verification or Examination of Foreign Vessel, revised in June 1981 to include new items not listed in the previous edition. However, the Coast Guard does not consider the CG-840 F to be a checkoff list to be completed during every examination but rather a memory aid to assist the inspector to record the items that were examined. One set of USCG inspection records (CG-840F) used for the examinations of the SCANDINAVIAN SUN indicated that the ship was constructed to Method I, while Method II and III standards

14/ Temperature at which oil self-ignites in air at one atmosphere.
15/ Temperature at which oil can be ignited by a spark or flame.
16/ Temperature at which oil can be ignited by a spark or flame and will burn for at least 5 seconds.

were noted on other inspection records. The three methods of construction are defined in Regulation 34 of SOLAS 60. In general, Method I construction consists of noncombustible fire resistant construction. Sprinklers or fire detectors are not required but may be installed. Method II construction allows unlimited combustible construction materials and compensates by requiring a sprinkler system throughout the ship to detect and suppress fire. Method III construction is similar to Method I but allows limited combustible construction materials and compensates by requiring a fire detection system throughout and limiting combustible furnishings. A ship is built to meet one particular set of construction requirements but may meet more than one method. In the 1966 and 1967 Amendments to SOLAS 60 and in SOLAS 74, standards based on the method of construction have been replaced by a single standard of structural fire protection.

ANALYSIS

Fire

The pipe fitting protruding above the surface of the access platform on the starboard side of the No. 1 diesel generator hampered the engineering personnel working on the starboard side of the engine. Even though the second engineer stated that the pipe fitting was not removed while repairs were being made to the cylinder, it seems quite likely that the fitting was removed to facilitate access to the cylinder while it was being overhauled and that the fitting probably was only hand tightened when it was replaced. The fitting probably vibrated loose while the generator was operating from 1630, August 19 until it rotated free of the threaded opening about 30 hours later at 2300 on August 20. After the accident, the fitting was replaced with a plug and wired to prevent it from rotating loose.

When the fitting rotated loose, lubricating oil which was under about 70 pounds pressure, sprayed vertically above the engine and probably atomized as it discharged under pressure. Droplets of oil probably fell back down on to the hot engine manifold. Atomized oil also was carried by the strong supply air ventilation draft toward the overhead escape trunk which led to the trunk space at the bottom of the port smokestack casing on the Bimini Deck. The most probable source of ignition of the lubricating oil was the hot exhaust manifold on the No. 1 diesel engine. While the manifold generally was well insulated, there were some exposed hot metal surfaces where minimum temperature exceeded the autoignition temperature of the lubrication oil.

The engine lost about 37 gallons of lubricating oil in the approximate 1 minute it took the engineer on watch to shut down the No. 1 diesel generator to stop the spraying oil. After the oil was ignited by the manifold, the flame spread along the path of the atomized oil and ignited other combustibles. The strong supply ventilation entering the generator room provided the ready supply of oxygen needed to produce intense burning of the lubricating oil and a medium for the rapid movement of the heat and flames out of the compartment. Although the fire in the generator room was hot, it did not burn very long especially at the generator level on the lower level of the generator room. The fire in this space was concentrated on the forward bulkhead around the electrical cabinets on the tween deck. The lubricating oil was the initial combustible, and the melamine veneer on the bulkheads in the stair tower and vestibule appears to be the major fuel contributing to the spread of the fire.

The motorman described a circuitous route to move the four cylinder liners from the port trunk. An easier path would have been through the port trunk manual WTD, the self-closing fire door leading into the vestibule, and onto the Bimini Deck vehicle area. The motorman denied that he opened these doors and could not recall if they were open or closed prior to the fire. When asked why he planned to take the longer route to the Bimini Deck vehicle area (down a ladder, up a ladder, and about 60 feet longer) to arrive at the same point in the starboard trunk as he started from in the port trunks, he could not

provide in a statisfactory explanation. It is not likely that the WTD and the fire door would have been kept open as a convenient passageway for engineering personnel because the supply ventilation from the machinery spaces would have allowed stale fume laden air to exhaust into passenger and crew accommodation spaces. It was more likely that the doors would have been temporarily blocked open for the transfer of the four cylinder liners to the Bimini Deck vehicle area. Flame and soot patterns on the doors and bulkheads between the port trunk and vestibule on the Bimini Deck, however, clearly indicated that the two doors were open during the fire. Had either the manual WTD or the self-closing fire door been closed during the fire in the generator room, the fire would have traveled upward into the smokestack and not aft into the vestibule or into any accommodation spaces.

Because the SCANDINAVIAN SUN was moored to the dock and in the process of disembarking passengers when the fire started, most of the passengers were out of their rooms and either disembarking or preparing to disembark when the fire started. This made crowd control easier and kept the passengers away from their rooms and being overcome by smoke.

Upon the discovery of smoke and flames, the senior ship's officers on the vehicle deck reacted quickly to form firefighting teams. This prompt action saved the life of one crewmember who was trapped in his room (room 236 on the Bimini Deck) by flame and smoke.

Vessel Design and Construction

When the ventilation was stopped and the fire doors in the stair tower were closed, the fire in the stair tower was effectively contained and any further propagation of fire outside the tower on the Andros Deck and above was prevented. There was no apparent damage behind the paneling in the stair tower although the veneer on the mineral board backing was burned on the Bimini and Andros Decks and on the after part of the Nassau Deck. Wherever doors were closed, whether fire doors or not, they prevented the passage of flames because the fire was of a relatively short duration. However, smoke was transported throughout the ship by the ventilation and air conditioning system as evidenced by the soot deposited in rooms, passageways, exhaust duct filters, and vent exhaust louvers. Soot deposits were greatest near the port stair tower and gradually decreased with distance away from the tower.

The original owners of the SCANDINAVIAN SUN adhered to the 1966 and 1967 fire safety amendments to SOLAS 60 during construction although they were not required to do so. Apparently they were anticipating that the amendments would be adopted internationally and that the ship would be required to meet them if the ship was to carry U.S. citizens out of a U.S. port. The firefighting efforts were enhanced by the low flame spread materials that were used during construction of the ship when it was built in 1968.

Some of the passengers, crewmembers, and Customs officials did not hear the general alarm. Duplicate electrical cables for emergency and essential control circuits lead down on each side of the ship and through the stair towers. The electrical cables in the port stair tower were burned on the Bimini, Andros, and Nassau Decks rendering them useless. The starboard stair tower was not affected by the fire, and the general alarm should have been heard across the ship.

With the exception of the smoke detection system in the lower trailer hold, the fire detection system on the SCANDINAVIAN SUN consisted of ionization and heat detectors with an aural alarm and indicating lights in the pilothouse. The detectors in the vicinity of the fire functioned properly and registered fire in the pilothouse detector

panels. The pilothouse was unmanned and a qualified person was not in position to take immediate action to close the automatic fire doors and to stop ventilation immediately upon activation of alarms in the detection panels. By the time the master arrived on the bridge, 14 of the 45 fire alarm zones on the fire detection panels already were indicating fire conditions. Although he secured the ventilation and closed the fire doors immediately upon assessing the situation, the flames already had entered the stair tower at the Bimini Deck and spread fire and smoke up to the top of the stair tower as well as outside the stair tower on the Andros and Nassau Decks where passengers were gathering to disembark. Therefore, the effectiveness of the system was diminished because no one was on hand to take immediate action to isolate the fire and secure ventilation. The local closure of the automatic fire doors in the lobby by crewmembers prevented flame spread and greatly reduced the damage in the lobby. The Safety Board believes that in order to protect the ship and the passengers, the pilothouse should be manned continuously to monitor the alarm systems, at least so long as there are passengers still on board. Alternatively, the automatic/manual switch should be placed in the automatic position when the watch is moved from the pilothouse to the gangway. The Board believes also that the USCG should urge IMO to require an automatic/manual fire control system for fire door closing and ventilation stops on all passenger ships, regardless of other built-in fire safety devices.

Automatic fire doors should be closed quickly in the event of a fire to prevent fire spread. A heat or smoke detector should be made part of the release switch on fire doors which would close the door in the event that the detector is activated and could quickly seal off the fire. The individual door switch should be in addition to any other fire door closing system on the ship. Closing a fire door in this manner would be accomplished quickly without depending upon manual or automatic remote operation of the door from the bridge after fire has been detected. This would pose no additional hazard to persons caught behind a door as a person can exit through a fire door that has been closed by turning the latch handle to open the door. The door will automatically close itself after the person has exited.

The only control cabinets for CO_2 release for the main engineroom/generator room, the stabilizer room, and the separator room are on the port side of the Exuma Deck on the outside bulkhead on the stair tower. Unlocking and opening the CO_2 cabinet door automatically caused the ventilation to shut down and an alarm to be sounded in the space served by the CO_2 system. On the night of the accident, only two of the three cabinets were labeled: the upper left cabinet was marked "separator room" and the upper right cabinet was marked "engineroom." The lower left cabinet was unmarked. SOLAS regulations require that CO_2 controls be labeled clearly. The cabinet marked "engineroom" contained a single CO_2 control for both the engineroom and the generator room. The lower left cabinet contained the CO_2 control for the starboard stabilizer room. This control was activated by the chief engineer after discussion with the engineers assembled at the cabinets as to which control provided CO_2 to the generator room. It was not learned until 5 days after the fire that four cylinders of CO_2 were released into the stabilizer room instead of the generator room. Therefore, the fixed CO_2 system contributed nothing to extinguishing the generator room fire. After the fire, the cabinets were properly labeled.

Coast Guard regulations for U.S. passenger ships require that there be at least two release controls for the CO_2 system: one immediately outside the space protected and one at the CO_2 cylinder room. SOLAS regulations require that CO_2 release controls be grouped together in as few locations as possible. Controls should be provided to allow activation of CO_2 systems locally outside the space protected as well as remotely from the master controls. If there had been a local control of the CO_2 system to the generator room, time would have been saved in releasing the CO_2 and the fire probably would have

been extinguished before it was able to propagate out of the generator room. Training ship's officers in the fixed firefighting systems aboard the ship and local CO_2 controls also would lessen the chance of releasing CO_2 into the wrong space.

Communications

When the USCG Group Miami radio watchstander failed to respond to the radio calls from the SCANDINAVIAN SUN, notification to the MFD was delayed. The MFD could have been at the scene 3 minutes earlier if the radioman had responded to the first call at 2314. U.S. Customs inspectors reacted to the fire quickly and called the MFD.

USCG Control Verification Program

Because millions of U.S. citizens are carried on foreign passenger ships out of U.S. ports each year, ships should be examined as thoroughly as possible within the context of the SOLAS conventions. The 1966 and 1967 Amendments to SOLAS 60 establish a single method of construction (essentially fireproof) which most closely resembles SOLAS 60 Method I construction with the addition of fire detectors. Since there is only one method of construction authorized for passenger ships built to the 1966 and 1967 Amendments to SOLAS 60 and the SOLAS 74-convention, the method of construction is not specified on the SOLAS certificate issued by the ship's government of registry. Because the SCANDINAVIAN SUN was built to the SOLAS 60 standards, including the 1966 and 1967 Amendments, the USCG examination records did not need to specify a method of construction for the SCANDINAVIAN SUN. However, the examination records variously indicated all three of the SOLAS 60 methods of construction for the ship although none of them, in fact, was applicable. This inconsistency is indicative of possible confusion on the part of the inspectors and suggests a need for additional guidance and training. The USCG should provide guidance to the inspection offices to upgrade the inspector's knowledge of passenger ship construction and in reviewing plans and conducting control verification examinations.

Emergency Drills

Because the SCANDINAVIAN SUN makes short international voyages, passengers are not required to participate in any emergency drills and there is no requirement to brief the passengers in emergency procedures. The only safety information provided to passengers on the SCANDINAVIAN SUN is that displayed on posters throughout the ship, that set out on the boarding card, and that incorporated in the welcoming announcement on the public address system. On its daily trips, the SCANDINAVIAN SUN can carry up to 1,100 passengers, or up to 34,100 passengers per month. On a longer international voyage, passengers are required to participate in a drill soon after sailing. Because the hazards which may arise on a short international voyage are no different, passengers should receive some type of safety orientation similar to, if not the same as, that given to passengers on longer international voyages. Because a drill or safety orientation was not required or held, the deceased passenger may not have been aware of the actions to take in case of a fire on board a ship. Attendance at a drill or safety orientation might have provided her with information that could have saved her life. An orientation similar to that given on commercial aircraft would not seem to be too burdensome in cruise operations. It would not need to be extensive or time consuming but should include a demonstration of the donning of life preservers, a description of evacuation or disembarkation routes, the function of the automatic fire doors, and actions to take in the event of a fire. The Safety Board believes that passengers on short international voyages should receive more thorough safety orientation than that which is printed on the boarding pass, announced over the public address system, or posted throughout the vessel. As the

U.S. representative to IMO, the USCG should propose adoption of a requirement for additional safety orientation for passengers on ships engaged on short international voyages.

Contingency Planning

Proper pre-planning by the USCG, the Port of Miami (Dodge Island), and the MFD resulted in an effective firefighting operation on August 20, 1984. The USCG MSO Miami Shipboard Fire Contingency plan and the MFD Firefighting Plan for Dodge Island indicated clearly who was to be in-charge of firefighting and the responsibilities of those involved in fighting the fire. The MSO Miami plan also states clearly that USCG equipment and manpower is limited and that the COTP only will be available for advice and consultation in matters of ship construction, stability, and other technical areas concerning vessels as to which the fire chief may need assistance. The MFD plan for fighting fires on Dodge Island states clearly that the ranking MFD officer on-scene is in overall charge of the firefighting operation. The fact that everyone knew that the MFD fire chief was in-charge upon arrival eliminated any confusion and all manpower was applied to useful functions. The actions taken by the ship's crew before the MFD arrived, firefighting by the MFD, and the crew's guidance to the firefighters led to the fire being quickly extinguished.

The Safety Board noted with interest that the COTP Miami has an indoctrination program whereby three to four MFD personnel are invited to board foreign passenger ships with the USCG inspectors during control verification examinations. The program creates an awareness of the unique problems involved in moving about a large compartmentalized ship. Because of the differences in ship arrangements, the professional firemen should continue to use ship's personnel as guides and as a source of information during shipboard fires. Nevertheless, this program in Miami is effective and should be considered for adoption at other ports where cruise ships dock.

Smoke Production and Movement

Shipboard fires typically produce a lot of smoke. Dense smoke reduces visibility and, in unfamiliar surroundings, passengers, firefighters, and even the ship's crew can become disoriented. This may have been the situation with the deceased passenger. Once the ventilation is stopped and the amount of fresh oxygen is reduced, the fire becomes oxygen limited and tends to produce more smoke. The amount, density, and spread of smoke are primary factors which make shipboard fires so difficult to fight. Inhalation of smoke containing carbon monoxide and other toxic agents can be fatal. More fatalities result from smoke inhalation than from thermal burns.

Lubricating oil was the initial combustible and smoke producer in this fire. The lubricating oil, the melamine bulkhead veneer, and the wool carpeting contributed to the smoke and flame spread on the SCANDINAVIAN SUN. Melamine is a product of formaldehyde and urea and is mixed with cellulose or wood flour or stone powder, depending upon its application. Two possible toxicants produced are hydrogen cyanide and carbon monoxide. Wool carpeting also can produce these by-products. Control of smoke is imperative and reducing the combustibility and smoke production of materials used on ships would improve the safety margin that passengers and crew need in a ship fire to avoid injury and to be able to leave a ship safely. There is no limiting international smoke standard for shipboard materials. The United States has standards for testing for smoke development for interior materials but not for furniture, draperies, or electrical insulation.

As a result of its investigation of the fire on the SCANDINAVIAN SEA, the Safety Board made the following recommendation to the U.S. Coast Guard:

> Propose to the International Maritime Organization (IMO), modification of the fire standards of SOLAS 74 to include criteria (1) to limit smoke generation as well as flame spread of bulkhead paneling for passenger vessels, (2) to reduce the fuel loading in passenger and crew accommodations, and (3) to standardize the testing of combustible materials used in construction. (Class II, Priority Action) (M-85-32)
>
> Status: The USCG has not had the opportunity to respond to this recommendation which was issued to them on May 24, 1985.

The August 20, 1984, accident continues to point to the need for measures to limit smoke generation in shipboard construction and furnishing materials. Safety Recommendation M-85-32 is therefore reiterated.

CONCLUSIONS

Findings

1. A plugged pipe fitting in the lubricating oil line from the No. 1 diesel generator which had not been tightened adequately vibrated loose, allowed oil to spray onto the engine's hot exhaust manifold and then ignite.

2. Crewmembers' action to individually close the fire doors in the Nassau Deck lobby to contain the fire in the stair tower and to move passengers from the lobby to the open decks when the gangway was secured prevented injury to passengers waiting to disembark.

3. Prompt action by the U.S. Customs inspectors in calling the Miami Fire Department resulted in an early response to the fire.

4. The fire could have been isolated earlier if a pilothouse watch had been maintained to monitor the fire detection system on the bridge or if the automatic/manual fire control system had been switched to the automatic position.

5. The fire would have been confined to the generator room and the smoke stack had either the manual WTD or the self-closing fire door on the Bimini Deck between the port trunk and the vestibule been closed.

6. The fire could have been prevented from entering the stair tower on the Bimini Deck had the automatic fire door control switch on the door been equipped to be activated by a heat or smoke detector in addition to the pilothouse master control.

7. The delay in closing the automatic fire doors and the delay in stopping the ventilation allowed the fire to enter the stair tower at the Bimini Deck and toxic fumes to enter living spaces where a passenger lost her life.

8. Because one CO_2 cabinet was unmarked and because the crew was not sufficiently familiar with the CO_2 system, the CO_2 erroneously was released into the starboard stabilizer room instead of the generator room where the fire started.

9. The Coast Guard Group Miami Communications Center watchstander did not respond promptly to the SCANDINAVIAN SUN's calls on the radio.

10. There was good coordination between the Miami Fire Department and the SCANDINAVIAN SUN personnel in fighting the fire and coordinating rescue operations.

11. The fire resistant construction of the SCANDINAVIAN SUN proved effective in containing the fire within the stair tower after the automatic fire doors were closed and ventilation was shut down.

12. The safety of passengers on short international voyages would be enhanced if passengers were given a safety orientation or were required to participate in an emergency drill.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the fire on board the SCANDINAVIAN SUN was the crew's failure to tighten a threaded pipe fitting on the No. 1 diesel generator's lubricating oil line adequately which allowed the fitting to vibrate free and oil to spray from the line which ignited when it contacted the hot exhaust manifold of the engine. Contributing to the spread of the fire outside auxiliary machinery (generator) room was the failure of the crew of the SCANDINAVIAN SUN to keep closed the watertight door and the self-closing fire door between the engineering spaces and the accommodation spaces. Also contributing to the spread of the fire was a delay in closing the automatic fire doors and stopping the ventilation system because a watch was not maintained in the pilothouse where the alarms and fire detection cabinets were located.

RECOMMENDATIONS

As a result of this accident investigation, the National Transportation Safety Board made the following recommendations:

--to the U.S. Coast Guard:

Direct inspectors conducting control verification examinations to stress to ships' officers the need to close fire doors and to stop ventilation immediately upon detection of a fire. (Class II, Priority Action) (M-85-57)

Provide inspectors additional training and guidance in passenger ship control verification examinations, including the correct determination of the fire safety method of construction of a vessel as the basis for an appropriate and thorough inspection. (Class II, Priority Action) (M-85-58)

Propose to the International Maritime Organization an amendment to SOLAS 74 to require that passenger ships on short international voyages conduct drills or safety orientations for passengers at emergency muster stations immediately upon departure from port. Safety orientation briefings should include a demonstration on the donning of life preservers, evacuation or disembarkation routes, information concerning the function of automatic fire doors, and actions to take in the event of a fire or other emergency. (Class II, Priority Action) (M-85-59)

Propose to the International Maritime Organization an amendment to SOLAS 74 to require that heat or smoke detectors be made a part of each automatic fire door release switch on passengers ships so that the door will close when the detector is activated. (Class II, Priority Action) (M-85-60)

Propose to the International Maritime Organization an amendment to SOLAS 74 to require that all passenger ships carrying more than 36 persons on international routes have an automatic/manual fire control system in the pilothouse that integrates the fire detectors, the automatic fire door controls, the ventilation system controls, and the general alarm into a unified system. (Class II, Priority Action) (M-85-61)

--to Scandinavian World Cruises:

Require that officers instruct crewmembers at each weekly fire drill aboard the SCANDINAVIAN SUN and other vessels in the company fleet on the importance of keeping self-closing fire doors unobstructed and of keeping watertight doors closed. (Class II, Priority Action) (M-85-62)

Initiate a training program on the fixed CO_2 systems, including selection of the compartments to be flooded, for all deck and engineering officers and selected crewmembers on the SCANDINAVIAN SUN and other vessels in the company fleet. (Class II, Priority Action) (M-85-63)

Require that the SCANDINAVIAN SUN and other vessels in the company fleet maintain a watch in the pilothouse manned by qualified personnel whenever passengers are aboard to monitor the alarm systems and to take immediate action in the event of an emergency. (Class II, Priority Action) (M-85-64)

Require that the SCANDINAVIAN SUN and other vessels in the company fleet equipped with the automatic/manual fire control system set the switch controlling the automatic fire door release, ventilation stops, and general alarm in the automatic position whenever the pilothouse watch is secured. (Class II, Priority Action) (M-85-65)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G.H. PATRICK BURSLEY
Member

July 9, 1985

APPENDIXES

APPENDIX A

PERSONNEL INFORMATION

Master

Captain Finn E. Hansen, 42, was the relief master of the SCANDINAVIAN SUN. He began his seagoing career in 1958 on DFDS cargo vessels as a deck apprentice and advanced progressively to chief officer. In 1966, he obtained a Danish Certificate of Competency as Mate first class and in 1982 as Master first class. He had served 5 years on DFDS passenger ships employed in positions as second officer to relief master. In 1981, he obtained his license as first officer and, in 1983, as Master first class from the Commonwealth of the Bahamas.

Staff Captain

Mr. Richard Berg-Larsen, 30, started sailing on DFDS cargo vessels as a deck apprentice and advanced progressively to first officer. In 1975, he obtained a Danish Certificate of Competency as Mate second class and Mate first class in 1975 and Master first class in 1983. He had served 4 years on DFDS passenger ships employed in positions as second officer to staff captain. In 1982, he obtained his license as first officer, and in 1984, as Master first class from the Commonwealth of the Bahamas.

First Officer

Mr. Tom W. Olsen, 29, began working for DFDS as a first officer on cargo vessels in 1978. He obtained a Danish Certificate of Competency as mate second class in 1978 and a Bahamian license as second mate in 1984.

First Officer

Mr. Tommy Isaksen, 35, started sailing in 1967 as an apprentice officer. He worked as first officer on DFDS cargo vessels in 1979, and on passenger vessels in 1983. He obtained a Danish Certificate of Competency as Mate second Class in 1979, and a Bahamian license as second Mate in 1983.

Chief Engineer

Chief Mogens R. Enevoldsen, 55, had served on the SCANDINAVIAN SUN for 1 month before the accident. He began sailing in 1948 as an assistant engineer. He began working for DFDS in 1957 on cargo vessels as third engineer and progressed to chief engineer. He has served 17 years on DFDS passenger ships as chief engineer. The chief obtained his Danish Certificate of Competency as engineer in 1948, and chief engineer in 1960. He also holds an equivalent Bahamian license issued in 1982.

First Engineer

Mr. Claus Jensen, 29, started sailing as an assistant engineer in 1976. Since 1980, he had served on DFDS cargo vessels as third and second engineer. He has served 2 years on passenger ships as second and first engineer. In 1980, he obtained his Danish Certificate of Competency and Bahamian license as third engineer

First Engineer

Mr. Ole Jorgensen, 28, began working on DFDS cargo vessels in 1978 and had served 3 years as third and second engineer on DFDS passenger vessels. In 1982, he obtained a Danish Certificate of Competency as third engineer and in 1984 a license as second class engineer of motor ship at London, England.

Second Engineer

Mr. Gert Jensen, 31, began working on DFDS cargo and passenger ships as second engineer in 1979. He obtained a Danish Certificate of Competency in 1981 as third engineer and in 1982 a license as second class engineer of motor ships at London, England.

Third Engineer

Mr. Anders Jensen, 24, began working for DFDS on the SCANDINAVIAN SUN in May 1984 as third engineer. In 1984, he obtained a Danish Certificate of Competency as third engineer and third class engineer of motor ships at London, England.

APPENDIX B

EFFECTS OF CARBOXYHEMOGLOBIN AND HYDROGEN CYANIDE

The toxicological effects of various carboxyhemoglobin (COHb) concentrations have been listed by Kimmerle (1974) 17/ in the table below. While the table does not define incapacitation or disorientation, it can be concluded that incapacitation will occur at approximately 50 percent COHb saturation. On the average, death is likely to occur at 60 percent COHb or greater.

Human Responses at Various Concentrations of Carboxyhemoglobin

Percent COHb Concentration	Symptoms in Humans
0-10	None
10-20	Tension in forehead, dilation of skin vessels.
20-30	Headache, pulsation in sides of head.
30-40	Severe headache, ennui, dizziness, weakening of eyesight, nausea, vomiting, prostration.
40-50	Same as above, increase in breathing rate and pulse, asphyxiation and prostration.
50-60	Same as above, coma, convulsion, Cheyne-Stokes respiration.
60-70	Coma, convulsions, weak respiration and pulse, death possible.
70-80	Slowing and stopping of respiration, death within hours.
80-90	Death in less than an hour.
90-100	Death within a few minutes.

To determine how long it takes to reach the incapacitating concentration of COHb, one must choose a concentration of CO in the air. In typical fires, the rate of growth of the fire is usually exponential, which is also the most likely rate of generation of CO. In this accident, a flash fire occurred as the result of atomized lubrication oil ignition so that exponential growth may not be as appropriate as selecting an average concentration which was assumed to be 5,000 ppm. Using the Coburn equation, 18/ it was calculated that it took approximately 10 minutes during this fire for the victims to reach 50 percent

17/ G. Kimmerle 1974, Aspects and methodology for the evaluation of toxicological parameters during fire exposure, Journal of Fire and Flammability Combustion Toxicology Supplement 1.

18/ R. Coburn, R. Foster and P. Kane 1965, Consideration of the physiology and variables that determine the blood carboxyhemoglobin concentration in man. Journal Clin Invest. 41: 1899-1910.

COHb saturation, the point of incapacitation. Incapacitation is defined as the inability to perform a simple learned response. Animal studies 19/ suggest that physical collapse occurs almost simultaneously with incapacitation. It could not be determined if loss of clarity of thought occurs before physical collapse from these studies. How these results relate to humans in terms of ability to think and make decisions is unknown.

The toxicology of hydrogen cyanide (HCN) is also well documented (Doull, Klassen and Amdur 1980). Basically, it inhibits respiration at the cellular level. Even though the pharmacology of HCN is known, the correlation of environmental concentrations with blood levels and resulting toxicity has not been documented. One of the reasons this relationship has not been established is the difficulty in determining the HCN concentration in accidental poisoning and in experimental animal exposure. The two victims in this fire had toxic levels of HCN that contributed to their deaths. The two toxic products, HCN and CO, are additive in their effect on the human body.

19/ H. Kaplan et al. 1984, a research study of the assessment of escape impairment by irritant combustion gases in postcrash aircraft fires. DOT Final Report No. DIFA-3-81-006.

*U.S. GOVERNMENT PRINTING OFFICE: 1985-491-098:20044