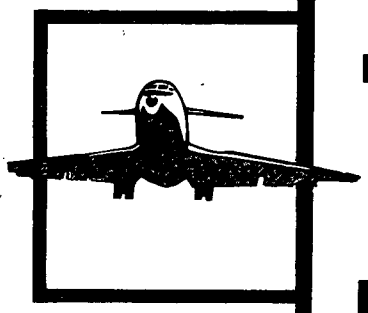

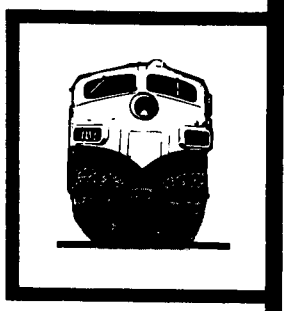

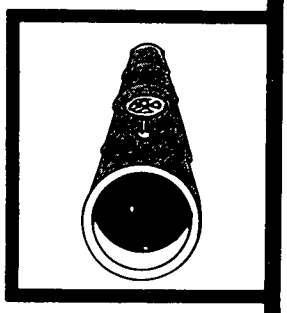

PB87-916407

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

ENGINEROOM FLOODING OF THE U.S. TANKSHIP PRINCE WILLIAM SOUND NEAR PUERTO VALLARTA, MEXICO MAY 9, 1986

NTSB/MAR-87/07

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/MAR-87/07	2. Government Accession No. PB87-916407	3. Recipient's Catalog No.
4. Title and Subtitle Engineroom Flooding of the U.S. Tankship PRINCE WILLIAM SOUND near Puerto Vallarta, Mexico, May 9, 1986		5. Report Date September 15, 1987
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 4707
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Marine Accident Report May 9, 1986
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

About 0115 on May 9, 1986, seawater was discovered flooding the engineroom of the U.S. flag tankship PRINCE WILLIAM SOUND, which was in the Pacific Ocean about 80 nautical miles west-southwest of Puerto Vallarta, Mexico. The vessel was en route from Valdez, Alaska, to Puerto Armuelles, Panama, with a cargo of 876,000 barrels (36,120,000 gallons) of Alaskan North Slope crude oil. The water level rose rapidly, and by the time the crew discovered the flooding, the electric motor drives of the bilge pumps and the sea valves were submerged before the pumps could be started or the valves closed electrically. The crew dived into the flooding engineroom and succeeded in manually closing, all but one of the main sea valves. The flooding stabilized about the 61-foot level (above the keel) of the engineroom. The vessel subsequently was towed to Long Beach, California, where the engineroom was completely dewatered. Damage to the vessel was estimated to be $12 million. There were no injuries or fatalities.

The National Transportation Safety Board determines that the probable cause of the flooding of the engineroom of the PRINCE WILLIAM SOUND was Trinidad Corporation's failure to replace a deteriorated nonmetallic (rubber) expansion joint in the main seawater circulating system as requested on several occasions by the vessel engineering personnel. Contributing to the magnitude of the flooding and the severity of the damage was the design of the bilge alarm system which failed to provide early warning of the flooding. Also contributing to the magnitude of the flooding and the severity of the damage was the failure of the chief engineer to close the main seawater overboard discharge valve upon learning of the flooding.

17. Key Words Expansion joint; engineroom flooding; flooding; main seawater circulators; bilge high level alarms; salt water circulating system; nonmetallic expansion joint; engineroom emergency procedures; vital ship systems		18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 42	22. Price

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CONTENTS

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MARINE ACCIDENT REPORT

NEAR CAPSIZING OF THE CHARTER PASSENGER VESSEL
MERRY JANE, BODEGA, CALIFORNIA, FEBRUARY 8, 1986.

NTSB/MAR-86/11 (PB86-916412)

			Change	To
Page 1 -	Paragraph 1 -	Line 2:	1985	1986
Page 2 -	Paragraph 1 -	Line 1:	65-foot	64-foot
Page 2 -	Footnote 1:		64.8 feet	64.44 feet
Page 7 -	Paragraph 2 -	Line 1:	33-footer	30-footer
Page 9 -	Paragraph 2 -	Line 2:	64.8	64.44 feet
			19.1 feet	about 19.7 feet
Page 16 -	Figure 4		Heading 013°	Heading about 015°
			Heading 355°	Heading 001°

Position in Photo No. 2 should be moved west northwest closer to the 30-foot water depth contour curve.

Figure 4 will not be revised to reflect the above changes.

Page 18 - Photo No. 1 - Column 2

Change	To
013 ± 2°	014° - 017°
2900 ± 50 feet	2860 ± 60 feet
about 430 yards, 250° from the center of Bodega Rock;	about 440 yards, 250° from the center of Bodega Rock;
about 550 yards, 171° from Bodega Head Light.	about 560 yards 174° from Bodega Head Light.

Photo No. 2.-Column 2

Change	To
355°	001°

			Change	To
Page 20 -	Paragraph 1 -	Line 5:	430 yards	440 yards
		Line 6:	013°	015°
	Paragraph 2 -	Line 2:	285 feet	250 feet
		Line 3:	150 yards	125 yards
	Paragraph 3 -	Line 2:	013°	015°

SEPTEMBER 15, 1987

EXECUTIVE SUMMARY

About 0115 on May 9, 1986, seawater was discovered flooding the engineroom of the U.S. flag tankship PRINCE WILLIAM SOUND, which was in the Pacific Ocean about 80 nautical miles west-southwest of Puerto Vallarta, Mexico. The vessel was en route from Valdez, Alaska, to Puerto Armuelles, Panama, with a cargo of 876,000 barrels (36,120,000 gallons) of Alaskan North Slope crude oil. The water level rose rapidly, and by the time the crew discovered the flooding, the electric motor drives of the bilge pumps and the sea valves were submerged before the pumps could be started or the valves closed electrically. The crew dived into the flooding engineroom and succeeded in manually closing all but one of the main sea valves. The flooding stabilized about the 61-foot level (above the keel) of the engineroom. The vessel subsequently was towed to Long Beach, California, where the engineroom was completely dewatered. Damage to the vessel was estimated to be $12 million. There were no injuries or fatalities.

The safety issues discussed in the report are:

1. The location and number of hi-level bilge alarm sensors required in the engineroom bilge;

2. The use of repaired expansion joints; and

3. The lack of remote manual control connections (reach rods) to the vital valves in the main seawater circulating system.

The National Transportation Safety Board determines that the probable cause of the flooding of the engineroom of the PRINCE WILLIAM SOUND was Trinidad Corporation's failure to replace a deteriorated nonmetallic (rubber) expansion joint in the main seawater circulating system as requested on several occasions by the vessel engineering personnel. Contributing to the magnitude of the flooding and the severity of the damage was the design of the bilge alarm system which failed to provide early warning of the flooding. Also contributing to the magnitude of the flooding and the severity of the damage was the failure of the chief engineer to close the main seawater overboard discharge valve upon learning of the flooding.

Safety recommendations concerning nonmetallic expansion joints in the main seawater circulating system, multiple bilge high level sensors, and reach rods for remote manual valve operation were issued to the U.S. Coast Guard, the American Bureau of Shipping, and Sun Refining and Marketing Company.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

Adopted: September 15, 1987

ENGINEROOM FLOODING OF THE U.S. TANKSHIP PRINCE WILLIAM SOUND NEAR PUERTO VALLARTA, MEXICO MAY 9, 1986

INVESTIGATION

The Accident

The U.S. flag tankship PRINCE WILLIAM SOUND with a crew of 27 departed Valdez, Alaska, on May 1, 1986, en route to Puerto Armuelles, Panama, with a full load (876,000 barrels) of Alaskan North Slope crude oil. The vessel draft at departure was 53 feet 4 inches forward and 55 feet aft. The tankship was making one of its 12 annual, 27-day round trips, which consisted of bunkering (refueling) in Long Beach, California; steaming to Valdez to load North Slope Crude oil and on to Puerto Armuelles to discharge the cargo; and then returning to Long Beach for bunkering.

About 0100 on May 9, the tankship was proceeding at a sea speed of 16 knots on a southerly course approximately 80 nautical miles west-southwest of Puerto Vallarta, Mexico. (See figure 1.) At the time, the weather conditions consisted of calm seas and clear skies with unlimited visibility. According to the second mate who was in charge of the navigation bridge watch, "it was a perfect morning at sea."

About 2330 on May 8, before assuming the 0000-0400 watch in the steamship's engineroom, the second assistant engineer and the engineering watch oiler conducted an inspection of the engine spaces. They visually checked the plant machinery and operating pressures and temperatures, starting with the forced draft fans above the boiler down to the main condensate pumps near the bilges. (See figure 2.) The oiler said that it was his pre-watch routine to check the engineroom bilges in at least four locations: the starboard side between the two main seawater circulating pumps, aft on the centerline at the bilge high level alarm sensor bilge well (below the propeller shaft), the port side at the main condenser outlet head, and forward at the main condensate pumps. The second assistant engineer conducted a similar engineroom inspection using a different route. Neither the oiler nor the second assistant engineer noted any abnormal conditions during their pre-watch inspection. The bilges were dry and all equipment appeared to be operating normally.

The second assistant engineer and the engineering watch oiler then met the engineering watch they were relieving at the engineroom control console on the starboard side of the engineroom at the 39-foot operating flat. The 0000-0400 watch personnel were told that the previous watch had been normal and uneventful. After a brief conversation, the second assistant engineer and the oiler assumed the engineroom watch responsibility about 2355. It was the usual routine, after assuming the watch, for the second assistant engineer to chemically test the boiler water while the oiler switched over and cleaned the fuel oil service pump suction and discharge strainers. The oiler proceeded from the 39-foot operating flat down the starboard ladder between the two main seawater circulating pumps and aft in the lower engineroom to the fuel oil heaters.

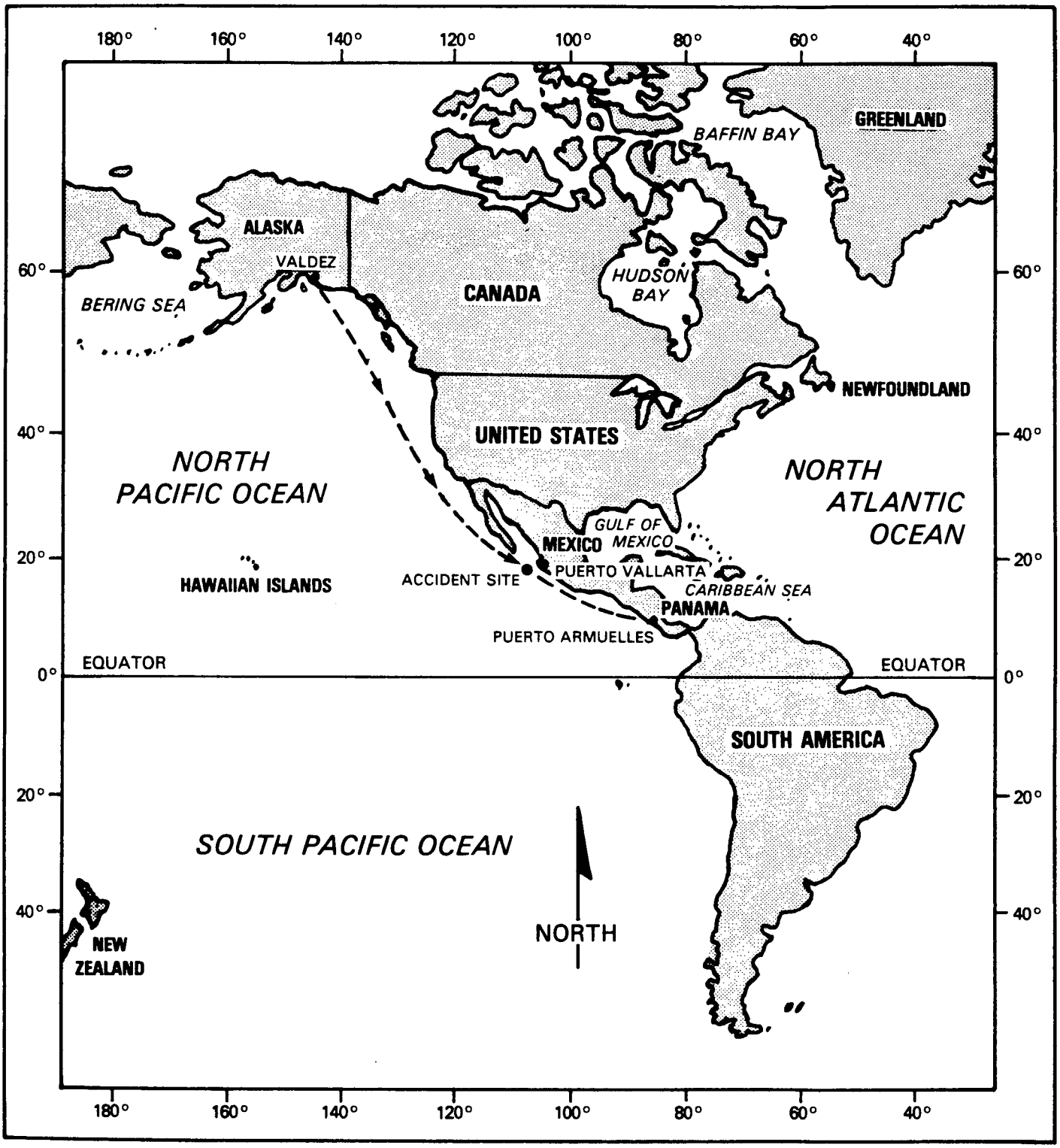


Figure 1.—Normal routing of the S.S. PRINCE WILLIAM SOUND between Valdez, Alaska, and Puerto Armuelles, Panama.

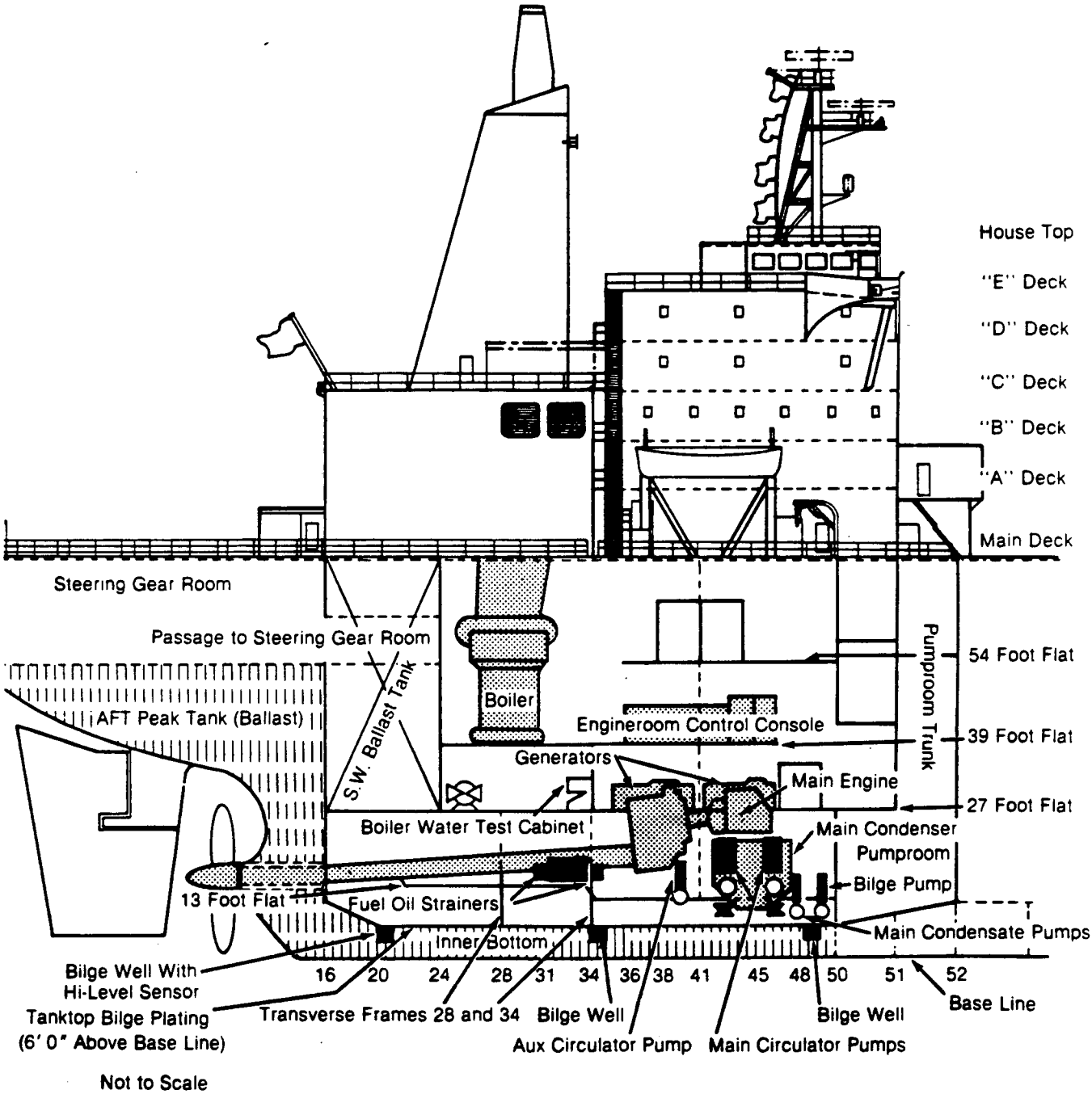


Figure 2.—Inboard profile of engineroom.

The strainers were located on the 13-foot flat in the engineroom below the fuel oil heaters (about 7.5 feet above the bilge tanktop plating). The second assistant engineer proceeded to the boiler water test cabinet aft on the 27-foot flat.

About 0055, the oiler returned to the control console. The second assistant engineer returned about 5 minutes later. The second assistant engineer called the bridge watch, which consisted of the second mate and the quartermaster, to inform them that he was reducing the vessel speed from 87 to 82 revolutions per minute (rpms) to steam clean the outer surface of the boiler tubes (blow the tubes). About 0112, an alarm sounded, warning of a low water level in the boiler feedwater heater. A second alarm, indicating a high condensate (boiler feedwater) level in the main condenser, followed almost immediately. The second assistant engineer was standing at the engineroom control console slowing the ship to build up the additional steam required when cleaning boiler tubes, and the oiler was opening valves and preparing to blow the tubes. The second assistant engineer silenced the audio portion of the alarms by depressing the acknowledge pushbutton on the control console. However, warning lights on the console continued to flash. He said that after the second alarm, the vacuum level of the main condenser began to drop. He telephoned the chief engineer, who was asleep in his cabin, and reported the situation in the engineroom. He then directed the oiler to close the steam valves to the soot blowers (blowing tubes) while he closed the valves for the soot blower compressed air.

The chief engineer arrived at the engineroom control console shortly afterward. Just as the chief engineer reached the control console, the bilge high water level alarm activated. The bilge high level alarm indicating light on the control console began flashing on and off and the alarm horn sounded. The second engineer silenced the audio alarm, while the flashing light remained on, indicating the continued high level in the bilge.

The chief engineer said that the main condensate pump run indicator light on the control console showed the pump was not running. He depressed the condensate pump remote start pushbutton, but the pump failed to start. Next, the chief engineer started the standby main condensate pump. He said that the pump run light illuminated and that he continued to survey the control console for other malfunctions. When the chief engineer returned to that part of the console where the condensate pump pushbutton was located, the standby main condensate pump run indicator light showed that the pump was not running. The chief engineer attempted to reset the switch (circuit breaker) for the main condensate pump at the electrical controller, but he was unsuccessful. He said he knew at that time that the main condensate pump circuit breakers had tripped due to electrical overload. The chief engineer instructed the second assistant engineer to go to the lower engineroom to determine the problem with the main condensate pumps. The second engineer said that as he proceeded down the ladder to the lower engineroom, the water level in the engineroom was about 9 feet above the tanktop plating, the lowest level in the engineroom.

The second assistant engineer returned to the control console and reported the flooding to the chief engineer. About 0118, the chief engineer notified the bridge watch of the flooding situation and that he was shutting down the main propulsion steam turbines. Both the chief engineer and the second assistant engineer attempted to start various electric motor driven bilge pumps by remote control, and they attempted to close the electric motor operated valves in the main seawater circulating system. According to the second engineer, by that time, the rising water level in the engineroom had submerged the motor drives to the bilge pumps and to the main seawater circulating valves, leaving them electrically inoperable. The chief engineer then stopped the two main seawater

circulating pump motors. The second assistant engineer activated the engineers' emergency call alarm for assistance in the engineroom. The chief engineer then directed the second assistant engineer to go below to the starboard side of the lower engineroom, to close the main seawater circulating pump suction valves manually, and to see if he could determine the source of the flooding.

The first assistant engineer had been asleep in his cabin when he heard the engineers' emergency call, about 0118. Both the first assistant engineer and the third assistant engineer reported shortly afterward to the chief engineer at the control console in the engineroom. The chief engineer told the first assistant engineer of the flooding and directed him to go to the port side of the lower engineroom and open the emergency bilge suction valve in preparation for starting the emergency bilge pump (auxiliary seawater circulating pump). When the remaining engine department personnel arrived at the engineroom control console, the chief engineer sent the third assistant engineer below to help the first assistant engineer. While seawater was rising rapidly in the engineroom, the second assistant engineer was manually closing the discharge valves from each of the two main seawater circulating pumps on the starboard side of the lower engineroom.

Meanwhile, the first and the third assistant engineers had opened the discharge valve from the emergency bilge pump on the port side of the lower engineroom. They were diving underwater, trying to open the emergency bilge pump suction valve so that the proper valves would be open to dewater the engineroom. The suction valve handwheel was located about 1 foot above the tanktop plating.

The watch oiler went down to the starboard side of the lower engineroom and attempted to locate the source of the flooding, but he was unsuccessful. The oiler then doubled back, went down to the port side of the engineroom, and assisted the first assistant engineer. The three men began diving down to the emergency bilge suction valve handwheel and attempted to open the valve. The first engineer said, "It was an exhausting ordeal, holding your breath and diving under the flooding seawater, grabbing onto something to hold yourself underwater while trying to open the emergency bilge suction valve with one hand." Their efforts were soon aided by the arrival of an able seaman and another oiler. When they finally opened the emergency bilge suction valve, the third assistant engineer hurried up to the 39-foot operating flat and told the chief engineer to start the emergency bilge pump. The pump started and appeared to momentarily hold the water level steady. However, shortly afterward, the water level began to rise against the electric motor housing of the emergency bilge pump. The first assistant engineer returned to the chief engineer at the control console and told him that the emergency bilge pump was running but that the water level was still rising. The chief engineer directed the first assistant engineer to close the main seawater overboard discharge valve in the port lower engineroom. At the time, the water in the engineroom was about 20 feet deep.

After numerous attempts to fully close the main seawater overboard discharge valve, the first and third assistant engineers and the oiler noticed that as they were treading water in the port lower engineroom their heads were touching the pipes and steel structure of the overhead. The continued flooding of the engineroom forced them to abandon their task and to seek safety before they were trapped between the deck above and the rising water level. To escape being trapped and drowned, they swam underwater to the main engine and climbed a ladder to the 39-foot operating flat.

When the engine department crewmen returned to the control console, the first assistant engineer told the chief engineer that they did not have sufficient time to close

the main seawater overboard discharge valve before they were forced to return to the 39-foot flat. The chief engineer directed the men to secure the boiler and the plant auxiliaries. The superheater vents and the boiler safety valves were opened by hand.

Meanwhile, the flooding water had stopped the fuel oil service pump motor and numerous other plant auxiliaries. The chief engineer had managed to keep the vessel steam turbine generators running and supplying electricity for as long as he could. At the time, the water level in the engineroom was just below the 27-foot generator flat. All engineroom crewmen were at the 39-foot flat when the chief engineer warned them that the lights would go out momentarily while he switched electrical power from the main steam turbine generators to the emergency diesel generator. The chief engineer sent two men to secure the two main steam turbine generators and another crewman to the 54-foot flat to secure the watertight door between the engineroom and the steering gear room.

About 0220, when the flood waters reached the 32-foot level in the engineroom, the chief ordered all personnel to evacuate the engineroom, to get their exposure suits and don their personal floatation devices, and to standby at their assigned lifeboat stations. The chief engineer proceeded to the main deck where he closed the engineroom fuel oil valves from the remote (reach rod) 1/ shutoff station. He instructed his men to prepare the fire pump and to break out the firefighting gear and hoses. The emergency diesel generator provided electrical power to the 150-horsepower main deck deepwell fire pump. The fire main system, a foam firefighting system, and CO2 extinguishers were still operational.

The master of the PRINCE WILLIAM SOUND was on the bridge when the chief engineer called the bridge watch at 0118 to report the flooding casualty. The master then proceeded to the engineroom to assess the condition of the vessel. After conferring with the chief engineer, the master went to the radioroom and contacted the vessel fleet manager at Aston, Pennsylvania. The master gave the fleet manager a full report up to that time; the master told him that he was concerned that the bulkheads surrounding the engineroom, especially the pumproom bulkhead, might not be able to withstand the pressure of the seawater in the engineroom. The fleet manager instructed the master to keep the company informed of the water level and informed him the company would attempt to calculate the stresses on the hull and the pumproom and other bulkheads. About 0200, the master sent a radio distress message to the U.S. Coast Guard (Coast Guard) in Alameda, California, explaining that the vessel was taking on water in the engineroom from an unknown source. The tankship radio operator activated the vessel automatic distress call on the Marisat (satellite communication) transceiver unit. At that time, the vessel position was 19° 50' North latitude and 106° 33' West longitude, about 80 nautical miles west southwest of Puerto Valarta, Mexico. (See figure 1.) The master then returned to the engineroom to determine the rate of the rising water.

When the master returned to the bridge, he ordered the first mate to lower the vessel lifeboats to the embarkation deck (main deck) in preparation for abandoning the vessel and to have someone verify the watertightness of the spaces surrounding the engineroom. The spaces were reported to be watertight; the crewmembers were mustered and verified to be at their assigned lifeboat station with their survival gear. About 0615, the flooding in the engineroom stabilized at the 61-foot level (above the keel) leaving the vessel with a 10-foot freeboard aft (distance from the main deck to the sea level). The master determined that since there was no explosion from the engineroom, there was no immediate need to abandon the tanker into the waiting lifeboats.

1/ A reach rod is a steel rod or flexible cable mechanism fitted to a valve handwheel and extended upward to a location for remote manual valve operation.

The PRINCE WILLIAM SOUND was without propulsion power and adrift in calm seas in the Pacific Ocean. The emergency diesel generator provided electrical power for lighting, navigation, firefighting, and communication equipment. The vessel draft in the flooded condition was 61 feet aft and 49 feet forward. Some leaking from a small crack was discovered near the top of the transverse bulkhead that separated the pumproom from the engineroom and there was concern that the bulkhead might collapse. The crew was concerned because flooding of the pumproom could be sufficient to sink the vessel. Seawater was leaking into the steering gear room around the watertight door that led from the engineroom to the steering gear room. The crewmembers shored the leaking watertight door from the steering gear side with wood and stopped the leak. The crew continued to monitor the condition of the bulkheads surrounding the engineroom while they waited for assistance.

Search and Rescue

About 0210 on May 9, the Coast Guard transmitted an Urgent Marine Information Broadcast (UMIB) to alert all vessels that the PRINCE WILLIAM SOUND was stricken 300 miles south of the Baja Peninsula, that it was taking on water in the engineroom, and that it was in danger of sinking. The UMIB requested that vessels in the vicinity of the stricken tankship lend assistance.

At 0220, the Coast Guard requested clearance from the U.S. Defense Attache Officer (USDAO) at the U.S. Embassy in Mexico City for a Coast Guard Falcon jet (HU-25) to enter Mexican airspace. When clearance was granted at 0400, the Falcon jet departed San Diego Air Station loaded with various items of emergency and rescue equipment; it arrived at the location of the drifting tankship about 0700.

The aircraft circled and communicated with the vessel via radio. After ascertaining the condition of the vessel and the crew, the aircraft dropped (via parachute) two 140-gallon per minute (gpm) pumps and then departed for Puerto Vallarta. The master of the PRINCE WILLIAM SOUND directed some of his crew to retrieve the pumps from the ocean. Once on board the tankship, the pumps were used to pump seawater that had accumulated in the steering gear room.

About 0320, the Coast Guard cutter LAUREL was dispatched to Puerto Vallarta. The LAUREL carried pumps and other emergency equipment to be used to aid the tanker. At 0426, the Coast Guard Pacific Strike Team was alerted to assist the PRINCE WILLIAM SOUND. Emergency equipment, including antipollution gear, air deliverable (parachute) pumps, two diesel-driven 1,100-gpm pumps (ADAPTS), and other emergency Search and Rescue (SAR) equipment was placed on pallets and was loaded aboard a Coast Guard HC-130 fixed wing aircraft stationed at Coast Guard Air Station Sacramento.

According to the master of the PRINCE WILLIAM SOUND, the SONIA M, a container ship, was the first vessel to arrive on the scene at 0630. It remained on the scene until it was relieved about 0830 by the M/V GLORIOUS ACE. The SS LOS ANGELES arrived on the scene at 1100 and relieved the GLORIOUS ACE. The master of the PRINCE WILLIAM SOUND stated, "We had a vessel in attendance with us all the time. He also stated that the vessels offered to take the crew to Long Beach.

The Coast Guard HC-130, with the Pacific Strike Team on board, arrived over the tankship about 1500 and communicated with the stricken vessel by radio. Upon finding the PRINCE WILLIAM SOUND in a relatively stable condition and with a merchant vessel standing by, the HC-130 headed inland and landed at the Puerto Vallarta airport where

the emergency equipment was transferred to a Coast Guard (HH-3F) helicopter. Beginning at 0700 on May 10 and until darkness each day, personnel and emergency gear were shuttled via Coast Guard helicopter between Puerto Vallarta and the tankship.

About noon on May 10, representatives of the Coast Guard and the tankship operator met with Mexican Navy officials. The government of Mexico, under the U.S./Mexico agreement on prevention and cleanup of oil spills, furnished two Mexican naval patrol boats to stand by the PRINCE WILLIAM SOUND in case of an emergency. The Coast Guard helicopter and a Mexican Petroleum Company (Pemex) helicopter continued to shuttle equipment and personnel between the tanker and shoreside. The Coast Guard helicopter was released on May 11 to return to duty in San Diego.

The Coast Guard cutter LAUREL arrived in Puerto Vallarta during the afternoon of May 11. After clearing customs with the Mexican government, the LAUREL loaded provisions, drinking water, and other materials for transfer to the PRINCE WILLIAM SOUND. The LAUREL departed Puerto Vallarta about 2100 on May 11, and it arrived at the tankship about 1100 on May 12, about the time the Coast Guard Pacific Strike Team completed setting up the emergency ADAPTS equipment.

The vessel operator contracted salvage and towing vessels to attend to the tanker. Salvage divers were shuttled to the tanker via the Pemex helicopter on May 12. Once on board the tankship, divers examined the exterior hull in the area of the engineroom to determine the source of the flooding. The examination did not reveal any hull problems.

Efforts by the Coast Guard Pacific Strike team to dewater the engineroom were unsuccessful because as water was removed by the pumps, it flooded back into the engineroom from the ocean. The salvage divers descended into the flooded engineroom and guided by the chief engineer's instructions over a radio, closed all the open sea valves in the engineroom. Pumping operations resumed about 2100 on May 12, and the floodwater in the engineroom began to decrease.

Seawater was pumped from the engineroom lowering the water level approximately 10 feet to the 54-foot flat. The salvage crew applied a chemical solution to engineroom equipment to combat the effects of saltwater contamination. When the equipment on this flat had been completely treated with the chemical solution, the water level was pumped down to the next flat and the equipment on this flat was treated with chemicals. The pumping was stopped when the water level in the engineroom was about 33 feet deep, just above the steam turbine electric generators.

About 0230 on May 13, the SEA ROBIN, a tug contracted by the vessel operator, arrived at the PRINCE WILLIAM SOUND. By 1000, a towing bridle was rigged on the tankship and the tug payed out towing cable. Divers secured the propeller and shaft in preparation for the tow to Long Beach. At 1745, the Coast Guard cutter LAUREL was released and returned to normal duty. At 2330, the tug GLADIATOR, also contracted by the vessel operator, arrived to assist in the tow. A second tow line was rigged and passed to the tug and the PRINCE WILLIAM SOUND was towed to Long Beach.

Injuries to Persons

None of the 27 crewmembers were injured.

Vessel Damage

Saltwater, which had flooded the entire machinery space, damaged all main and auxiliary machinery, electric motors, switchboards, controllers, electric cables, wireways,

and insulation. The tankship arrived at Long Beach anchorage on May 30. The remaining 33 feet of seawater in the engineroom and all the cargo was off-loaded into tank barges and transported to shore.

On June 2, 1986, a survey team comprised of Safety Board investigators, American Bureau of Shipping (ABS) surveyors, Coast Guard marine inspectors, the vessel port engineer, and representatives of the vessel owner boarded the PRINCE WILLIAM SOUND and conducted a survey to determine the source and the cause of the engineroom flooding.

The damage survey began on the 11-foot level above the flat keel in the forward starboard side of the engineroom near the main condenser and the two main seawater circulating pumps. Based on the chief engineer's testimony that the leak was in "the main seawater circulating system of the main condenser—one of the expansion pieces probably," the survey team examined the flexible nonmetallic expansion joints in the main seawater circulating system.

All five expansion joints in the main seawater circulating system were examined: four expansion joints on the inlet side of the main condenser (one on the suction side and one on the discharge side of each of the two main circulating pumps) and one expansion joint on the overboard discharge side of the main condenser. The two expansion joints on the suction side of the two main seawater circulating pumps, the main seawater overboard discharge expansion joint, and the aft main circulating pump discharge expansion joint appeared to be in satisfactory condition. The expansion joint on the discharge side of the forward main seawater circulating pump had separated completely through the joint in the area of the joint shoulder where the joint flange and body meet on the 36-inch-diameter inboard end of the expansion joint. (See figure 3.) The separation measured about 30 inches long circumferentially along the bottom half of the expansion joint and continued about 6 inches along the axis at the bottom. The separation began about the 4 o'clock position and ended about the 7 o'clock position.

Measurements were taken of the separation between the face of the flange on the main condenser forward inlet piping and the face of the flange on the outlet side of the forward main seawater circulating pump discharge valve. (See figure 4.) The measurements were taken using different methods at different times of the day with varying ambient air temperatures. The separation exceeded the manufacturer's elongation tolerance by an average of 10/16 inch. Angular misalignment (nonparallel planar alignment of flange faces) of the main seawater circulating piping amounted to approximately 5/16 inches. Deviation from the concentric alignment of the two metal flanges amounted to a maximum eccentricity of approximately 1 1/16 inches.

On June 19, the PRINCE WILLIAM SOUND was towed to a shipyard in Portland, Oregon, for extensive repairs to the electrical power production and distribution system; the main propulsion machinery; the auxiliary machinery; and the potable water, heating, ventilation, refrigeration, and sanitation systems. The estimated cost to repair the damage was about $12 million.

Crew Information

The 27-member crew of the PRINCE WILLIAM SOUND consisted of 9 licensed officers, 17 unlicensed crewmembers, and a deck cadet midshipman. All were licensed or documented as required by the Coast Guard for the positions they served aboard the vessel. (See appendix B.)

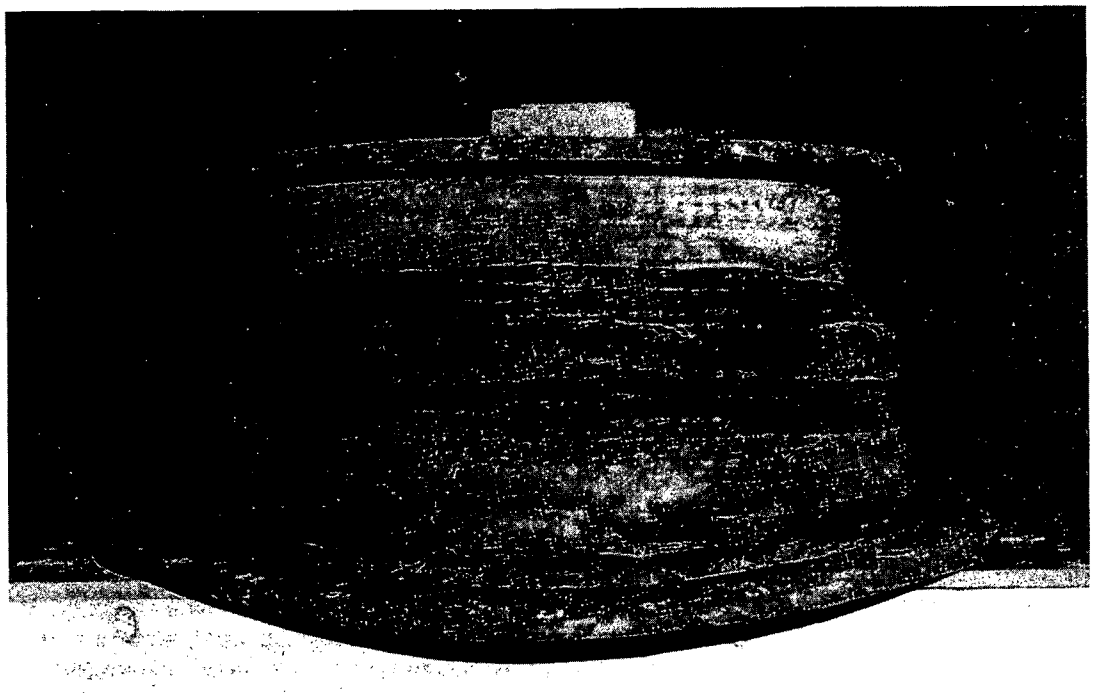
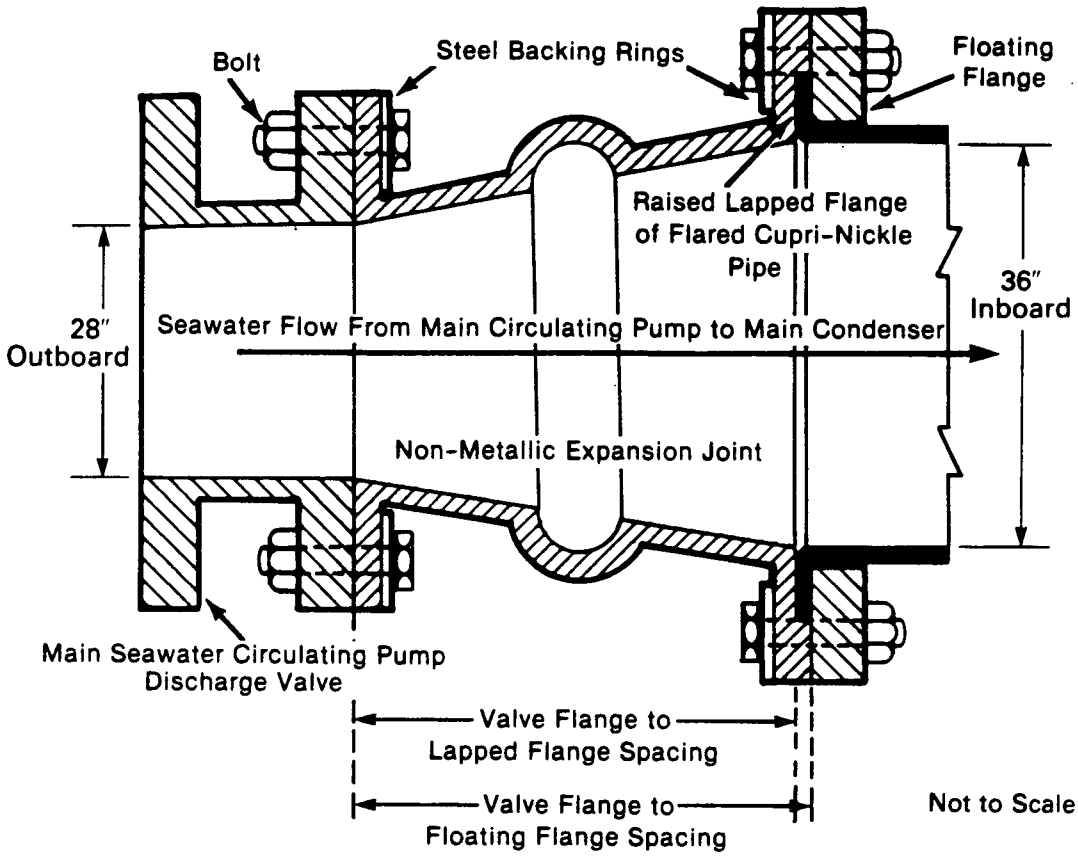


Figure 3a.—Forward main circulating pump discharge expansion joint removed, showing rupture at joint shoulder near flange.

Figure 3b.—Forward main circulating pump discharge expansion joint in place, view looking up from engineroom tanktop at rupture in joint bottom.

Figure 3.—Forward circulating pump discharge expansion joint.



Cross-Sectional View of Concentric Tapered Expansion Joint as Installed in the PRINCE WILLIAM SOUND

	Location Around Joint				
Spacing Measured	Top	Bottom	Aft	Forward	Average
Flanges Face to Face (A)	19-3/16	19-1/16	19-7/16	18-13/16	19-2/16
Flanges Face to Face (B)	19	19-1/16	19-3/16	18-14/16	19-1/16
Valve Flange/Lapped Flange (B)	18-10/16	18-12/16	18-13/16	18-8/16	18-11/16
Valve Flange/Lapped Flange (C)	18-9/16	18-9/16	18-12/16	18-7/16	18-9/16

Note:

A. Measurements, from flange edge to flange edge at an angle, taken by Goodall Rubber Company on June 6, 1986 using a flexible steel tape measure. Axial measurements were then calculated from these measurements.

B. Measurements taken by Goodall Rubber Company on June 11, 1986 using precision vernier calipers.

C. Measurements taken by Sun Refining and Marketing Company on June 10, 1986 using a mechanics square.

NOTE: The original flange face-to-face dimension of the expansion joint was 18 inches, plus 1/2 inch of tolerance for axial and transverse.

Figure 4.—Axial flange spacing measurements.

With the application of modern control technology to marine power systems, the maritime industry requested that the Coast Guard permit a reduction in the customary number of engineering watchstanders. Some years ago, it was customary to operate a steam propulsion plant with a three-person engineering watch, consisting of a fireman/watertender, an oiler, and a licensed engineer. The fireman/watertender managed the operation of the boilers; the oiler made hourly patrols of the engineroom, recording data on plant machinery operation, and was an assistant to the licensed engineer, who supervised the watch. The three-person watch, using their senses of sight, sound, smell, and engineering training and judgment, performed as a trouble detection system in the event of fire, flooding, or machinery malfunction. In the sixties, the Coast Guard established vessel equipment and machinery requirements necessary for a crew reduction. On December 31, 1975, due to the level of engineroom and bridge control technology (automation), the tankship PRINCE WILLIAM SOUND was certificated by the Coast Guard for a two-person engineroom watch consisting of one licensed engineer and one oiler, junior engineer or deck engine mechanic per watch.

Vessel Information

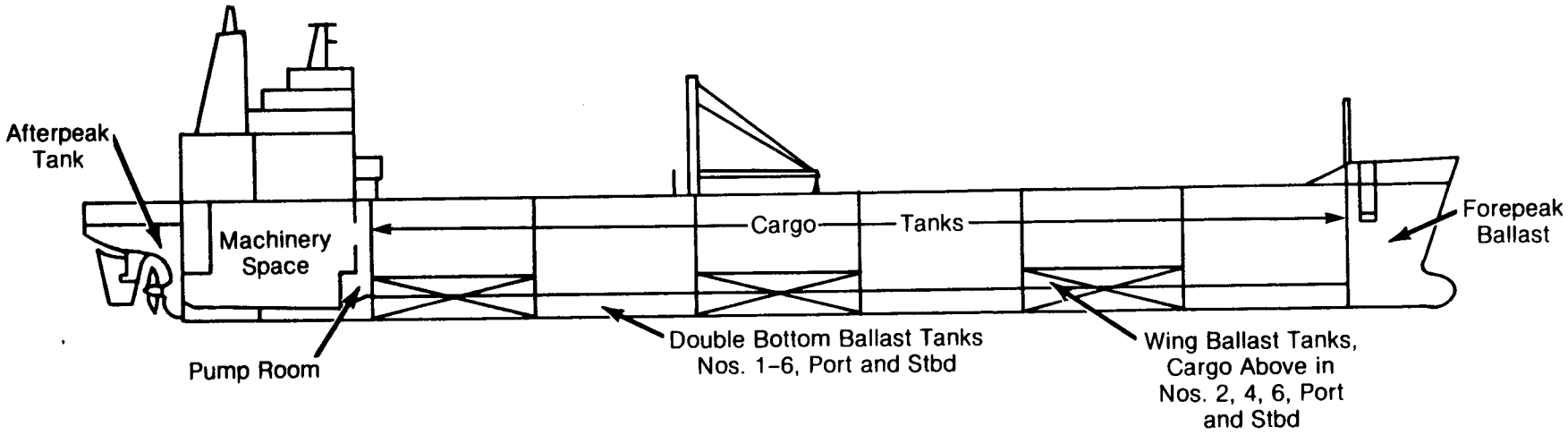
General.--The PRINCE WILLIAM SOUND, Official No. 570108, is owned by Alaska Bulk Carriers, Inc., of Wilmington, Delaware. It was constructed in December 1975 by the Sun Shipbuilding and Drydock Company, Chester, Pennsylvania, according to ABS Rules for Building and Classing Steel Vessels. The steel hulled tankship was registered in the United States, and it was certificated by the Coast Guard. The Trinidad Corporation (Trinidad) of Philadelphia, Pennsylvania, operated the vessel from 1976 to August 1983, at which time the vessel operation was transferred to the Sun Refining and Marketing Company (Sun), of Aston, Pennsylvania. The vessel characteristics are as follows:

Length overall	869	feet
Breadth, molded	136	feet
Depth, molded	71.7	feet
Draft, design (molded)	54	feet
Gross tonnage	60,084	tons
Deadweight tonnage	121,000	tons
Horsepower	30,000	
Designed speed	17	knots (19.6 mph)

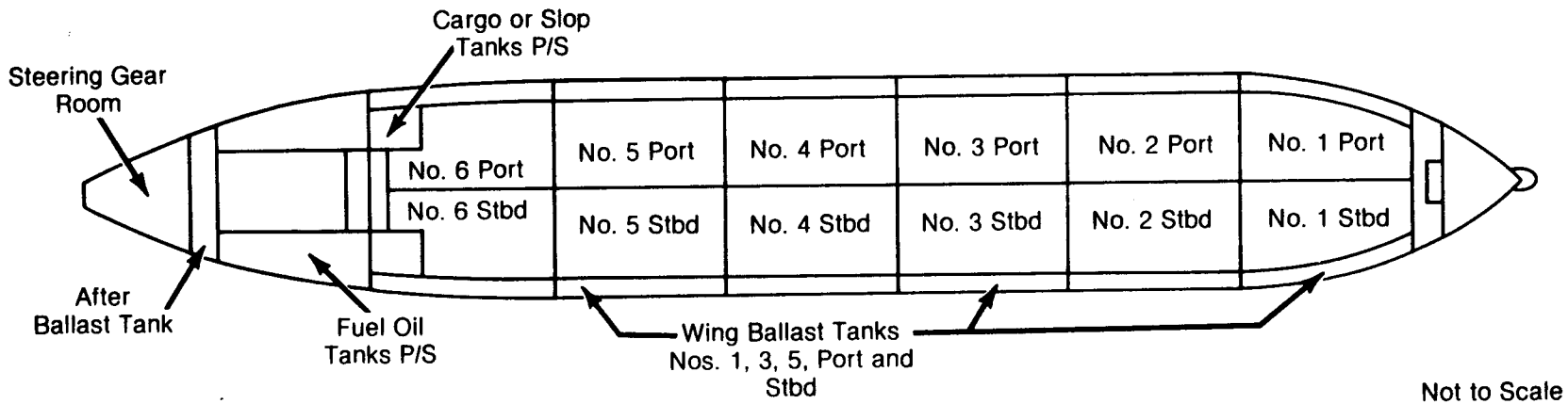
The tankship was powered by General Electric steam turbines, geared to a single shaft and propeller, and it was steered by a single rudder. Steam was furnished by two Babcox and Wilcox water tube boilers. The hull was double-skinned (see figure 5) with inner bottom tanks and wing tanks surrounding the cargo section, which consists of 12 main cargo tanks numbered 1 through 6, port and starboard. The individual cargo tanks were separated by one centerline longitudinal bulkhead and five transverse bulkheads. All double bottom and wing tanks were designated for ballast, except wing tanks Nos. 2, 4, and 6 port and starboard, which also carried cargo.

The navigation bridge and crew quarters were located in a superstructure over the machinery space. The bridge was equipped with a gyrocompass, two radars, a fathometer, a radio direction finder, a Loran receiver, a VHF-FM radiotelephone and a marine radio console. A 21-person capacity inflatable liferaft and a 41-person capacity diesel-powered motor lifeboat were located on each side of the superstructure.

Seawater Circulating System.--Cooling water for the main condenser was supplied by two 150-horsepower, electric-motor-driven, main seawater circulating pumps, each with a pump discharge capacity of 22,000 gpm. The main seawater circulating pumps were located on the starboard side of the lower engineroom about 9 feet 4 inches above



Inboard Profile



Not to Scale

Ballast and Cargo Arrangements

Figure 5.—PRINCE WILLIAM SOUND arrangement.

the tanktop plating between frames 42 and 46. Each main circulating pump discharged seawater into a separate 28-inch-diameter pipeline while taking suction from a common sea chest. Seawater flowed into the main condenser and passed through thousands of horizontal tubes before being discharged overboard. Steam from the boilers was piped to the main engine steam turbines and was exhausted onto the exterior of the tubes in the main condenser. The seawater flowing through the tubes cooled and condensed the steam to form condensate/boiler feedwater. The condensate was pumped from the main condenser to the boiler feedwater heater before being returned to the boiler. The chief engineer said that he generally used only one main seawater circulating pump when the PRINCE WILLIAM SOUND sailed in cold Alaskan waters of 40° F. Two main seawater circulating pumps were used when the vessel sailed in warmer waters of 75° F off the coast of Mexico. Both main seawater circulating pumps were operating before the machinery space flooded. (See figure 6a.)

A 36-inch-diameter main condenser overboard discharge pipeline, located on the port side of the machinery space led to a single separate sea chest; it was fitted with one discharge valve. The main seawater circulating system expansion joints were under pressure at all times when the ship's steam plant was in operation. All five valves in the main seawater circulating system were motor-driven butterfly valves with pushbutton controls and position (open/closed) indicating lights installed in the control console on the 39-foot operating flat. The valves also could be controlled manually by a handwheel located at each valve. To close the valves manually required about 2 minutes; to close the valves electrically required about 45 seconds. None of the main seawater circulating valves had reach rods affixed to their handwheels.

During vessel construction, a floating steel flange was installed on the forward and aft 36-inch-diameter inlet head cupri-nickel piping to the main condenser. The main condenser cupri-nickel inlet head piping was fabricated so that the outboard end was turned or rolled 90° to the axis of the pipe to form a restraint flange which held the floating flange on the pipe. (See figure 7.)

A 9,000-gpm, electric-motor-driven, auxiliary seawater circulating pump/emergency bilge pump, supplied seawater cooling to the auxiliary condenser and, in an emergency, could be used to supply cooling water to the main condenser. The auxiliary circulating pump also could be used as an emergency bilge pump taking suction at the tanktop to dewater the engineroom bilge spaces. An auxiliary condenser was located on the port side of the machinery space below the ship service steam turbine generator. Circulating water for the auxiliary condenser was supplied from an independent seachest.

The PRINCE WILLIAM SOUND had only one bilge high level alarm sensor installed in the machinery space bilge. It was located aft, between frames 20 and 21 on the centerline below the propeller shaft. The sensor was installed in a bilge drain well which was 6 feet wide 33 inches long, and recessed 2 1/2 feet deep into the inner bottom of the double hull through the tanktop plating. Two 24- by 30-inch cutouts in the tanktop steel plating, spaced equally to the port and starboard of the centerline, provided openings for the bilge water to drain into the well.

The bilge alarm was controlled by a float sensor and was set to sound when the bilge water reached the top of the drain well which was level with the tanktop plating. When the bilge high level alarm is activated, a horn is sounded and a light begins flashing behind a red translucent nameplate on the engineroom control console to indicate specifically the source of the alarm. When the alarm is acknowledged at the control console, the horn is silenced but the light continues to flash until the alarm condition is corrected. According to the vessel plans, a float switch in the drain well automatically started a 900-gpm bilge

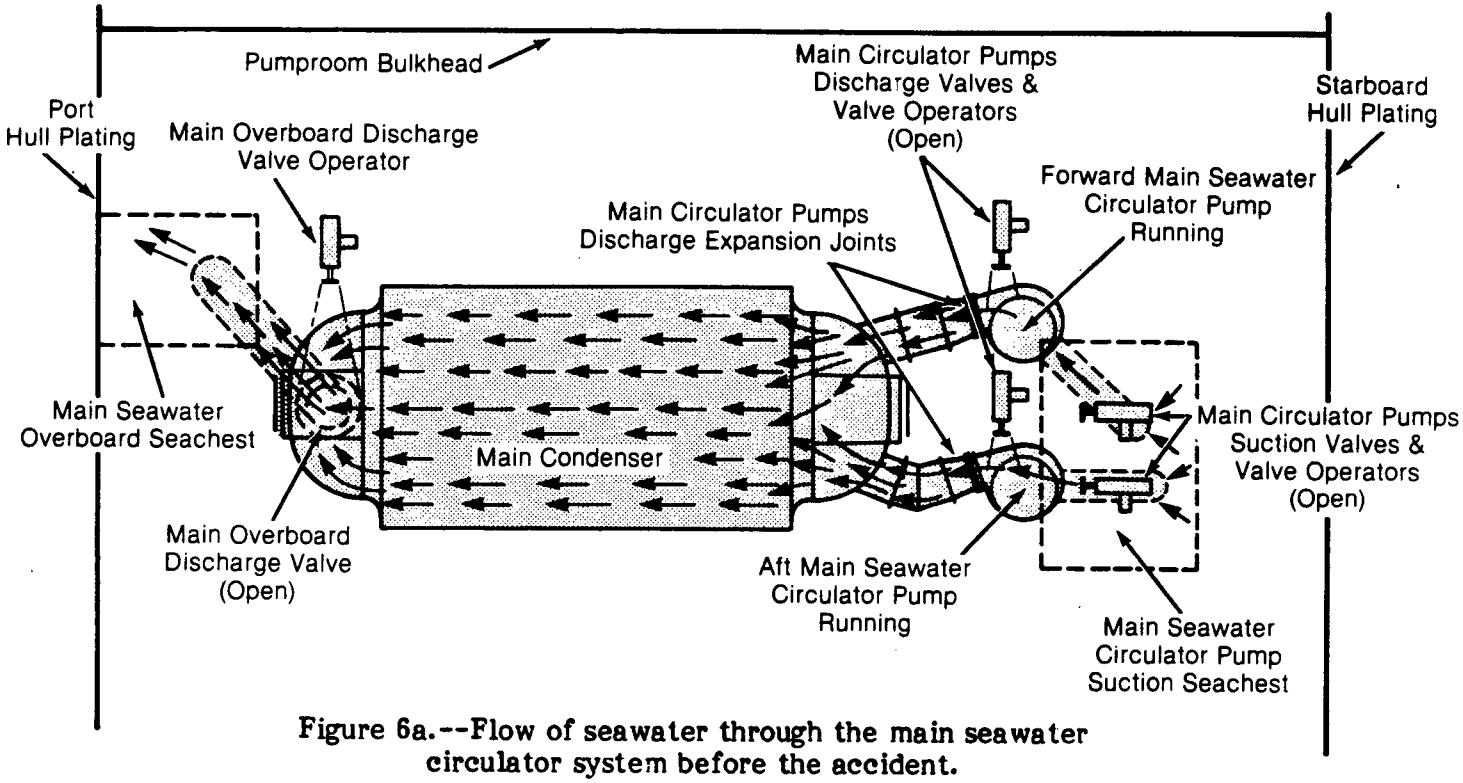


Figure 6a.--Flow of seawater through the main seawater circulator system before the accident.

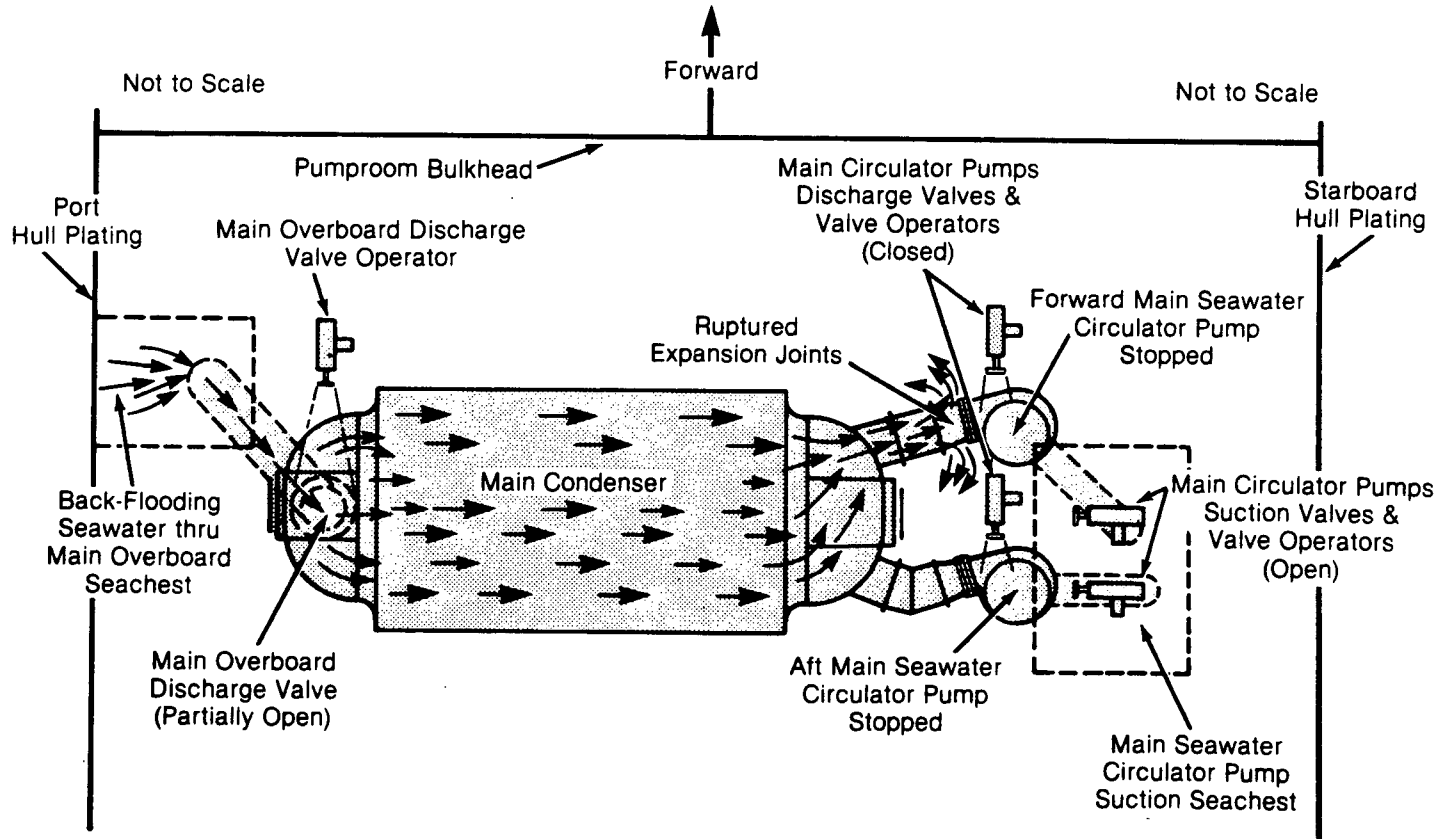


Figure 6b.--Backflow of seawater through the main seawater circulator after the main circulator pumps discharge valves were closed and the main seawater overboard discharge valve was partially open.

Figure 6.—Plan view of the main seawater circulating system.

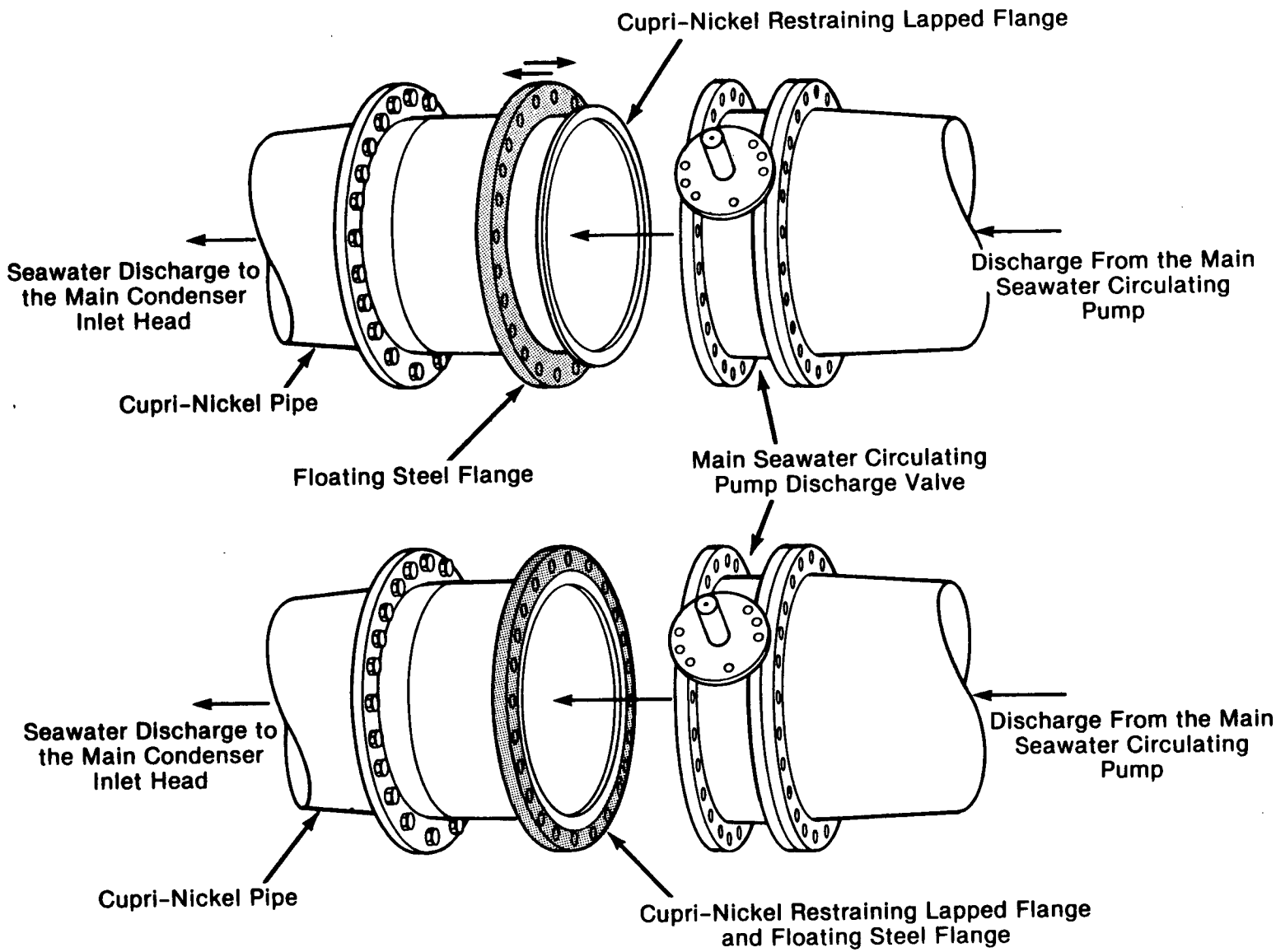


Figure 7.—Cupri nicked pipe with lapped flange.

pump when the level in the drain well reached 6 inches below the tanktop; the switch automatically stopped the bilge pump when the level dropped to 27 inches below the tanktop. There are a number of reasons for the activation of the bilge high level alarm: water fills the aft drain well and the automatic bilge pump (either mechanically or electrically) fails; water fills the aft drain well faster then it can be removed by the automatic bilge pump; the automatic bilge pump suction and/or discharge valves are not open; or debris blocks the bilge pump suction piping, allowing the water level in the bilge well to rise and activate the alarm. Coast Guard Navigation and Inspection Circulars (NVIC) I-69 and 6-84 require a bilge high level alarm sensor to be installed in the engineroom; however, there is no requirement for the installation location, or the number of bilge high water level alarm sensors.

According to the vessel plans, four other drain wells with pump suctions were located in the machinery space; none were equipped with a high level alarm sensor or a switch to automatically start a bilge pump. Two drains wells, each 18 inches deep with 23-inch-diameter circular openings in the tanktop were located in the forward end of the machinery space: one about 14 feet off the centerline to starboard and 4 feet aft of the engineroom forward bulkhead between frames 49 and 48, and the other about 11 feet off the centerline to port and about 1.5 feet aft of the engineroom forward bulkhead between frames 50 and 49. Two mid-engineroom bilge drain wells were located about 44 feet aft of the engineroom forward bulkhead between frames 34 and 35; each was about 12 feet off the centerline, one to port and the other to starboard.

Two transverse frames were located forward of the after drain well at frames 28 and 34. These frames provided support for the main thrust bearing for the propeller shaft at frame 28 and support for the main steam propulsion turbine reduction gear at frame 34. Although both frames had 3-inch-diameter drain holes at the bottom, each could act as partial bulkheads and restrict the free flow of large quantities of bilge water to the drain wells. Frames 34 and 28 were each 7 feet 6 inches high and extended from the hull on the port side to the hull on the starboard side in the engineroom.

Expansion Joints.--Rubber expansion joints used in marine installations are designed to provide for lineal expansion and contractions in the piping system caused by temperature changes, insulation of the piping system from vibration, compensation for movement caused in a seaway, and reduction of the danger of electrolysis in the piping system. Fourteen expansion joints of various sizes were installed throughout the machinery space of the PRINCE WILLIAM SOUND. Two 36- x 28- x 18-inch tapered, nonmetallic, flexible expansion joints, specification type E-103 were installed in the main seawater circulating system during vessel construction.

The ruptured expansion joint, serial No. 46705, was manufactured by the Goodall Rubber Company of Trenton, New Jersey, in January 1974. The type E-103 expansion joint was a standard service, spool-type, single arch, concentric tapered rubber expansion joint. The inside diameter (I.D.) of the expansion joint measured 36 inches at the inboard end nearest the main condenser, and it tapered to 28 inches in diameter at the outlet side of the forward main seawater circulating pump discharge valve. The face-to-face dimension of the expansion joint was 18 inches. The joint was manufactured with a red neoprene cover over a black neoprene tube with a center carcass of multiple layers of cotton fabric for strength and one layer of steel bead wire mesh for reinforcement.

According to the Goodall Rubber Company's (Goodall) specification sheet, dated March 27, 1974, the expansion joint was designed for a maximum allowable working pressure of 35 pounds per square inch gauge (psig), a vacuum of up to 29 in.Hg, and a

maximum temperature of 180° F. Maximum allowable movements were 15/16 inch for compression, 1/2 inch for elongation, and 1/2 inch for eccentricity. Goodall's allowances for angular movement was 3° for a 28-inch I.D. expansion joint and 2° for a 36-inch I.D. expansion joint. Allowable torsional movement of sizes 22 to 120 inch I.D. spool type expansion joints was 1°. The recommended hydrostatic test pressure was 1.5 times maximum allowable working pressure. The PRINCE WILLIAM SOUND main seawater circulating pump discharge pressure was about 9 psig when the tankship was fully loaded and 6 psig when in a light load condition.

Vessel Maintenance

The records of the prior and current vessel operators, the Goodall Rubber Company, the Coast Guard, and the ABS indicated that the maintenance, repairs, and inspections discussed below were made to the main seawater circulating system.

Trinidad.—On February 24, 1977, the vessel received a Coast Guard Mid-period Inspection of Hull and Machinery and an ABS Annual Hull, Machinery and Load Line Surveys at Sun Shipbuilding and Drydock Company. The ABS surveyors stated in ABS Survey Report No. PA3526 that:

> A general examination was made of the main and auxiliary machinery, anchor windlass and fire extinguishing apparatus and all found satisfactory.

The ABS survey did not comment on expansion joints and it did not cite the vessel for any deficiencies. The Coast Guard reports did not cite any deficiencies.

On July 17, 1977, the vessel chief engineer submitted to Trinidad a request for a spare 36- x 28- x 18-inch nonmetallic expansion joint for the vessel. The spare part request did not contain any information concerning the condition of the existing expansion joint to be replaced, and the request was denied.

On April 9, 1979, the vessel underwent an Annual ABS Classification Survey of Hull and Machinery while it was berthed at San Francisco, California. The ABS surveyor reported:

> A general examination was made of the main and auxiliary machinery, nonmetallic expansion pieces in the salt water circulating system, boilers, steering engine, port and starboard windlasses and all are apparently in satisfactory condition.

From August 23 to October 2, 1979, the PRINCE WILLIAM SOUND was drydocked in Dillingham Shipyard, Portland, Oregon, for voyage repairs, a Coast Guard Bienniel Inspection for Recertification, and an ABS Special Survey No. 1 of Hull and Machinery. In report No. WFH/1001, dated September 30, 1979, the Trinidad port engineer stated:

> Noticed what appeared to be new cracks in forward main circulator discharge expansion joint, approx. 3-5" long, 1/2" deep (the joint is 1" thick).

The report was distributed to a list of persons at the Trinidad company office, including the director of engineering. However, there was no attempt at the time to replace the forward main seawater circulating pump discharge expansion joint.

The director of engineering held the position of senior port engineer from 1976 to June 30, 1981, and from October 1982 to 1983. He said that as port engineer he routinely examined numerous expansion joints when he inspected ships, including the PRINCE WILLIAM SOUND. He stated that to inspect an expansion joint:

> I used a sharp rigid instrument such as a thin small blade screw driver to probe any visual cracks to determine if they were surface cracks or of a greater depth. I would have looked for any distortion, bulge or sagging of material that might indicate water penetrating the material of the joints. I would have checked for [piping] misalignment if misalignment was visible.

Coast Guard marine inspectors and an ABS surveyor inspected the tankship at various times during the August 23 to October 2, 1979, drydocking. The Coast Guard inspectors did not indicate the existence of any problems concerning the condition or the need to replace the forward main seawater circulating pump discharge expansion joint. In ABS Survey Report No. P04796, dated October 2, 1979, the ABS surveyors stated:

> The nonmetallic flexible expansion pieces in the main circulating system were examined internally and externally and found to be in satisfactory condition.

On November 8, 1979, after the PRINCE WILLIAM SOUND departed Dillingham Shipyard, the tankship chief engineer submitted the following request for repairs/renewals to Trinidad management:

> Renew For'd (sic) and Aft Main Circulator Discharge reducing spool Rubber pieces [expansion joints] between Main Circulator pumps, Fwd. and Aft Pumps and Main condenser: Both spool pieces completely rotten and cracked all around outside surfaces.

Between September 11-21, 1981, the vessel received an underwater (hull) survey in lieu of a drydocking and a biennial inspection to renew the 2-year Coast Guard Certificate of Inspection. ABS surveyors also were aboard to inspect miscellaneous repairs. No comments concerning the expansion joints were made in the reports of inspection. Drydocking of the vessel was deferred until the next shipyard overhaul, March 31, 1982.

In Trinidad's Addendum No. 4 to the shipyard repair specifications for the PRINCE WILLIAM SOUND, dated February 1, 1982, item 142, FORWARD AND AFTER MAIN CIRCULATOR EXPANSION JOINTS, directed the shipyard to:

> Remove the (2) main circulator reducer-type expansion joints from discharge side of injection piping and check piping for misalignment. Report findings to Port Engineer. When directed install owner furnished replacements.

A request from the vessel alternate chief engineer for Repairs/Renewals (RR 136/81), dated February 9, 1982, stated:

> Fwd & Aft Main Circulator Discharge spool pieces (expansion). Failed to check these before this; remaining non-metallic expansion joints apparently satisfactory. But these two are bad-Alignment must be out.

The request also contained the instructions to "check alignment of piping, report any misalignment and best method of correcting. When directed, install new owner furnished expansion joints."

In a memorandum dated February 11, 1982, to the vice president of engineering at Trinidad, the vessel's chief engineer noted, regarding RR 136/81, that the main seawater circulating pump's discharge expansion joints should have been checked earlier. "THESE TWO ARE MUST DO. Don't believe Coast Guard/ABS can miss these, but couldn't sleep nights if they miss and not done."

The Trinidad director of engineering said he felt sure that "the Coast Guard and/or ABS inspected the existing joints," although he did not recall whether or not there were any comments. He assumed, "they did not overlook the condition of the joints during past inspections and would also assume that they were considered to be suitable for continued use when these inspections [before April 1982] were made."

A Bidder's Survey for vessel repairs was conducted on February 19, 1982. The following note was made on a Trinidad report as a result of the survey: "Expansion joint AFT main circulator is cracked circumferentially for about 1/2 the circumference just off flange and crack at present is 1/2" deep."

On March 8, 1982, Trinidad sent Goodall an "URGENT" order for two new main seawater circulating pump discharge expansion joints. The PRINCE WILLIAM SOUND arrived in the Dillingham Shipyard in Portland on April 4, 1982, for a shipyard overhaul and inspections by the Coast Guard and the ABS. The two expansion joints were fabricated by Goodall and were shipped via air freight to the shipyard. The first new expansion joint was delivered about April 20, 1982, and was installed on the aft main seawater circulating pump discharge.

About April 16, 1982, the forward and aft expansion joints, which were removed from the discharge side of the two main seawater circulating pumps, were sent to Griffith Rubber Mills in Portland. The Sales Order Memorandum accompanying the expansion joints contained the following information:

> Delivery date: "4/20/82 PM Sure. Repair Expansion joint 1700.00 24194DLN64 Take easiest joint of 2 to repair and fix-Return extra joint with repaired one."

The Trinidad port engineer who attended the vessel during this period said, "To the best of my knowledge the condition of one [original] joint was such that it was believed that it could be used with a repair being made and that I participated in the original decision to repair the forward expansion joint. This repair . . . was a vulcanized repair." One expansion joint was repaired and the other expansion joint was returned without being repaired. The repaired expansion joint was delivered to the vessel on April 21. The port engineer stated, "A new joint was installed in the aft pump and we installed it [the repaired joint] in the forward pump." The port engineer and representative of the (rubber) repair company said that they considered the repair of the existing forward main seawater circulating pump discharge expansion joint to be excellent and quite satisfactory for continued service.

The port engineer further stated, "It is possible that since we repaired one joint either the second expansion joint was not delivered, or we thought it would not arrive in time to meet the vessel departure schedule." The second fabricated expansion joint was

delivered to the vessel on April 28, 1982; it was stored in its crate in the vessel spare parts storeroom. The port engineer stated, "The decision not to install the new joint in the discharge of the forward main seawater circulating pump after it was received on the vessel would have been jointly made by the vessel's chief engineer, the port engineer, and Trinidad's vice president of engineering. This decision would not have been reported to ABS or Coast Guard."

According to the director of engineering at Trinidad, "It was contemplated that the forward repaired joint would be replaced at the next convenient opportunity and a replacement joint was placed onboard for this purpose."

Safety Board investigators did not uncover any records to indicate if a check for pipe misalignment was made. The director of engineering said that, although the expansion joint was repaired, it was Trinidad's policy that, "expansion joints, as all other components, were renewed when considered necessary in accordance with good marine practice." He also stated, however, that, [before this incident] he was not aware of Trinidad ever using a repaired expansion joint.

The Coast Guard and the ABS were furnished copies of all shipyard repair specifications and shipyard work orders and made the inspections of the work aboard the vessel. In reviewing the 1982 Dillingham Shipyard repair specifications for the PRINCE WILLIAM SOUND, Trinidad Corporation found a specification for the renewal of both the forward and aft main seawater circulating pump discharge expansion joints. However, there was no record in the shipyard repair work specifications of the repair of the forward expansion joint, and there was no Coast Guard or ABS record concerning the expansion joint repair.

Sun.—In mid 1983, Sun's manager of ship repair and maintenance conducted a 1-week inspection aboard the PRINCE WILLIAM SOUND before the vessel operation was transferred from Trinidad to Sun. Sun's manager of ship repair and maintenance examined all the machinery in the engineroom and particularly the expansion joints. He stated that he had the misfortune of being a crewmember on another vessel which had suffered an expansion joint failure and that he made a particular point of looking at the expansion joints on the PRINCE WILLIAM SOUND. His recollection of the visual examination of the exterior of all the expansion joints, including the one on the discharge side of the forward main seawater circulating pump, showed the expansion joints to be in satisfactory condition. Also, he advised that at no time did he or anyone on his staff receive any information from Trinidad regarding any repairs to the expansion joint on the forward main seawater circulating pump, or that the expansion joint had been scheduled for replacement. He did not prepare a written report of the 1-week inspection.

On August 27, 1983, a new Sun crew boarded the vessel. They conducted a detailed inspection of the vessel to determine its condition. Nothing unusual was noted about the expansion joints.

In April 1984, the PRINCE WILLIAM SOUND arrived at Portland for a layup (inactive) period. During this time, Sun's ship repair superintendent conducted an inspection of the vessel in order to write detailed repair specifications. He stated that his inspection included: a visual examination of the expansion joint nuts and bolts for corrosion, a visual check of the outer casing for cracks or deterioration from oil or chemical contact; and feeling the expansion joints for hollow spots, bubbles, or mechanical damage. He stated that the two discharge expansion joints for the main seawater circulating pumps "appeared to be new."

Between September and November 1984, the vessel was drydocked at Mitsubishi Koygan Shuzan Shipyard, Nagasaki, Japan, for overhaul and repairs and inspections by ABS and Coast Guard marine inspectors. The motors and the discharge valves, of each of the two main seawater circulating pumps were removed and taken to shipyard shops for overhaul. The manhole covers were removed from the inlet and outlet heads of the main condenser for access to conduct an interior inspection of the main condenser tube sheets, tubes, piping, and associated expansion joints.

During the ABS Special Survey No. 2 of the vessel hull and machinery, the ABS senior surveyor climbed inside the main condenser outlet head and examined the interior of the 36-inch-diameter main seawater overboard discharge expansion joint. He also climbed into the main condenser inlet head and crawled through the pipelines and examined the interior of the forward and aft main seawater circulating pump discharge expansion joints. The ABS senior surveyor also examined the exterior of the expansion joints and found them to be satisfactory for continued use.

Two Coast Guard marine inspectors conducted a Biennial Inspection for Certification and examined the underwater hull during this shipyard period. The forward and aft main seawater circulating pump discharge expansion joints were also examined. One inspector and an engineering officer from the PRINCE WILLIAM SOUND examined the expansion joints externally; the other inspector examined them internally. They concluded that the expansion joints were in satisfactory condition and that they did not need to be replaced.

The Coast Guard inspectors, the ABS surveyor, and the Sun repair superintendent did not have any knowledge of the history of the expansion joints, and they were not able to discern that the forward main seawater circulating pump discharge expansion joint had been repaired.

In 1985, the PRINCE WILLIAM SOUND was drydocked at the Dillingham Shipyard for repairs to the main reduction gear, a Coast Guard mid-period inspection, and ABS required Annual Surveys of Hull, Machinery, Loadline, and the Inert Gas System. The surveyor stated that "the main and auxiliary machinery installations were generally examined as far as could be seen and found in satisfactory condition."

Test and Research

On October 7, 1986, investigators from the Safety Board and representatives from Sun, Goodall, the ABS, and the Coast Guard examined the ruptured forward main seawater circulating pump discharge expansion joint. The examination was conducted at Laboratory Testing, Inc., Dublin, Pennsylvania.

The initial visual examination of the ruptured expansion joint confirmed that the forward main seawater circulating pump discharge expansion joint had been repaired before it ruptured on May 9, 1986. The repair to the joint totally obscured the material condition of the original outer cover of red neoprene rubber, which was covered by a layer of black neoprene rubber at the time of the repair. Extensive color photography and a radiographic examination revealed cracks and/or tears in the area where the repairs had been made. The arch of the expansion joint was "opened up" or stretched beyond original design specifications. In the area of the rupture, the carbon steel bead wire mesh had corroded and was partly missing and the cotton duck fabric of the carcass had rotted. Layers of the expansion joint had delaminated in the area of the rupture. A cut was found inside the large 36-inch-diameter flange area at the edge of the tube.

Meteorological Information

The deck logbook of the PRINCE WILLIAM SOUND indicated that at 2400 on May 8, 1986, the winds were northeast, force 3 (gentle breeze 7 to 10 knots), with small northwesterly sea and swell. The sky was clear with good visibility. The barometer was rising slowly and was 29.80 in.Hg; the air temperature was 76° F, and the sea temperature was 75° F.

Statutory and Regulatory Information

When the forward main seawater circulating pump discharge expansion joint was repaired in April 1982, Trinidad Corporation failed to notify the Coast Guard of its intention to repair the expansion joint. Title 46 of the Code of Federal Regulations (CFR) Subchapter D-Tank Vessels, Section 30.01-10, states:

> When minor alterations or minor repairs of tank vessels become necessary such work shall be under the direction of the Officer in Charge, Marine inspection, and shall be in accordance with the regulations in effect at the time the vessel was contracted for or built, or in accordance with the regulations in effect for new construction insofar as possible.

From September 1979 to February 1982, reports from Trinidad port engineers and chief engineers of the PRINCE WILLIAM SOUND to Trinidad management described the deteriorated condition of the forward main seawater circulating pump discharge expansion joint and requested replacement with a new expansion joint. During the Coast Guard inspections that were conducted from September 1979 to February 1982, neither the vessel engineers nor the Trinidad port engineers reported to the Coast Guard the deteriorated condition of the forward main seawater circulating pump discharge expansion joint.

Title 46 of the United States Code, Chapter 11, Section 234, Officers to assist in examinations: dismissal of official disclosing source of information, states:

> All officers licensed under the provisions of sections 214, 224, 226, 228, 229, and 230 of this title shall assist the Coast Guard in its examination of any vessels to which such licensed officers belong and shall point out all defects and imperfections known to them in the hull, equipment, boilers, or machinery of such vessel, and shall also make known to the Coast Guard at the earliest opportunity all accidents or occurrences producing serious injury to the vessel, her equipment, boilers, or machinery, and in default thereof the license of any such officer neglecting or refusing shall be suspended or revoked.
>
> No Coast Guard official receiving information from a licensed officer who is employed on any vessel as to defects in such vessel, or her equipment, boilers, or machinery, or that any provisions of title 52 of the Revised Statutes is being violated, shall impart the name of such licensed officer, or the source of his information to any person other than his superiors in the Coast Guard. Any Coast Guard official violating this provision shall be subject to dismissal from the service.

Manufacturer's Affidavit System.—According to the Coast Guard, the purpose of the Manufacturer's Affidavit System is to identify the companies who manufacture certain types of approved or certified valves, fittings, and flanges used aboard vessels subject to Coast Guard inspection. Title 46 CFR Chapter I requires that miscellaneous equipment, such as valves, fittings, and flanges meet certain pressure and temperature classification requirements of Subchapter F, Part 50, Marine Engineering Regulations. Goodall's nonmetallic expansion joints were certified under the Coast Guard Manufacturer's Affidavit System. The Coast Guard, in granting this certification, relies on the manufacturer's integrity to comply with these requirements on a continuing basis. Products of an affidavited manufacturer must be reviewed by the Coast Guard as to their suitability for the intended service. Title 46 CFR Section 56.60-25(e) addresses the design features and tests of nonmetallic expansion joints including installation. (See appendix C.)

Coast Guard Inspection.—For recordkeeping purposes, Coast Guard marine inspectors use pocket-size vessel inspection notebooks which list specific items and systems to be inspected. Separate notebooks are used for hull, machinery, and drydock inspections. A small check-off box is provided in the inspection booklets for the marine inspector's initials to indicate that he has made the required inspection. None of the notebooks list expansion joints, and at present, there is no mandatory requirement for the internal inspection of expansion joints in the main seawater circulating system during drydock inspections.

Recognizing the effect of improved hullcoatings and propeller shaft stern tube sealing, the Coast Guard is presently working on a proposal to increase the interval between drydockings from 2 to 2 1/2 years for vessels operating in salt water This schedule will coincide with the current ABS requirement of drydocking vessels for survey every 2 1/2 years.

In accordance with Coast Guard Commandant's Instruction 5941.18B, Inspection and Testing of Control and Safety Systems on Vessels with Automated Boilers and Propulsion Machinery, and Navigation and Inspection Circular (NVIC) No. 1-69, Automated Main and Auxiliary Machinery, the automated boiler management and the bridge and engineroom control systems on the PRINCE WILLIAM SOUND were installed and tested per plans and procedures approved by the Coast Guard. Sea trials for the PRINCE WILLIAM SOUND were conducted December 15-18, 1975, at which time the tankship was subjected to various speed changes and loads. Both bridge and engineroom throttle controls were used.

Other Information

On June 16, 1982, the engineroom of the U.S. tankship OGDEN WILLAMETTE flooded to about 6 feet below the main deck as it was proceeding in the Caribbean Sea about 50 nmi southeast of Jamaica. 2/ Rupture of the nonmetallic expansion joint in the suction piping to the main seawater circulating pumps was cited as a causal factor in the accident. As a result of the accident, the Coast Guard dispatched an urgent message to all Coast Guard marine inspectors to "take note of the condition of nonmetallic expansion joints during the course of routine inspection . . . ." (See appendix D.) In July 1985, the Coast Guard published a list of expansion joint problem areas and their associated causes in the Marine Safety Manual, Volume II, Material Inspection. (See appendix E.)

2 Marine Accident Report—"Engineroom Flooding and Near Foundering of U.S. Tankship OGDEN WILLAMETTE, Caribbean Sea, June 16, 1982" (NTSB/MAR-83/06).

In response to the accident, the ABS issued a Circular of Instructions to all surveyors. The circular emphasized the importance of careful examination of the rubber expansion joints in seawater [pipe] lines and provided guidelines for the renewal of the expansion joint when that joint is 8 to 10-years old. (See appendix F.) Additionally, the ABS inserted into its Rules more specific information concerning the installation and the plan approval of nonmetallic expansion joints. (See appendix G.) Also, the ABS amended its Rules in Part 45, Surveys after Constructions, to include a requirement for the internal and external examinations of nonmetallic expansion joints at every drydocking, which would increase the frequency of such examinations from 5 to 2 1/2 years.

ANALYSIS

The Accident

A flexible, nonmetallic expansion joint installed in the discharge pipeline of the forward main seawater circulating pump, between the pump discharge valve and the main condenser, ruptured along the bottom half of its circumference. Because of the configuration of the vessel plant, the rupture in the expansion joint allowed seawater in the main seawater circulating system to enter the engineroom bilges from three sea sources: the two main seawater circulating pump inlet seachest connections and the main seawater circulating system overboard discharge seachest connection.

When the expansion joint ruptured, both the forward and aft main seawater circulating pumps were supplying cooling seawater to the main condenser. While the two main seawater circulating pumps continued to operate, with their suction and discharge valves open, pressurized seawater flowed through the rupture in the expansion joint and into the machinery space bilge from the discharges of the forward main seawater circulating pump and from the after main seawater circulating pump through the main condenser inlet waterbox.

As the flooding seawater accumulated in the engineroom bilge, transverse steel frames 28 and 34 and longitudinal steel plating in the engineroom bilge appear to have functioned as partial bulkheads. Transverse frame 34 was 7 feet 6 inches high and extended from the engineroom starboard hull plating to the port hull plating. Although 3-inch drain holes were located in the bottom of the plating, the transverse frame acted as a weir and restricted the flow of seawater moving aft. Transverse frame 28, which was the same height as frame 34, also extended from the port to the starboard hull in the engineroom. As the section of the engineroom bilge forward of frame 34 was nearly filled with seawater, the bilge between frames 28 and 34 continued to fill. Longitudinal steel plating welded to the aft side of transverse frame 28 on the port and starboard sides of the propeller shaft formed a barrier around the bilge high level sensor located at frame 20. The bilge high level alarm did not activate immediately. Flooding seawater in the engineroom rose 5 feet above the tanktop plating to the level of the two main condensate pump electric motors, causing the electric motors to stop.

The failure of the main condensate pumps allowed the condensate level to fall in the boiler feedwater heater and to rise in the main condenser which actuated alarms for each unit, the first indication of a problem in the engineroom. However, there was no indication that the flooding of the lower engineroom caused the main condensate pump to shut down. Consequently, while the engineering watch and the chief engineer were taking corrective actions to keep the steam plant functioning, no one was aware that seawater was flooding into the lower engineroom. Both the first and second alarms were indicative of steam system engineering problems that could be solved by the operation of a condensate pump.

The chief engineer's concerns at the time were to maintain vacuum in the main condenser, to keep feedwater (condensate) in the boilers, and to keep the steam turbine electric generators operating. Had the chief engineer directed someone to investigate the reason the bilge alarm activated, the engineroom flooding may have been discovered in sufficient time to permit the closure of the sea valves electrically, using the controls at the main console. Clearly, the single bilge high level alarm sensor at one end of a 95-foot-long engineroom bilge did not provide any redundancy to alert the engineering watch early of the flooding condition. Therefore, the Safety Board believes there should be a requirement for multiple bilge high level alarm sensors installed in various locations in engineroom bilges.

The rapidly flooding seawater also shorted out the electric motors, which operated the bilge pumps, and the valves in the main seawater circulating system. Once the flooding was discovered, the 28-inch-diameter discharge valves on the forward and aft main seawater circulating pumps were closed manually by order of the chief engineer. The closure of the pump discharge valves isolated the engineroom from two of the three main seawater circulating system sea connections and eliminated two possible sources of the flooding. At the same time, the chief engineer should have directed someone to close the 36-inch-diameter main seawater overboard discharge valve to completely isolate the main seawater circulating system and the engineroom from the sea. Instead, the chief engineer directed the first assistant engineer to open the emergency bilge pump valves so that the emergency bilge pump could be started. Seawater continued to back-flow through the open main seawater overboard discharge valve and through the main condenser to the ruptured expansion joint.

The chief engineer should have known that sudden and rapid flooding of the engineroom is normally the result of one of two possibilities: a breach of the hull in the engineroom area or a failure in the main seawater circulating system. Isolating the main seawater circulating system from the sea by closing the main sea valves would have indicated to the chief engineer which problem existed. The chief engineer should have instructed someone to close the valves in the main seawater circulating system because it was the most likely method of controlling the seawater flooding in the engineroom. If all three valves had been closed immediately, the flooding in the engineroom would have ceased, precluding additional damage to the engineroom equipment.

When the crew attempted to manually close the 36-inch-diameter main seawater circulating system overboard discharge valve, they were able to close only 75 percent of the overboard valve opening before the rising seawater level in the engineroom forced them to abandon their task. Had the valves in the main seawater circulating system been equipped with reach rods, the valves could have been closed from a higher, safer platform level. The time-consuming effort expended in diving into the flooding engineroom and closing the main seawater overboard discharge valve could have been avoided if reach rods had been installed. The level of damage to the vessel would have been reduced and the risk of injury or death by drowning could have been avoided. Therefore, the Safety Board believes the Coast Guard and the ABS should require reach rods on valves in vital ships systems, such as the main seawater circulating system and the emergency bilge pumping system.

In attempting to pump out the seawater in the engineroom, the crew dived repeatedly into the flooded engineroom to open the emergency bilge pump suction valve which was located just above the tanktop. Also, a belated effort was made to close the main seawater overboard discharge valve when the valve handwheel was already 20 feet underwater. It is important the engineering personnel thoroughly understand the proper

procedures to follow in the event of engineroom flooding. The Safety Board believes that had procedures been established to combat various engineroom incidents, the engine department personnel would have been better prepared to react to the flooding situation.

Inspections, Maintenance, and Repairs

In February 1982, during a vessel survey conducted by Trinidad for competing shipyards bidding for the ship repair contract, the aft main seawater circulating pump discharge expansion joint was found to be cracked circumferentially. As a result, on March 8, 1982, an "URGENT" order was placed with Goodall for two new replacement expansion joints, one each for the discharge side of the forward and aft main seawater circulating pumps. Trinidad, the vessel operator at the time, had written a shipyard repair specification for the removal of the two existing main seawater circulating pump discharge expansion joints and the installation of two new expansion joints. When the first new expansion joint arrived in the shipyard, it was installed in the discharge pipeline of the aft main seawater circulating pump. However, because of the delayed arrival of the second new expansion joint, a need to conduct an operational test of the main boilers, or the vessel's scheduled cargo commitment, the existing forward main seawater circulating pump discharge expansion joint was repaired and reinstalled in the piping system. When the second new expansion joint arrived in the shipyard, it was placed, still in its shipping crate, into the vessel spare parts storeroom.

Trinidad's vice president of engineering said that he and representatives of the rubber repair company considered the repair of the forward expansion joint to be excellent and contemplated that the forward repaired joint would be replaced with the new expansion joint at the next convenient opportunity. However, 16 months after the installation of the repaired expansion joint, when the change in vessel operators occurred in August 1983, the repaired expansion joint was still in place in the discharge pipeline of the forward main seawater circulating pump. Further, there is no record that Trinidad informed the new operator, Sun, that the forward main seawater circulating pump discharge expansion joint had been repaired.

While the vessel was drydocked, in Nagasaki, Japan, from September to November 1984, two Coast Guard marine inspectors and an ABS surveyor inspected all the expansion joints in the main seawater circulating pipelines. Both main seawater circulating pumps were removed for overhaul, and the main condenser access was opened which allowed an internal, as well as an external, examination of the two main seawater circulating pump discharge expansion joints. The joints were found to be in satisfactory condition and replacement was not recommended. In fact, from the time of the repair of the expansion joint until the postaccident survey, no one who examined the expansion joints, including the Coast Guard inspectors, the ABS surveyors, the Sun port engineer, and the engineers on board the vessel, were aware of or recognized that the forward expansion joint had been repaired.

The vulcanized repair made to the forward main seawater circulating pump discharge expansion joint covered the original expansion joint material. This repair concealed the deteriorated condition of the underlying original expansion joint from the view of marine inspectors, surveyors, port engineers, and the ship engineers. Goodall does not recommend repairs to expansion joints that exceed one ply in depth. The company does market an expansion joint repair kit; however, repairs are confined to minor repairs to blemishes on the outer cover surface. Therefore, the Safety Board believes that the Coast Guard and the ABS should prohibit repairs to nonmetallic expansion joints installed in vital ship systems.

There is no evidence that the Coast Guard or the ABS, while conducting inspections and surveys during the period from November 1979 to April 1982, detected the deterioration of the forward and aft main seawater circulating pump discharge expansion joints.

At present, the ABS requires an internal and an external survey of expansion joints in the main seawater circulating system every 2 1/2 years during the mandatory ABS drydocking survey. The Coast Guard should have a similar mandatory requirement for those U.S. flag vessels not classed with ABS. Additionally, the Coast Guard should revise its drydock inspection booklet to include a check-off item for the external and internal inspections of expansion joints installed in the main seawater circulating system.

Both the ship engineering personnel and the Trinidad port engineers were aware of the deteriorated condition of the expansion joints, but they failed to relay this information to the Coast Guard as required in the Laws Governing Marine Inspection. Furthermore, one would expect that the chief engineers' and port engineers' descriptions of the deteriorated condition of the forward and aft main seawater circulating pump discharge expansion joints in their reports to Trinidad would have excluded any decision to repair the expansion joints. Nevertheless, Trinidad had the forward main seawater circulating pump discharge expansion joint repaired and reinstalled in the main seawater circulating system without requesting the approval or reporting the repair to the Coast Guard as required by Federal regulations.

Expansion Joint

The expansion joint which ruptured was installed during construction of the vessel. Records from Trinidad indicated that the deteriorated condition of the forward main seawater circulator pump discharge expansion joint was recognized in 1979 and continued until the joint was repaired in April 1982. Additionally, in February 1982, the companion joint on the aft main seawater circulating pump discharge showed signs of a similar deterioration. The Safety Board was unable to determine the service life of the type of expansion joints involved in this accident. The expansion joint manufacturer could not provide an average service life expectancy because followup studies have not been done and no studies have been performed in the nonmetallic expansion joint industry to compare the service life of similar expansion joints manufactured by other rubber expansion joint manufacturers.

Although studies had not been carried out to establish the average service life of such an expansion joint, exposure to some environmental factors (high temperature, humidity, and chemicals) that are found in steamship enginerooms are known to affect the service life of rubber materials. It is known that rubber undergoes auto-oxidation which is accelerated by light, ozone, humidity and high temperatures which leads to accelerated aging and cracking. Ozone is produced by operating electrical motors and other electrical devices found throughout the engineroom.

The service life of nonmetallic (rubber) expansion joints is also affected by stresses created by a nonuniform sealing surface (lapped flange face), eccentric and angular pipe misalignment, excessive axial separation (elongation), system pressure, and vibration magnitude and frequency. The pipe flange to which the 36-inch-diameter flange face of the forward main seawater circulator pump discharge expansion joint was attached consisted of a lapped flange. (See figure 7.) This lapped flange design created an uneven sealing surface which increased the stress in the corner between the expansion joint flange and the body of the expansion joint. Eccentric, angular, and axial piping misalignment was detected by the measurements of the face-to-face flange spacing

between the forward main seawater circulator pump discharge valve flange and the main condenser forward inlet piping flange. The angular and eccentric misalignment and elongation of the expansion joint which exceeded the manufacturers specified tolerances also increased the stresses on the expansion joint, particularly at the corner.

Based on the Trinidad port engineers' reports on vessel conditions, the vessel chief engineers' repair/replacement requisitions, and other Trinidad records, it is apparent that the forward main seawater circulator pump discharge expansion joint showed signs of deterioration as early as September 1979. At least part of this deterioration could be related to the misalignment (axial, angular, and eccentric) that exceeded the manufacturer's specifications tolerances. Vibrations and/or movement caused by pump vibrations may have further increased the deterioration and decreased the service life. In February 1982, a 1/2-inch-deep crack was found at the base of the flange about half way around the circumference of the 36-inch-diameter end of the aft main seawater circulator pump discharge expansion joint. The joint involved in this accident had an extensive crack at the base of the large flange in the failure area that could have initiated the failure.

Failure also could have occurred because seawater passing through the neoprene inner layer into the carcass of the expansion joint degraded the cotton duck reinforcement layers and corroded the reinforcing wire mesh inside the expansion joint. When and why this process started cannot be determined. However, this process would have required two steps, either of which could have occurred first. It is possible that leakage of seawater into the wire reinforcement area was followed by progressive corrosion of the wire and delamination, that is, leakage caused the delamination. Alternatively, seawater leaking into the reinforcement area may have occurred in one of the areas where excess rubber was trimmed during manufacture.

Although the Safety Board cannot determine the precise reason for the failure of the expansion joint, it is clear that the expansion joint should have been replaced and not repaired. Clearly these joints should be (as they are required to be) inspected periodically and replaced when their condition warrants replacement. However, the Safety Board believes that there should be a limit to the length of time they are allowed to remain in service even if there has been no apparent deterioration. Although data are not available to determine systematically the safe service life of nonmetallic expansion joints, representatives of the Coast Guard and the ABS have indicated to Safety Board investigators that a 10-year period is reasonable. A 10-year expansion joint replacement interval coincides with the current ABS required drydock survey schedule and the proposed Coast Guard drydock inspection schedule. Therefore, the Safety Board believes that a 10-year limit should be placed on the service life of nonmetallic expansion joints installed in vital ship systems.

A program of data collection on the service life of nonmetallic expansion joints in marine installations by the expansion joint manufacturer could help ultimately to confirm the replacement period or to form the basis for modification of this period.

CONCLUSIONS

Findings

1. Seawater flooded into the engineroom through the rupture of the forward main seawater circulating pump discharge expansion joint.

2. Flooding of the engineroom could have been reduced if the main condenser overboard discharge valve had been closed about the same time that the main circulator pump discharge valves were closed.

3. The rupture of the forward main seawater circulator pump discharge expansion joint could have been caused by exterior or interior deterioration, or both.

4. The observed "cracking" and "rotting" of the forward main seawater circulating pump discharge expansion joint may have been caused by exposure to any combination of, or all of, the following: heat, high humidity, ozone, uneven flange face, vibrations, excessive elongation, and flange misalignment.

5. Saltwater penetrated the carcus (interior) of the expansion joint and caused extensive deterioration of the cotton duck fabric reinforcement and extensive corrosion of the the carbon steel wire mesh reinforcement in the area of the expansion joint rupture.

6. The vulcanized repair to the forward main seawater circulator pump discharge expansion joint in April 1982 effectively obscured the condition of the expansion joint material during the inspections and surveys that took place in 1983-85.

7. Trinidad Corporation should have replaced rather than repaired the deteriorated nonmetallic expansion joint for the vital main seawater system.

8. The steel structure of the engineroom bilge which formed the longitudinal and transverse foundations of the main propulsion steam turbines, reduction gears, and thrust bearing restricted the free flow of seawater in the engineroom bilge from activating the single bilge high level alarm in a timely fashion.

9. Additional bilge high level alarm sensors appropriately located in the forward engineroom bilges could have given an earlier warning to the engineroom crew in time to minimize the flooding in the engineroom.

10. Reach rods installed on vital sea valves would have minimized the flooding in the engineroom and would have enabled the crew to close those valves from a higher, safer platform level.

11. The inspections and surveys during 1979, 1980, and 1981 by the Coast Guard and the ABS failed to detect the deterioration of the forward main circulator pump discharge expansion joint and the companion joint in the aft pump.

12. There is no evidence to indicate that the 1983-1985 Coast Guard inspections and ABS surveys of the PRINCE WILLIAM SOUND were not performed in accordance with the existing standards.

13. Regulatory requirements and classification society rules should prohibit major repairs to nonmetallic expansion joints installed in vital seawater systems.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the flooding of the engineroom of the PRINCE WILLIAM SOUND was Trinidad Corporation's failure to replace a deteriorated nonmetallic (rubber) expansion joint in the main seawater

circulating system as requested on several occasions by the vessel engineering personnel. Contributing to the magnitude of the flooding and the severity of the damage was the design of the bilge alarm system which failed to provide early warning of the flooding. Also contributing to the magnitude of the flooding and the severity of the damage was the failure of the chief engineer to close the main seawater overboard discharge valve upon learning of the flooding.

RECOMMENDATIONS

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

—to the U.S. Coast Guard:

Require that expansion joints in the main seawater circulating system be replaced at least once every 10 years, and require that the date of manufacture and the serial number be clearly and indelibly affixed to the nonmetallic expansion joint. (Class II, Priority Action) (M-87-84)

Require a complete internal and external examination of nonmetallic expansion joints installed in the main seawater circulating system during drydock inspections. (Class II, Priority Action) (M-87-85)

Require on vessels of 500 gross tons and more that multiple bilge high level sensors be installed in various locations in the engineroom bilge to provide the redundant coverage necessary to detect flooding at an early stage. (Class II, Priority Action) (M-87-86)

Require on vessels of 500 gross tons and more that reach rods for remote manual control of valves be installed in the vital main seawater circulating system and the emergency bilge pumping system. (Class II, Priority Action) (M-87-87)

Revise the Drydock Inspection Booklet to include a check-off for external and internal inspections of nonmetallic expansion joints in the main seawater circulating system. (Class II, Priority Action) (M-87-88)

Establish regulatory requirements which prohibit major repairs to nonmetallic expansion joints installed in the main seawater circulating system. (Class II, Priority Action) (M-87-89)

—to the American Bureau of Shipping:

Require that expansion joints in the main seawater circulating system be replaced at least once every 10 years, and require the date of manufacture and serial number be clearly and indelibly affixed to the nonmetallic expansion joint. (Class II, Priority Action) (M-87-90)

Require on vessels of 500 gross tons and more the installation of multiple bilge high level sensors in the engineroom bilge to provide the redundant coverage necessary to detect flooding at an early stage. (Class II, Priority Action) (M-87-91)

Establish rules which prohibit major repairs to nonmetallic expansion joints installed in the main seawater circulating system. (Class II, Priority Action) (M-87-92)

Require on vessels of 500 gross tons and more that reach rods for remote manual control of valves be installed in the vital main seawater circulating system and the emergency bilge pumping system. (Class II, Priority Action) (M-87-93)

—to Sun Refining and Marketing Company:

Establish written emergency procedures for engine department personnel to follow in the event of engineroom flooding. (Class II, Priority Action) (M-87-94)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOSEPH T. NALL
Member

/s/ JAMES L. KOLSTAD
Member

JOHN K. LAUBER, Member, did not participate.

September 15, 1987

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident on May 9, 1986. The Safety Board's on-scene investigation was conducted May 14-17, 1986.

The Sun Refining and Marketing Company, the Goodall Rubber Company, the American Bureau of Shipping, and the U. S. Coast Guard participated as parties to the investigation.

2. Depositions

Sworn testimony regarding this accident was taken on May 30, 1986, at Long Beach, California; on June 19, 1986, at Philadelphia, Pennsylvania; on September 8, 1986, at Yorktown, Virginia; and on September 11, 1986, at Washington, D.C.

APPENDIX B

PERSONNEL INFORMATION

Master Robert W. Mcknett, Jr.

Captain Robert McKnett, 57, received his masters license in 1969. He first went to sea in 1945, working as a cabin boy for 1 year followed by 4 years of service in the U. S. Navy. Following his discharge from the Navy in 1950, he began working for Sun as an able seaman. He was issued his third mate's license in 1960, and he was licensed to sail as master in 1969.

Chief Engineer Paul F. Allen

Mr. Paul Allen, 35, has been going to sea for about 14 years and has served as chief engineer on board the PRINCE WILLIAM SOUND since 1983. After graduating from the Maine Maritime Academy in 1972, he was hired by Sun in the position of third assistant engineer. In 1980, he was issued a Coast Guard license as chief engineer of steam vessels of unlimited horsepower.

First Assistant Engineer Edward R. Riemenschneider

Mr. Edward Riemenschneider, 33, has been going to sea as an engineer for 12 years. He currently holds a Coast Guard license as chief engineer of steam vessels of unlimited horsepower. He had served as first assistant engineer on board the PRINCE WILLIAM SOUND since January 1984. He began his employment with Sun as a third assistant engineer, following his graduation from Fort Schuyler Maritime Academy in 1974.

Second Assistant Engineer William Shaw

Mr. William Shaw, 59, has been going to sea for 38 years and has served as second assistant engineer for the past 11 years on board various vessels operated by Sun. He had a total of 3.3 months sailing time on board the PRINCE WILLIAM SOUND and had been on board the tankship for 23 days before the accident. Mr. Shaw was hired by Sun in 1966 and during the past 20 years, he has served on board various vessels operated by the company.

Second Mate Stephen G. Fuccillo

Mr. Stephen Fuccillo, 30, holds a Coast Guard license as second mate of oceangoing vessels of unlimited gross tons. He began his employment with Sun after graduating from the Maine Maritime Academy in 1977.

Oiler Umar Yakub Zafar Ahmad

Umar Yakub Zafar Ahmad, 31, received his oiler sailing document from the Coast Guard in 1979 and had sailed as oiler on various Sun operated tankship. He signed on board the PRINCE WILLIAM SOUND on March 10, 1986, about 60 days before the accident.

APPENDIX C

46 CFR PART 56.60-25(e)

U.S. COAST GUARD INSTALLATION REQUIREMENTS FOR NONMETALLIC EXPANSION JOINT

(c) *Nonmetallic flexible hose.* (1) The installation requirements for nonmetallic flexible hose shall be as specified in Table 56.60-25(c).

TABLE 56.60-25(c)—INSTALLATION REQUIREMENTS FOR NONMETALLIC FLEXIBLE HOSE

Type of service	Maximum service pressure (p.s.i.)	Type cover required	Required hose reinforcement	Where permitted
Vital fresh and salt water	150	Self-extinguishing [1]	Wire or polyester	[2] [3]
Nonvital fresh and salt water	150	do [1]	do	[3]
Nonvital water and pneumatic	50	do [1]	None	[3]
Do	150	do [1]	Fiber	[3]
Lube oil and fuel systems		do [1] [4]	Wire	For flexibility only [5]
Fluid power systems		do [1]	Wire or polyester	[3]

[1] The hose cover shall be judged self-extinguishing by test method ASTM D 1692.
[2] May be used in duplicate installations in accordance with § 56.60-25(b) for plastic pipe or in reasonable lengths where flexibility is required at pressures not exceeding manufacturer's rating subject to the limitations of § 56.60-25(a) (1) through (6) for plastic pipe.
[3] Casualty control systems, such as firefighting and bilge systems, may utilize a flexible connection only if the pump is flexibly supported and the flexible connection is located directly at the pump.
[4] May be used subject to the limitations of § 56.60-25(a) (1) through (6) for plastic pipe.
[5] The hose assembly shall be capable of withstanding free burning gasoline for 2½ minutes test obtain available from the Coast Guard (MVT).
[6] May only be used in reasonable lengths for the purpose of flexibility at pressures not exceeding manufacturer's rating.
[7] See § 56.30-20 of this subchapter for installations permitted.

(2) Wire reinforced nonmetallic flexible hose shall be fabricated with an inner tube and a cover of synthetic rubber or other suitable material reinforced with wire or polyester braid.

(3) The innertube for nonmetallic flexible hose shall be of seamless construction, uniform gage and shall be compatible with the substances carried therein.

(4) Flexible hose assemblies shall be designed for a bursting pressure of not less than 4 times the maximum working pressure of system in which it is to be installed.

(5) Hose shall be complete with factory-assembled and fittings requiring no further adjustment of the fittings on the hose, except that reusable type fittings may be used provided they are of a type whose design is approved by the Commandant. A hydrostatic test of hose assemblies shall be conducted in accordance with Subpart 56.97.

(6) Nonmetallic flexible hose shall be marked with the manufacturer's name or trademark, type or catalog number and maximum allowable working pressure.

(d) Plastic valves, fittings, and flanges may be used in systems employing plastic pipe. Such valves, fittings, and flanges shall be designed, fabricated, tested, and installed so as to satisfy the intent of the requirements for plastic pipe contained in this section.

(e) Short nonmetallic expansion joints may be used in vital and nonvital machinery sea connections inboard of the skin valve. Such joints shall be reinforced with wire braid, polyester or fibrous materials. The cover materials shall be judged self-extinguishing by test method ASTM D1692. Design shall provide a burst pressure of not less than four times the maximum allowable working (rated) pressure. These joints shall not be used to correct for improper piping workmanship or misalignment. Joint movements may not exceed the limits set by the joint manufacturer. Refer also to § 56.35-10.

(f) If it is desired to use nonmetallic materials other than those specified in this section, a request furnishing the chemical and physical properties of the material shall be submitted to the Commandant for consideration.

(5 U.S.C. 552; 14 U.S.C. 633)

[CGFR 68-82, 33 FR 18843, Dec. 18, 1968, as amended by CGFR 69-127, 35 FR 9976, June 17, 1970; CGD 72-104R, 37 FR 14234, July 18, 1972; CGD 72-206R, 38 FR 17229 June 29, 1973; CGD 73-254, 40 FR 40165, Sept. 2, 1975; CGD 78-108, 43 FR 46545, Oct. 10, 1978]

APPENDIX D

COAST GUARD INSPECTION MESSAGE

08 JUL 82

(5) FROM COMDT COGARD WASHINGTON DC

G-M
G-MVI
G-MTH
G-MP
G-MMI

(6) ACTION INFORMATION ADDEES (SINGLE SPACE)

TO AIG 8994

(7) (BEGIN TEXT ON LINE 10 DOUBLE SPACE ALL SUBJECTS IN SHORT ALPHA

UNCLAS //N16711//

FROM MVI

SUBJ: SS OGDEN WILLAMETTE, O.N. 518738, FAILURE OF MAIN SEA SUCTION EXPANSION JOINT

1. ON 16 JUNE 1982 THE SS OGDEN WILLAMETTE SUFFERED A FAILURE OF THE MAIN CONDENSER SEA SUCTION EXPANSION JOINT JUST INBOARD OF THE SEA VALVE. THIS FAILURE RESULTED IN THE COMPLETE FLOODING OF THE ENGINE ROOM AND VERY NEARLY THE LOSS OF THE VESSEL. ALTHOUGH IT APPEARS THAT THE CREW SECURED THE MAIN SEA SUCTION SEA VALVE, THE ENGINE ROOM CONTINUED TO TAKE ON WATER THROUGH AN OPEN AUXILLIARY MAIN CONDENSER OVERBOARD DISCHARGE VALVE.

2. DURING A RECENT ROUTINE INSPECTION OF ANOTHER VESSEL THE COAST GUARD INSPECTOR FOUND THAT THE SHIPYARD, WHILE MAKING REPAIRS TO MAIN CONDENSER PIPING, HAD ALTERED THE SPACE FOR THE EXPANSION JOINT FROM THE ORIGINAL 10" TO 11 1/2". THE EXPANSION JOINT WAS THEN ELONGATED DURING INSTALLATION IN ORDER TO FILL THE SPACE. 46 CFR 56.60-25E ADDRESSES NON-METALLIC EXPANSION JOINTS AND SPECIFICALLY PRECLUDES THEIR USE TO CORRECT ALIGNMENT PROBLEMS.

3. MARINE INSPECTION PERSONNEL SHOULD TAKE NOTE OF THE CONDITION OF NON-METALLIC EXPANSION JOINTS DURING THE COURSE OF ROUTINE INSPECTIONS KEEPING IN MIND THAT ALTHOUGH THESE JOINTS ARE INBOARD OF SEA VALVES, SERIOUS FLOODING MAY OCCUR BECAUSE OF THE INTER CONNECTION OF MANY OF THE SYSTEMS.

(8) DRAFTER NAME, TITLE, OFFICE

T. W. BOERGER, CDR, USCG
CHIEF, INSP. MP. BR. X61464

(10) RELEASING OFFICER NAME, TITLE, OFFICE

R. F. Butler
Capt, USCG
Chief, G-MVI

APPENDIX E

EXCERPT FROM MARINE SAFETY MANUAL, VOLUME II, CHAPTER 8, DRYDOCK INSPECTIONS

MARINE SAFETY MANUAL

8.G.3. Nonmetallic Expansion Joints. A recent casualty to a rubber expansion joint in the main low-sea suction intake of a vessel resulted in flooding of the engineroom and the near loss of the vessel. The life expectancies of nonmetallic expansion joints depend upon their applications and the surrounding environments. A complete internal examination should be made of nonmetallic expansion joints when external visual inspections reveal excessive wear or other signs of deterioration or damage. If an adequate external or internal examination cannot be conducted by the inspector, the expansion joint shall be removed for inspection. Following are various problem areas associated with rubber expansion joints, their probable causes, and recommended repairs:

a. Leaks At The Flange. Retaining ring splits should be as close together as possible, and flat steel washers should be used on the bolts over the splits. The bolts should be tightened uniformly by moving alternately around the flange from bolt to bolt, until the rubber on the joint flange bulges slightly and uniformly between the steel retaining ring and the piping flange.

b. Cracks At Base Of Arch Or Flange. These are caused by unexpected pipe movements that put excessive stress on the joint, most commonly from initial misalignment at the time of installation, excessive pipe movement, improper anchorage, or failure to use control rods. If such cracks are severe enough to interfere with the integrity of the joint, it must be replaced after the cause of the damage has been corrected.

c. Ballooned Or Otherwise Deformed Arches. These indicate interior displacement of reinforcing rings or wire, usually because of higher-than-recommended pressures. The joint must be replaced after all working conditions have been checked and proper recommendations made.

d. Loose Outer Body Fabric. A feeling of softness or looseness near the surface of the arch indicates a loss of adhesion between fabric plies. If plies have separated, the joint must be replaced.

e. Spongy Feeling Of The Joint Body. This is caused by moisture penetration and deterioration of the fabric, usually from loose bolts or deterioration of, or physical damage to, the bolt hole sealant. Operating conditions should be checked and the joint replaced.

f. Hardness And Cracking Of The Cover. This is caused by exposure to extreme heat, chemical fumes, ozone, and other elements in service conditions. The joint should be replaced after the cause has been determined and corrected.

g. Cuts And Gouges In The Cover. These are caused by careless handling or damage from tools. If the damage is no deeper than one ply, repairs may be made with a self-vulcanizing material.

APPENDIX F

ABS CIRCULAR OF INSTRUCTIONS

AMERICAN BUREAU OF SHIPPING
CIRCULAR OF INSTRUCTION

CIRCULAR NO. 380
INDEX NO. 6.2.1
DATE 10 November 195[illegible]

FROM New York Office

TO All Exclusive and Non-Exclusive Surveyors

SUBJECT RUBBER EXPANSION JOINTS

Gentlemen:

There have been several serious cases of engine room flooding recently due to failed non-metallic expansion joints. This is to emphasize therefore, the importance of careful inspection of rubber or other non-metallic expansion joints in sea water piping systems. Any failure of such flexible sections can result in very rapid flooding of the entire machinery space due to the relatively high head of water that may be involved, which in larger vessels may reach 80 ft or more.

Since the principal materials in these expansion joints are usually of organic origin such as rubber and cotton fibers, aging deterioration is inevitable and should be checked for at every drydocking. This deterioration may manifest itself first as a loss of external surface resilience then cracking; or alternatively, the arch of the bellows may become softened indicating loss of adhesion between the fabric plies. In either case, or if the expansion piece is more than 8 to 10 years old, renewal should be recommended. If it is not possible to determine the actual age, the expansion piece should be removed for close internal and external inspection. Failure may initiate either inside or outside, depending on the service conditions. Original misalignment or offset of the expansion section in the pipeline appears to significantly accelerate failure. Also, the greater the frequency or amplitude of the vibration or cyclic expansion and contraction of the piece, the more rapid the deterioration.

The Surveyor should particularly examine areas in corners or grooves where salts and other residues accumulate, also surfaces partially hidden from view such as under the rim of the bolting ring and on the underside.

The current Rules Section 45:11.2b require that the non-metallic expansion pieces in the main sea-water circulating system be internally and externally examined at the Special Survey drydocking, however all rubber expansion joints in seawater piping systems should be at least externally examined at every regular drydocking.

Very truly yours,

Louis V. Minett

LOUIS V. MINETT
Senior Vice President

APPENDIX G

ABS RULES CHANGE FOR APPROVAL OF EXPANSION JOINTS

AMERICAN BUREAU OF SHIPPING

February/83

SECTION 36 PUMPS AND PIPING SYSTEMS

36.9 General Installation Details

36.9.5 Non-metallic Expansion Joints

Molded expansion fittings of reinforced rubber or other suitable materials may be used in circulating water piping systems in machinery spaces. Such fittings are to be oil-resistant. The maximum working pressure is not to be greater than one-fourth of the hydrostatic bursting pressure of the fittings as determined by a prototype test. Plans of the molded or built-up flexible expansion joints in essential seawater piping systems over 150 mm (6 in.), including details of the internal reinforcement arrangements, are to be submitted for approval.

REASON: Engine room flooding casualties have been experienced due to failure of these rubber expansion pieces in main sea-water circulating lines. Subsequent examination has indicated the need to confirm that such pieces are properly shaped and internally reinforced.