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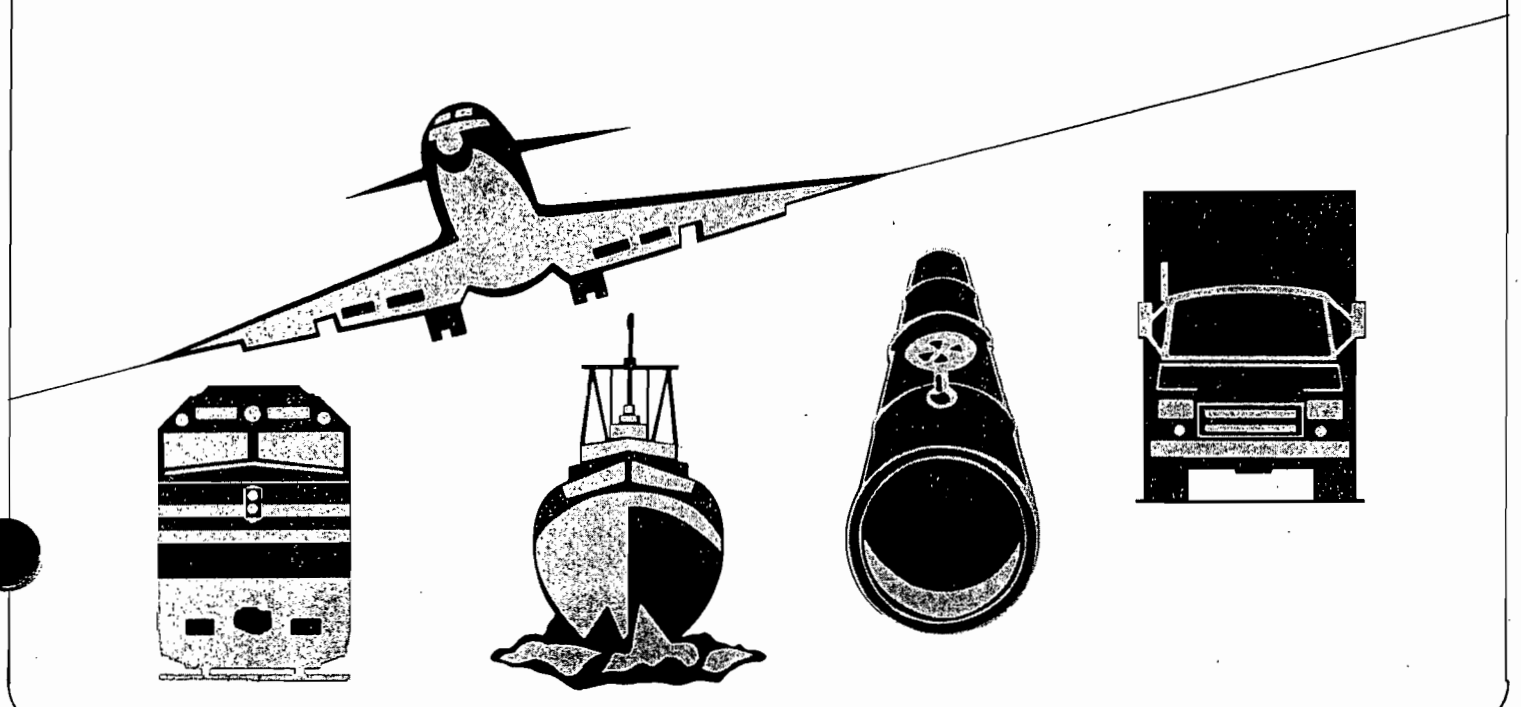
NTSB/MAR-90/04

NATIONAL TRANSPORTATION SAFETY BOARD

MARINE ACCIDENT REPORT

GROUNDING OF
THE U.S. TANKSHIP EXXON VALDEZ
ON BLIGH REEF, PRINCE WILLIAM SOUND
NEAR VALDEZ, ALASKA
MARCH 24, 1989



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16. Abstract

This report explains the grounding of the U.S. Tankship EXXON VALDEZ near Valdez, Alaska on March 24, 1989. The safety issues discussed in the report are the vessel's navigation watch, the role of human factors, manning standards, the company's drug/alcohol testing and rehabilitation program, drug/alcohol testing, vessel traffic service, and oil spill response. Safety Recommendations addressing these issues were made to the U.S. Coast Guard, the U.S. Environmental Protection Agency, the U.S. Geological Survey, the Exxon Shipping Company and other tankship companies carrying North Slope crude oil from Port Valdez, the State of Alaska, the Alyeska Pipeline Service Company, and the Alaska Regional Response Team.

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EXECUTIVE SUMMARY

About 0009, on March 24, 1989, the U.S. tankship EXXON VALDEZ, loaded with about 1,263,000 barrels of crude oil, grounded on Bligh Reef in Prince William Sound, near Valdez, Alaska. At the time of the grounding, the vessel was under the navigational control of the third mate. There were no injuries, but about 258,000 barrels of cargo were spilled when eight cargo tanks ruptured, resulting in catastrophic damage to the environment. Damage to the vessel was estimated at $25 million, the cost of the lost cargo was estimated at $3.4 million, and the cost of the cleanup of the spilled oil during 1989 was about $1.85 billion.

The safety issues discussed in the report are:

(1) The adequacy of the navigation watch on the EXXON VALDEZ on the night of the grounding;

(2) The role of human factors, including fatigue and alcohol abuse, in this accident;

(3) Coast Guard and Exxon Shipping Company manning standards and Exxon's procedures for determining manning levels for tankships;

(4) Exxon Shipping Company's drug/alcohol testing and rehabilitation program;

(5) Coast Guard regulations and procedures for drug/alcohol testing aboard commercial vessels;

(6) The role of the Coast Guard Vessel Traffic Service at Valdez; and

(7) Oil spill contingency planning and initial response to this accident.

Recommendations concerning these issues were made to the U.S. Coast Guard, the U.S. Environmental Protection Agency, the U.S. Geological Survey, the Exxon Shipping Company and other tankship companies carrying North Slope crude oil from Port Valdez, the State of Alaska, the Alyeska Pipeline Service Company, and the Alaska Regional Response Team.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the grounding of the EXXON VALDEZ was the failure of the third mate to properly maneuver the vessel because of fatigue and excessive workload; the failure of the master to provide a proper navigation watch because of impairment from alcohol; the failure of Exxon Shipping Company to provide a fit master and a rested and sufficient crew for the EXXON VALDEZ; the lack of an effective Vessel Traffic Service because of inadequate equipment and manning levels, inadequate personnel training, and deficient management oversight; and the lack of effective pilotage services.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

GROUNDING OF THE U.S. TANKSHIP EXXON VALDEZ ON BLIGH REEF, PRINCE WILLIAM SOUND NEAR VALDEZ, ALASKA MARCH 24, 1989

INVESTIGATION

The Accident

At 2335[1] on March 22, 1989, the EXXON VALDEZ (see figure 1) arrived at berth 5, Alyeska Marine Terminal, to load a cargo of Alaska North Slope crude oil. At 2350, the connections between the vessel's piping system and terminal pipelines were completed, and at 0054 on March 23, transfer of the vessel's ballast water to the terminal was started. By 0415, all ballast water had been discharged from the vessel, and at 0505, loading of the cargo of crude oil began. About 1030, the master, accompanied by the chief engineer and radio electronics officer, departed the vessel to go ashore.

The cargo loading operations were completed about 1924, and the chief mate directed the third mate, who had been assisting him with the topping-off operations,[2] to go to the bridge and test the navigation equipment. About this time, the chief mate ordered the deck force, consisting of six able seamen (ABs), to begin securing the decks for sea, which involved stowing or securing all deck firefighting equipment and all loose gear.

The third mate completed testing the navigation equipment on the bridge at 1948. He tested the steering system, navigation lights, whistle, and engine order telegraph and ensured that the following equipment was operating: compasses, course recorder, radars, radios, fathometers, and speed logs. The oil containment boom[3] was still in place encircling the vessel, making it unsafe to turn the propeller. All equipment tested was found to be operating properly. After testing the navigation equipment, the third mate stayed on the bridge to communicate with tugs, which were to assist in undocking when they arrived alongside.

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[1] All times are Alaska standard time based on the 24-hour clock. All miles are nautical miles, and all courses and bearings are true.

[2] The final loading of the cargo, usually at a reduced rate, to ensure that the desired amount of cargo is loaded in each tank.

[3] A flotable/inflatable unit placed in the water to serve as a barrier to the movement of oil on the surface of the water.

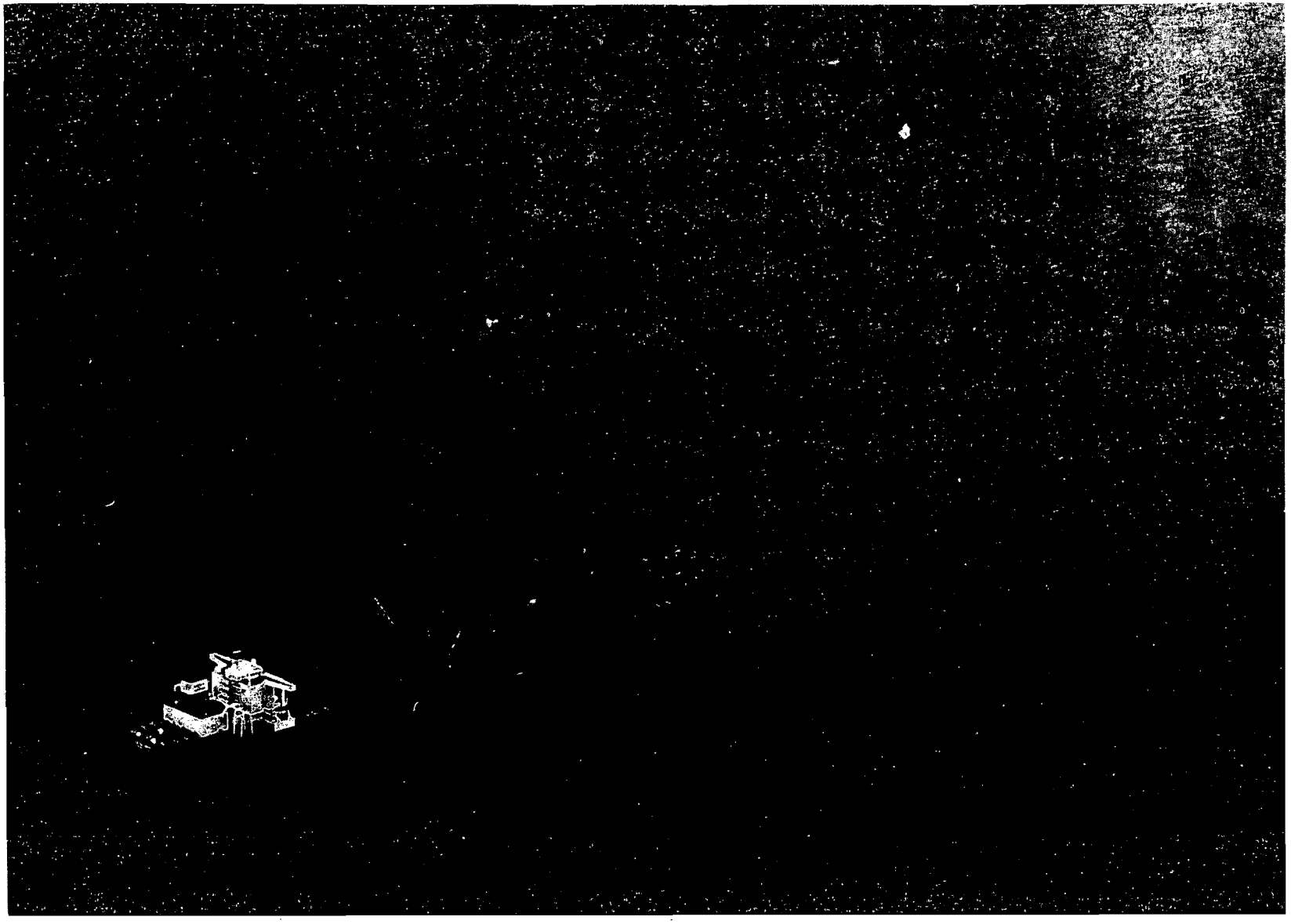

Figure 1.--EXXON VALDEZ.

At 2020, the same State pilot who had piloted the vessel into port, boarded the vessel. He stopped at the entrance to the master's office, but when there was no response to his knock, the pilot proceeded to the bridge. Once on the bridge, the pilot conducted his usual checks and found that the radios were on the correct frequencies, the radars were operating on the desired range scales, and the gyrocompass was operating and indicating the correct heading for the berth. About the time the pilot completed his checks, a representative from the agent's[4] office, who was seeking some cargo information, arrived on the bridge to await the arrival of the master. About 2030, the third mate was informed that the master had returned, and he in turn notified the pilot and the agent that the master was back on board.

About 2040, after ensuring that all cargo valves were closed and that the pumproom was secured, the chief mate proceeded to the bridge and relieved the third mate as the navigation watch officer. A short time later, the master arrived on the bridge, and following a brief conversation with the agent, he departed the bridge with her to obtain the needed cargo information in his office. At 2045, the oil containment boom around the vessel was removed, permitting the engineers to test the main engine at low speed. At that time, the chief mate retested the steering system by moving the rudder between hard right and hard left, using both pumps. When the master returned to the bridge a few minutes later, he inquired whether all navigation gear was ready, and the chief mate informed him that it was. At 2054, the master placed the main engine on bridge control. About 2100, on orders from the master, the deck force, consisting of three ABs on the bow under the direction of the second mate and three ABs on the stern under the direction of the third mate, began taking in the vessel's mooring lines to begin undocking procedures.

The navigation watch on the bridge consisted of the pilot, the master, and the chief mate. One of the two ABs on the 2000-2400 watch was scheduled to take the helm, but he was still handling lines on the stern. When the mooring lines were singled up (reduced to the minimum number necessary to hold the vessel at the berth), the AB left the stern and proceeded to the bridge, took his position at the steering stand, and stood by to move the helm as ordered.

At 2112, the last mooring line was removed from the pier, and the pilot began moving the vessel away from the berth. At that time, two tugs, under the direction of the pilot, were being used to assist in maneuvering the vessel from its berth. By 2121, the vessel was clear of the berth, and the pilot began conning the vessel toward the harbor entrance, known as the Valdez Narrows, which was about 6 miles away. One of the tugs was shifted to a position astern of the vessel, where it would remain to escort the vessel through the Valdez Narrows. The other tug was released.

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[4] A company representing the vessel's owner or operator in a port where the owner or operator does not have an office. The agent arranges for pilots and tugs for docking/undocking, ship's stores, fuel, repairs and other, similar support.

According to the chief mate, when the vessel was a few hundred feet from the pier, the third mate arrived on the bridge to relieve him. The chief mate went to his stateroom to sleep. According to the pilot, about 15 to 20 minutes after the vessel got under way, the master left the bridge. The pilot continued to issue orders to the helmsman, as necessary, to head the vessel toward the harbor entrance and to direct the third mate to make the necessary changes in engine speed. The third mate supervised the helmsman to ensure that all rudder orders from the pilot were correctly followed and also monitored the vessel's progress by logging the time abeam of prominent landmarks and navigation aids. As the vessel approached the Valdez Narrows, the pilot reduced the speed to 6 knots to conform with the established speed limit for loaded tank vessels in the Narrows and then maneuvered the vessel to position it on the optimum trackline.[5] (See figure 2.)

After the vessel passed through Valdez Narrows, the pilot brought it to 219°, the course of the outbound traffic lane. When the vessel was within about 15 minutes of arrival at the pilot station off Rocky Point, the pilot requested the third mate to call the master back to the bridge. The master returned to the bridge and a short time later relieved the pilot of the navigational control of the vessel. The master directed the third mate to escort the pilot to the debarkation ladder, which was rigged on the port side of the main deck. The master also called the AB acting as lookout on the bow by hand-held radio and instructed him to proceed aft and assist the third mate to disembark the pilot and to secure the pilot ladder after the pilot had left.

At 2324, the pilot departed the vessel. At 2325, the master informed the Coast Guard Vessel Traffic Center (VTC) for Valdez that the pilot had departed and that he was increasing the vessel's speed to "sea speed,"[6] about 16 knots. He also informed the VTC that the vessel's expected time of arrival adjacent to Naked Island, one of the locations in Prince William Sound where tankships report their position to the VTC, would be 0100. The VTC watchstander requested a report on ice conditions, and at 2325 the master responded:

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[5]The optimum trackline is the track that tank vessels and other large ships are required to follow in transiting Valdez Narrows. The trackline was determined by the Coast Guard and the Southwest Alaska Pilots Association after monitoring the tracklines followed by tankships during the first several months after the opening of Port Valdez to tank vessel traffic. Valdez Narrows is restricted to one-way traffic between Tongue Point south of the Narrows and Entrance Island at the northern end of the Narrows. Beyond the Narrows, tankships travel in northbound (inbound) and southbound (outbound) traffic lanes designated as a Traffic Separation Scheme.

[6]Sea speed is the normal sustained speed at which a vessel is designed to operate at sea. By contrast, maneuvering speed is a lower speed used in confined waters, such as channels and ports.

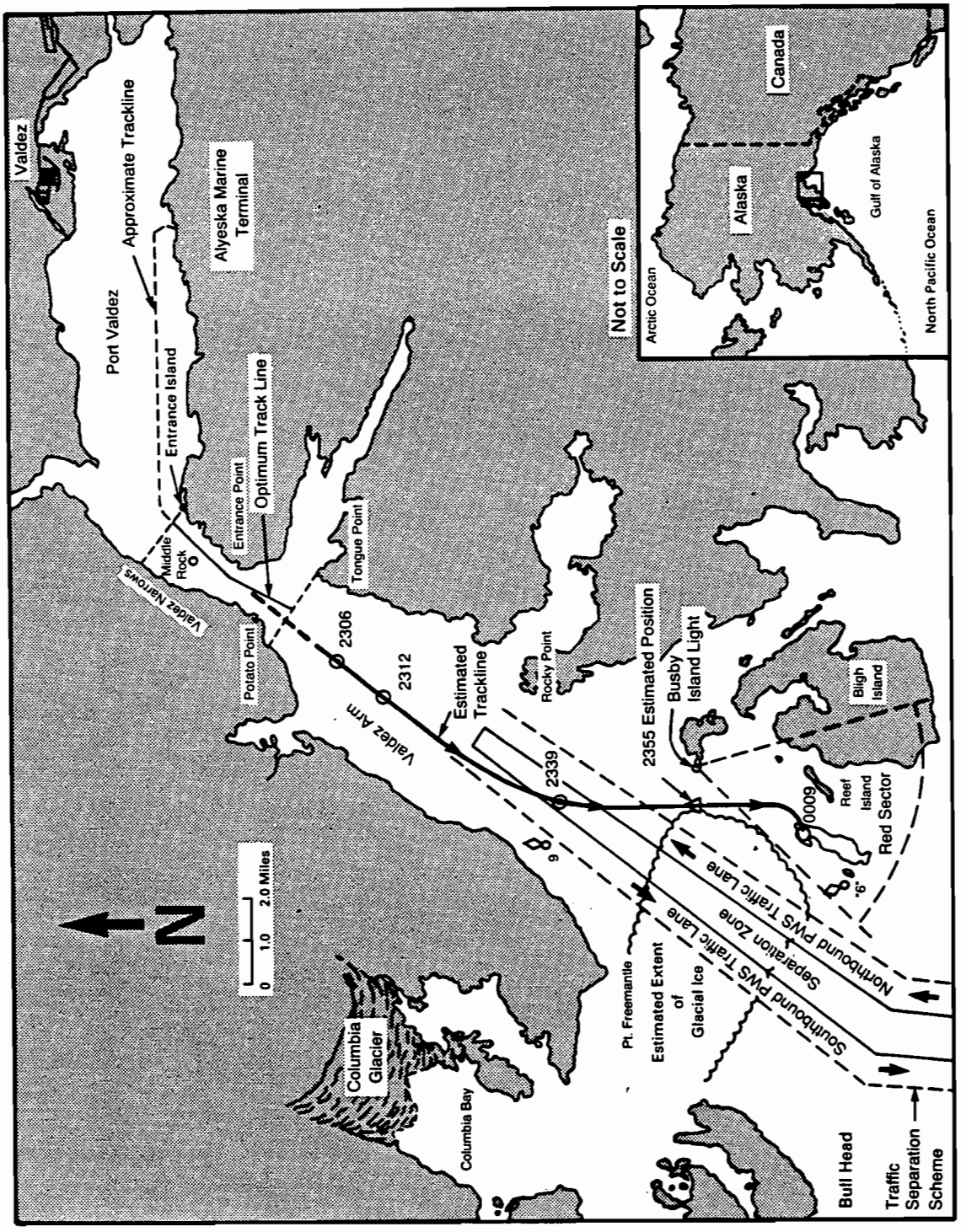

Figure 2.--Location of the accident.

> Okay. I was just about to tell you that, ah, judging by our radar, I we'll probably divert from, ah, the TSS Traffic Separation Scheme] and end up in the, ah, inbound lane if there's no conflicting traffic. Over.

The VTC watchstander indicated concurrence by stating that there was no reported traffic in the traffic lanes. The master again informed the VTC that the vessel might "end up" in the inbound lane, and he stated that he would notify the VTC when the vessel departed the traffic lanes. The master's transmission about 2326 is quoted below:

> That will be fine. Yeah. We may end up over in the, ah, inbound lane, outbound transit. Ah, we'll notify you when we leave the, ah, TSS and, and, ah cross over the separation zone. Over.

About 2331, the master again called the VTC regarding the ice in the traffic lanes. The master's transmission is quoted below:

> At the present time, I'm going to alter my course to two zero zero and reduce speed to about twelve knots to, ah, wind my way through the ice, and, ah, Naked Island ETA might be a little out of whack but, ah, once we're clear of the ice out of Columbia Gla ...Bay, we'll give you another shout. Over.

The helmsman on the 2000-2400 watch said that he had been steering 219° and then changed the vessel's course to 200° on orders from the master. The course recorder trace showed that the course change was made about 2331. The engineroom bell logger shows, however, that the vessel's speed was not decreased.

After the pilot ladder was secured, the AB assisting the third mate returned to his lookout station on the bow. The third mate then returned to the bridge, arriving there between 2334 and 2336. According to the third mate, the vessel was on course 200° when he arrived on the bridge and he believed the engine was speeding up to 55 rpm (about 11 knots) to match the order for full-ahead maneuvering speed. The bell book indicates that the vessel was placed on "load program up"[7] at 2352. The third mate stated that the master, before leaving the bridge, placed the vessel on load program up. (See figure 3.)

Shortly after the third mate returned to the bridge, the master informed the third mate that he (the master) would be bringing the vessel to 180° to avoid ice, and the master directed the third mate to take a fix of the vessel's position. The course recorder trace showed that the course change was started about 2339. The third mate took a visual bearing of Busby Island

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[7]The speed of the main engine was being increased slowly by a computer from maneuvering full ahead (55 rpm) to full-ahead sea speed (78.9 rpm), requiring about 43 minutes.

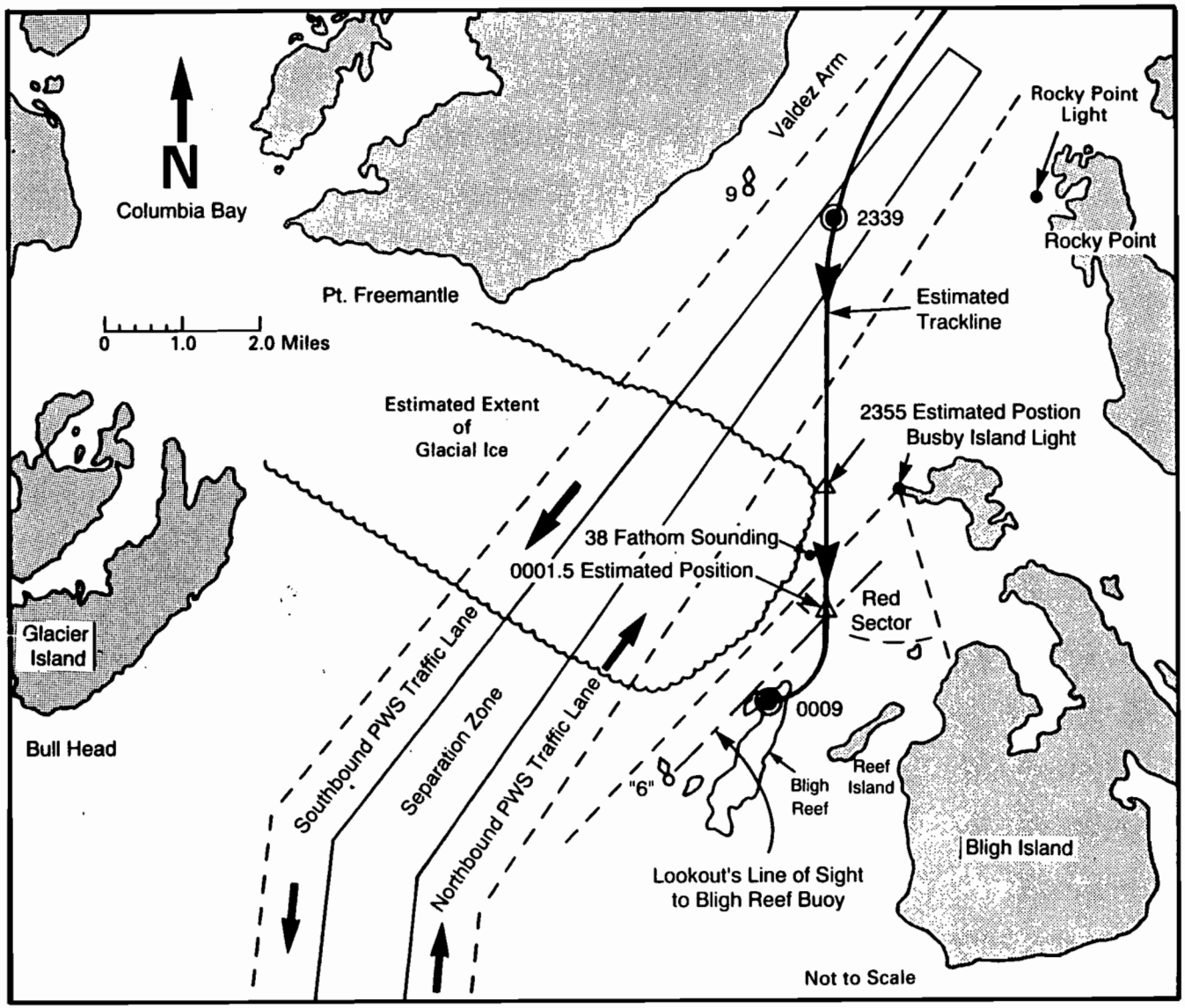

Figure 3.--Trackline of EXXON VALDEZ.

Light and Buoy No. 9 and a radar range to the land adjacent to Buoy No. 9. The third mate stated that the vessel was turning while he was taking the bearings. When plotted, his fix showed that the vessel's 2339 position was in the middle of the separation zone and approximately 2 miles west of Rocky Point Light. By about 2343, according to the course recorder, the vessel was steady on a course of 180°.

About this time, the master called the AB on lookout by hand-held radio and told him to go aft and tell the 0000-0400 AB, who would come on watch about 2350 as lookout, to report to the wing of the bridge instead of the bow to stand the lookout watch.

The 2000-2400 helmsman testified that shortly before he was relieved, the master had ordered him to bring the vessel to a course of 180° and to engage the automatic pilot. The helmsman testified that he changed the vessel's course to 180° and that when the vessel's heading was steady on 180°, he pushed the "gyro" button on the steering console to engage the automatic pilot.

At the change of the helm watch, about 2350, the helmsman being relieved reported to the third mate that he had been relieved of the helm, steering course 180° "on the gyro." According to the third mate, he learned that the vessel was on automatic pilot at this time. The third mate stated that he had not expected the vessel to be on automatic pilot because it was not in open water. He further stated that the vessel was not normally operated on automatic pilot when navigating the traffic lanes, but he stated that he did not discuss the reason that the vessel was on automatic pilot with the master. The third mate decided not to call his relief, the second mate, who was scheduled to come on watch at 2350, and to remain on watch until the vessel had cleared the ice flow.

According to the third mate, the master informed him that he would leave the bridge to send some messages that had to be sent before the vessel left Prince William Sound and that he wanted the third mate to start returning the vessel to the traffic lanes when Busby Island Light was abeam to port. The master said that he would be off the bridge a short time and that the third mate was to call him when he began returning the vessel to the traffic lanes if the master had not returned to the bridge by that time. The third mate said he and the master did not look at the chart together to review what the master expected him to do. The master asked the third mate whether he felt "comfortable" about what he was supposed to do, and the third mate replied that he did. The third mate testified that he had determined by radar that there was a distance of about 0.9 mile between Bligh Reef and the ice floe and that it would be possible to pass around the ice once Busby Island Light was abeam. The master left the bridge about 2352.

The third mate testified that he thought it would not be possible to turn sooner because of the ice. The third mate also testified that he never considered slowing the vessel because the decision had been made to avoid the ice rather than to proceed through it.

The third mate testified that according to the Exxon Shipping Company's **Bridge Organization Manual**, "Watch Condition C" was the watch condition required on the bridge at the time. The manual states that "Watch Condition C" is required during clear visibility when arriving or leaving port or operating in congested waters, and it also states that either the master or the chief mate is to be on the bridge in charge of the watch. The watch officer is responsible for fixing the vessel's position and assists as directed by the master or chief mate.

The third mate claimed that because he expected to change course in a few minutes, he went to the steering stand and pushed the hand steering button, removing the vessel from automatic pilot and placing it in hand steering. According to the third mate, the helmsman also attempted to push the hand steering button. He testified that he observed the indicator on the console illuminate, signifying that the steering system was in hand steering mode.

The third mate observed Busby Island on the radar and determined that the vessel would be about 0.9 mile from Busby Island Light when the light became abeam to port. The third mate then walked to the port wing of the bridge and took a visual bearing of Busby Island Light when it was abeam. At that time, while still on the wing of the bridge, he observed that the time on his watch was 2355. He then proceeded to the chart room, located in the after port side of the wheelhouse, to plot the fix. Although the third mate stated that the vessel was about 0.9 mile from Busby Island Light, he plotted the 2355 position 1.1 mile from the light.

The 0000-0400 AB scheduled to assume the lookout watch stated that she had arrived on the bridge about 2350. She looked briefly at the navigation chart to "get an idea of" the vessel's position and then looked at the radar, which, she stated, was her usual practice. She saw what she believed was ice, but she could not recall the distance to it. She noticed that the door to the port bridge wing was closed, so she proceeded to the starboard bridge wing, where the door was open, taking a position near the starboard side. Shortly after arriving on the starboard bridge wing, she observed Busby Island Light a few degrees forward of the port beam. A few minutes later she observed a red flashing light (Bligh Reef Buoy No. 6) on the starboard bow. She estimated that the light was broad on the starboard bow (45^{o}) and that it was flashing once every 5 seconds. She walked into the wheelhouse, located the third mate at the chart table, and reported the light to him. She noticed that the third mate appeared to be plotting a fix. According to the lookout, the third mate acknowledged her report in a calm, routine manner. The third mate stated that he knew the lookout was reporting the light on Bligh Reef Buoy No. 6 and that he had already located the buoy on the radar. The lookout then returned to the starboard bridge wing.

The third mate claimed that shortly after he plotted the 2355 fix, he ordered the helmsman to put the rudder to right 10^{o}. (See Test and Research section for time of turn and rudder used, as determined by computer simulation.) He estimated that he issued the order for right 10^{o} rudder about a minute after taking the visual bearing on the port bridge wing. He did not recall watching the rudder angle indicator to ensure that the rudder

was actually applied. He also stated that he did not order the helmsman to come to any particular course because he intended to make a gradual, sweeping turn to the right. After ordering the right 10° rudder, the third mate telephoned the master to inform him that he had started to turn the vessel back toward the traffic lanes. While speaking with the master, the third mate had his back to the rudder angle indicator. He estimated that the telephone call lasted about 1 1/2 minutes. He informed the master that he believed the vessel would pass through the edge of the ice floe. He stated that the master inquired whether the second mate had arrived on the bridge, and the third mate informed the master that the second mate had not yet been called for the watch. After the telephone call was completed, the third mate went to the port radar. The third mate stated that he was taking radar ranges from Bligh Reef buoy and Reef Island to determine any vessel movement to the left or right. While observing the radar, he recognized that the vessel had not moved to the right of its original trackline, and then he noticed that the heading had not changed.

About this time, the lookout again entered the wheelhouse to report that the red light on the starboard bow was flashing every 4 seconds instead of 5 seconds. She found the third mate at the port radar, and he again acknowledged her report in a calm, routine manner. At this time, according to the third mate, he looked out, sighted the light, and identified it as Bligh Reef buoy. The lookout returned to the starboard wing of the bridge, and a short time later, she noticed that the vessel was beginning to swing slowly to the right.

The third mate claimed that after he noticed that the heading was not changing, he ordered the rudder increased to right 20°. He said he looked at the rudder angle indicator and saw the rudder approach and stop at 20° right rudder. However, he did not recall the position of the rudder when he issued the order for right 20° rudder. The third mate estimated that his order for the right 20° rudder was made "1 to 1 1/2, . . . perhaps 2 minutes" after his order for right 10° rudder. He stated that he stepped onto the port bridge wing, looked aft at Busby Island Light, then ahead to Bligh Reef buoy light, and returned to the radar. The third mate said that the white sector[8] of Busby Island Light remained visible off the port quarter, indicating that the stern of the vessel was still in the white sector of the light.

According to the third mate, the radar indicated that the ship was still following a 180° track, although the vessel's heading was swinging right. The third mate then ordered hard right rudder. He estimated that Bligh Reef buoy was about 2 points (22 1/2°) on the port bow by this time that about 2 minutes had elapsed from the time of his order for right 20° rudder until he ordered hard right rudder.

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[8]Busby Island Light comprised a white sector and a red sector. The red sector showed over an arc of 60° over the area of Bligh Reef to warn mariners of the location of the reef and surrounding shoals. The white sector was visible to vessels navigating the traffic lanes on Valdez Arm.

After several seconds at the radar, following the order for hard right rudder, the third mate telephoned the master and said, "I think we are in serious trouble." At the end of the telephone conversation, the third mate felt the vessel contact the bottom. He said that the contact seemed to occur forward on the vessel's starboard side and to cause the vessel to roll slightly. According to the third mate, about 40 to 50 seconds later the vessel sustained a series of sharp jolts for about 10 seconds. The third mate said the vessel seemed to be riding over something. He stated that when the vessel started to jolt, he ordered hard left rudder and that when the helmsman seemed to hesitate, he immediately went to the helm and spun the wheel to hard left in an attempt to slow or stop the vessel's right swing and thus prevent the stern from swinging aground. He said that there was a significant swing on the vessel as a result of the right 20^{o} and hard right rudder and that the vessel continued to swing right during the grounding. The third mate stated that he believed the vessel was heading about 285^{o} after it came to a full stop following the series of jolts. He said that he heard the "bullets" (pressure and vacuum relief valves) in the inert gas system[9] lifting and smelled both inert gas and crude oil vapor.

The third mate estimated that the vessel grounded about 0005 on March 24; however, the course recorder printout showed that the vessel's heading reached 285^{o} about 0009 and that the heading was still swinging right very rapidly at that time. After the vessel stopped, the third mate went to the wings of the bridge and turned on the search lights. He recalled that the master arrived on the bridge sometime after the grounding, but he could not estimate how long after the grounding. The master told the Coast Guard investigating officer that he felt the vessel ground when the third mate phoned him and that he then proceeded to the bridge. He said that the vessel was aground and stopped when he arrived on the bridge.

The helmsman recalled receiving orders for the right 10^{o}, right 20^{o}, and hard right rudder and then receiving an order for hard left rudder as the vessel grounded. The helmsman further recalled receiving helm orders from the vessel's master shortly after the grounding.

The helmsman provided two different versions of his activities regarding the steering of the vessel. When the helmsman was interviewed a few days after the grounding, he was unable to recall whether the vessel was on automatic pilot when he relieved the 2000-2400 helmsman. He stated later at the Safety Board public hearing, however, that when he arrived on the bridge he observed the 2000-2400 helmsman push the "gyro" button to place the vessel on automatic pilot. He also testified that later he was about to push the hand steering button to put the vessel in hand steering but that the third mate pushed the "button." The helmsman stated during the interview that the third mate was "panicky" when he gave the order for hard right rudder. The helmsman indicated that he did not expect the hard right rudder because the

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[9] Inert gas produced by burning diesel oil in specially designed inert gas generators (or collected from the boiler flue gas on steam vessels) is piped to cargo tanks to provide an atmosphere that will not support combustion.

vessel was swinging well and he had already used some counter rudder to slow the vessel's swing as he was bringing the vessel to a course of either 235° or 245°, but he could not recall which course was correct. At the public hearing, the helmsman stated that he had received only helm orders and had not received an order to come to any particular course.

The lookout testified that the vessel was making a slow turn to the right at the time of the grounding and that as the vessel grounded, she saw an illumination in the water around the bow. She described the grounding as a series of jolts. When the vessel grounded, she heard what she believed were "bullets" lifting forward, and she smelled what she believed was inert gas. Shortly after the vessel stopped, she walked into the wheelhouse and noticed that the vessel's heading on the digital read-out located on the forward bulkhead was 289°. The course recorder printout showed that the vessel's heading was 289° shortly after 0009 and that the heading was still swinging right at that time.

The third mate could not recall the exact time that the master arrived on the bridge following the accident, but he recalled that the master gave a number of helm orders, including orders for hard left and hard right, and some orders for speed change following the grounding in an attempt to free the vessel. The third mate operated the engine controls during this period.

The chief engineer stated that he was in the engineroom control room as the vessel was proceeding out of Port Valdez. Sometime between 5 and 10 minutes after midnight he heard a noise that he thought might be related to one of the turbochargers on the main engine. The turbochargers had sustained some bearing failures at the start of the voyage in San Francisco, California, and had required repairs. He quickly stepped into the engineroom and walked over to the starboard side of the main engine to listen to the turbocharger. Hearing no unusual sounds from the turbocharger or the main engine, he returned to the control room about a minute later. Upon entering the control room, he noticed that the reading on the load indicator for the main engine was higher than normal, about 7.5 on a scale of zero to 8. The engine speed, according to the chief engineer, was 64 rpm, which he stated would normally produce a loading of about 5.5. Also, as he reentered the control room he immediately recognized that the vessel had acquired a starboard list, and an inspection of the inclinometer in the control room revealed that the list was 2° to starboard. Then he noticed that exhaust temperatures were slightly above normal. A few minutes later, he received a call from the third mate informing him that the bridge intended to stop the main engine. The chief engineer, who did not know that the vessel was aground, advised the third mate to reduce engine speed slowly. Shortly after that call, according to the chief engineer, the master called and informed him that the vessel was aground. The chief engineer immediately volunteered that the engine could be stopped quickly, and the engine was stopped soon afterward. The chief engineer said that the engine speed never rose above 64 rpm, although the engine was in "load program up" and according to him, the engine was stopped shortly after 0020.

The chief engineer testified that the master called again about 5 minutes after the engine was stopped and asked whether the main engine

could be used even though the vessel was aground. The chief engineer replied that the engine could be used. About 0027, the master notified the VTC that the EXXON VALDEZ was aground on Bligh Reef and leaking oil. At 0035, the master ordered the main engine restarted, which was done from the bridge, and resumed attempts to maneuver the vessel free of its strand, using various amounts of port and starboard rudder. The chief engineer stated that the highest engine speed thereafter was 55 rpm, that no particularly high loading was placed on the main engine after it was restarted, and that the main engine was never reversed during the more than 1 hour of resumed operation.

The chief mate was awakened by what he described as a "shuddering" of the vessel and by a "clanging" sound. He quickly dressed and went to the bridge. Upon arriving on the bridge, he was informed by the third mate that the vessel was aground and that the master was aware of the grounding. The chief mate then left the bridge and proceeded to the cargo control room, stopping briefly along the way to call the second mate. Once in the cargo control room, the chief mate observed that all center and starboard cargo tanks were rapidly discharging and that the starboard ballast tanks 2 and 4, which had been empty, were filling. Shortly before 0030, the chief mate called the master and informed him about the status of the cargo and ballast tanks and that about 115,000 barrels of cargo had been lost. The master, according to the chief mate, directed him to calculate the hull stresses and vessel stability. The chief mate began the stress and stability calculations, using the vessel's load master computer located in the cargo control room.

About 0030, the chief mate completed the calculations, which, he stated, revealed that the vessel's stability was adequate but that the stresses affecting the vessel's hull were in excess of acceptable limits. The chief mate took the computer printout of the calculations to the bridge to review the results with the master. En route to the bridge, the chief mate noticed strong cargo vapors in the passageways and upon arriving on the bridge he asked if the master wanted to sound the general alarm. The master stated that this might cause panic and that the crew was being informed about the grounding. The chief mate stated that he recommended to the master that the vessel not be moved. According to the chief mate, the master replied, "Yes, we are definitely not leaving this area." The chief mate returned to the control room and made further computer calculations, which he stated showed that the vessel's stability had become marginal and confirmed that the hull stresses were still beyond acceptable limits. Sometime before 0100, according to the chief mate, he informed the master that the computer calculations showed that the ship was "not stable to move," and he again recommended that the ship not be moved. The chief mate testified that he was unaware of any attempts to maneuver the vessel.

At 0107, the Coast Guard Captain of the Port (COTP) at Valdez called the EXXON VALDEZ and spoke with the master. During the conversation, the master stated, "We are working our way off the reef." The COTP cautioned the master to "take it slow and easy." The master further stated, "We are in pretty good shape right now stabilitywise...just trying to extract her off the shoal here." The COTP cautioned again against any "drastic attempt" to get under way. The master responded, "We are just kinda hung up in the

stern." According to the third mate, the master finally made a statement to the effect that "this isn't going to work, we better stop it now" and shortly afterward, ordered the main engine stopped. The engineroom bell logger showed that the main engine was stopped at 0141. The bell logger showed that the following engine orders were executed:

Time	Command	RPM
0035:57	Dead Slow Ahead	23
0040:24	Slow Ahead	31
0048:35	Half Ahead	41
0056:19	Full Ahead	50 to 56
0140:30	Slow Ahead	43
0140:43	Dead Slow Ahead	23
0140:53	Stop	

The course recorder showed that beginning about 0035, the vessel's heading, which had been nearly steady at 290° for about 6 minutes, started swinging to the left, reaching 280° about 0049. Thereafter, the vessel's heading swung back and forth about eight times between the headings of 291° and 276°, finally becoming steady at 280° about 0152.

The Executive Officer (XO) and the Senior Investigating Officer (SIO) of the Coast Guard's Valdez Marine Safety Office (MSO) boarded the vessel about 0335. The master told the XO that he wanted the third mate to start turning back toward the traffic lanes when Busby Island Light was abeam. However, the Coast Guard SIO stated that during separate interviews with the third mate and the master, both identified a position on the chart about 0.7 mile farther south at a 38-fathom sounding (bearing 235°, 1.2 miles from Busby Island Light) as the position where the third mate was to start turning back toward the traffic lanes.

The crew inspected the engineroom and pumproom and took soundings of fuel oil and water tanks adjacent to the engineroom. Later, the starboard anchor was lowered to steady the vessel, and then the crew commenced breaking out the lightering equipment, consisting of hoses and couplings, in preparation for transferring cargo off the vessel. During the evening of March 24, the EXXON BATON ROUGE moored with its port side to the port side of the EXXON VALDEZ, and cargo lightering began on the morning of March 25. During the following few days, preparations were made by Exxon to refloat the ship that required the installation of air compressors and blanking off the tank vents to pressurize the damage tanks.

Injuries

There were no personal injuries resulting directly from this accident.

Vessel Information

The EXXON VALDEZ was a typical modern tankship of all welded steel construction with a continuous main deck, raised foc'sle, straight raked stem, bulbous bow and transom-type stern. (See figure 4.) A split deckhouse was located aft on the main deck of the vessel above the engineroom. The forward section of the split deckhouse contained the navigation bridge (wheelhouse), radio room, recreation rooms, officer and crew dining facilities and accommodations, steward's stores, hospital, gymnasium, swimming pool, and the cargo control room. An overhead gantry-type crane for handling ship's stores was installed athwartship in the space between the forward and after sections of the split deckhouse. The after section of the deckhouse contained the emergency diesel generator room, inert gas system, halon cylinder storage room, and the emergency battery room. The machinery spaces below the split deckhouse contained the main propulsion engine, machinery control room, steering gear room, ships service electrical generators, and auxiliary machinery.

The EXXON VALDEZ, delivered to its owners on December 11, 1986, was the largest ship ever built on the U.S. West Coast. It was the first of two Alaska-class tankships designed and built for the Exxon Shipping Company (Exxon) by the National Steel and Shipbuilding Company in its San Diego shipyard from plans approved by the U.S. Coast Guard and the American Bureau of Shipping. The vessel was designed to meet the standards of the International Convention for the Prevention of Pollution from ships, 1973, as modified by the Protocol of 1978 (MARPOL '73/78). These standards provided for, among other items, protectively located segregated ballast tanks, maximum tank compartment length, and damage stability. The vessel was certificated by the Coast Guard for the carriage of crude oil products and flammable or combustible liquids Grade B or lower.

The EXXON VALDEZ measured 987 feet long overall, 166 feet wide, and 88 feet deep from the main deck (at the side) to the flat keel. The tankship had a maximum draft (loaded) of 64.5 feet with a corresponding deadweight tonnage of 214,861 and a displacement of 240,291 long tons. At maximum draft, the tankship could transport about 1.48 million barrels of crude oil per voyage.

Eighteen cargo, ballast, and slop tanks were located forward of the pumproom and were divided into five transverse tank sections. The sections were numbered from 1 to 5, beginning at the bow, with a port wing tank, a center tank, and a starboard wing tank in each section. The ballast tanks consisted of the forepeak, Nos. 2 and 4 port, and starboard wing tanks. The cargo oil tanks included Nos. 1 across (port wing, center, and starboard wing), center No. 2, Nos. 3 across, center No. 4, and Nos. 5 across. A permanently installed crude oil wash system was fitted in all the cargo tanks. Slop tanks were located aft of port and starboard wing cargo oil tanks Nos. 5. Void tanks (double bottoms) were located below the port and starboard slop tanks.

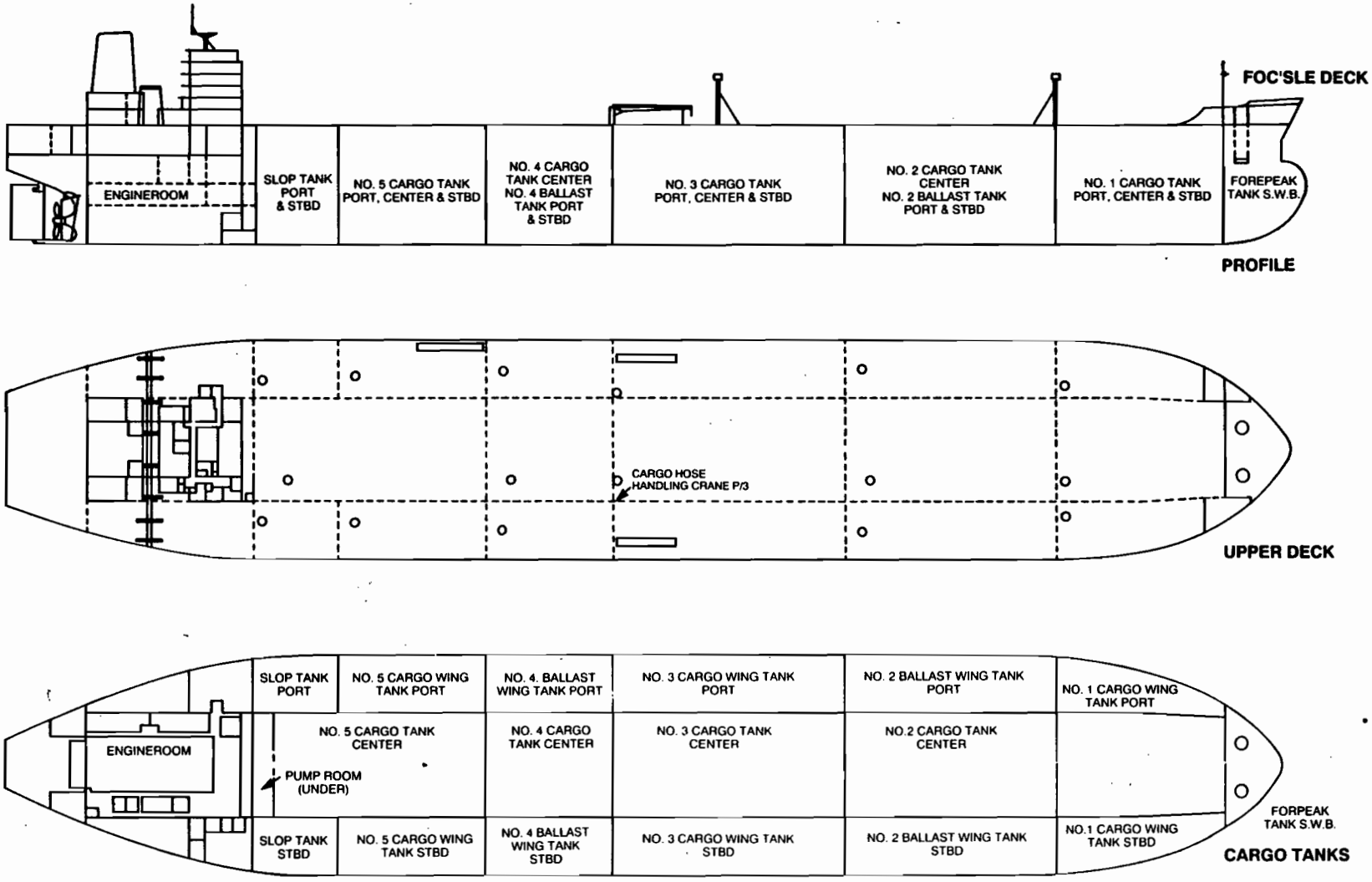

Figure 4.--Profile and plan views of EXXON VALDEZ.

The navigation bridge was located on E deck in the forward section of the split deckhouse. An island in the wheelhouse consisting of several consoles served as the main information and control center for the tankship. From these consoles the navigation watch received data concerning ship speed and direction, main engine speed and direction, selected engine operating parameters, fire detection and control data, alarms, the tankship's position, the position of other vessels and land masses relative to the tankship, and communications to locations about the ship.

From the port side to the starboard side of the wheelhouse, the island of control consoles consisted of:

1. a Raytheon 3-cm radar;

2. the general regulator console (see figure 5), containing a foghorn timer, general alarm switch, gauges for fire pump and firemain pressures, deck-watch annunciator call buttons, internal telephone communications, controls for the forward fire pump and associated remotely controlled fire main valves, and alarm indicators for the systems and equipment in the engineroom, steering gear room, and pumproom;

3. the Sperry SRP-2000 (see figure 6) steering control console;

4. the main engine (see figure 7) control console, which contained the engine order telegraph (throttle), shaft rpm preselection control, gauges indicating main engine control air and starting air pressures, main engine RPM indicator, and a variety of engine indicating lights and alarms; and

5. a Raytheon Raycas V, 10-cm radar with a 16-inch-diameter screen, equipped with an Automatic Plotting Aid.

Installed on the overhead, between the bridge main control consoles and the front windows, was a rudder angle indicator. The rudder angle indicator could be seen from either the port or starboard side of the wheelhouse, from the helm position, and from the chartroom behind the bridge control console when the night curtain was not closed.

Located above the windows on the forward bulkhead of the wheelhouse from left to right were:

- doppler speed log (connected to speed sensors located on the hull forward, midships, and aft),

- a digital display gyrocompass repeater with an analog indicator showing illuminated headings,

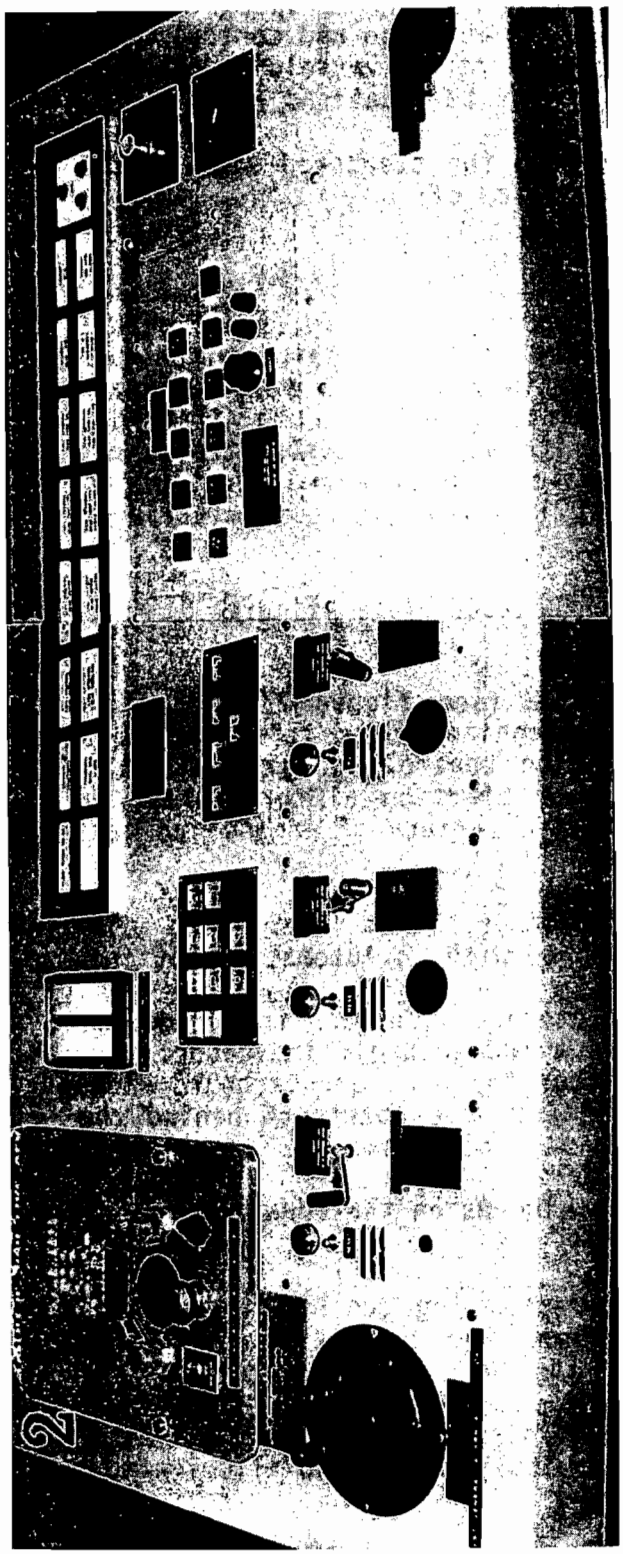

Figure 5.--Bridge control console.

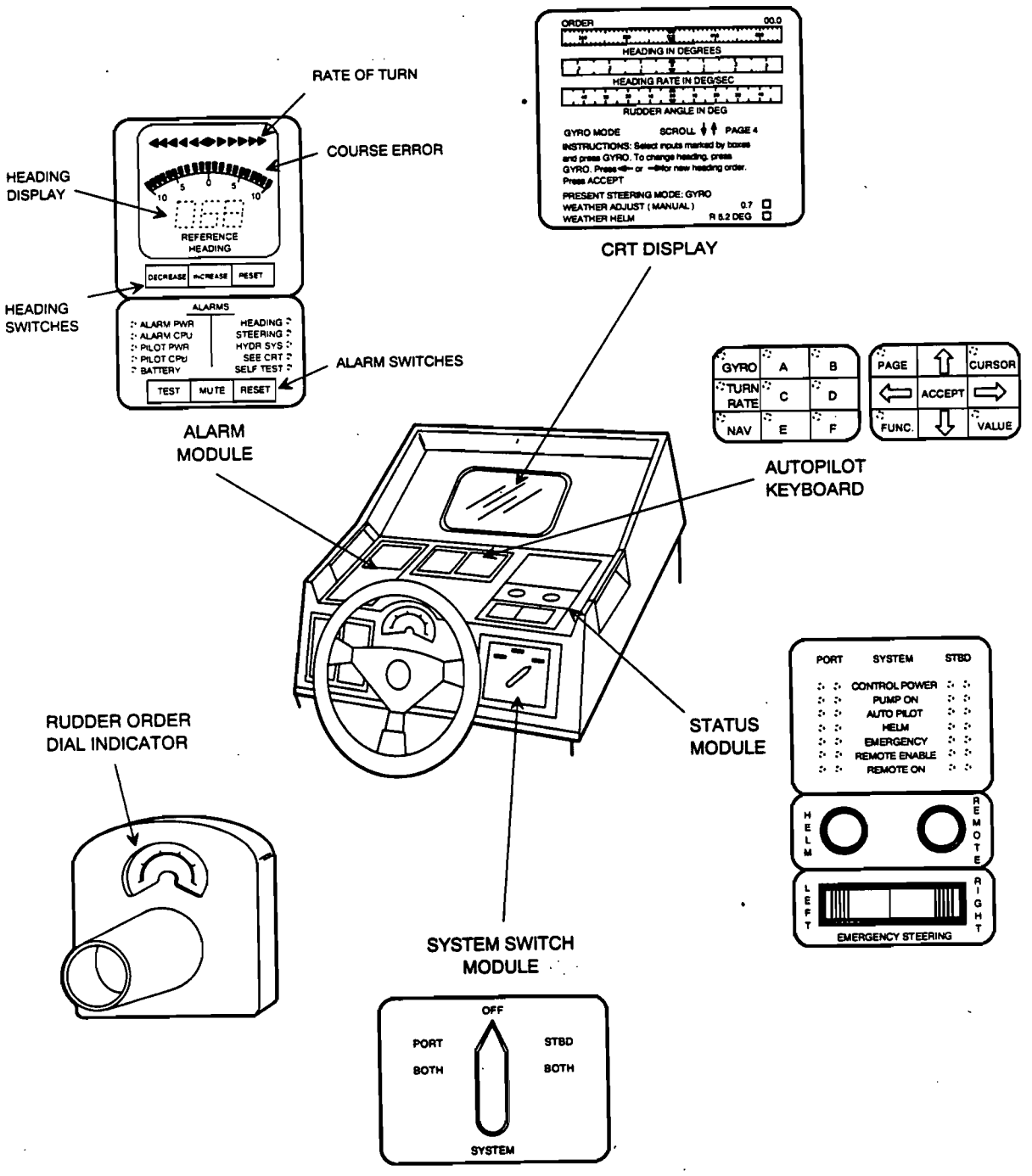

Figure 6.--SRP-2000 console.

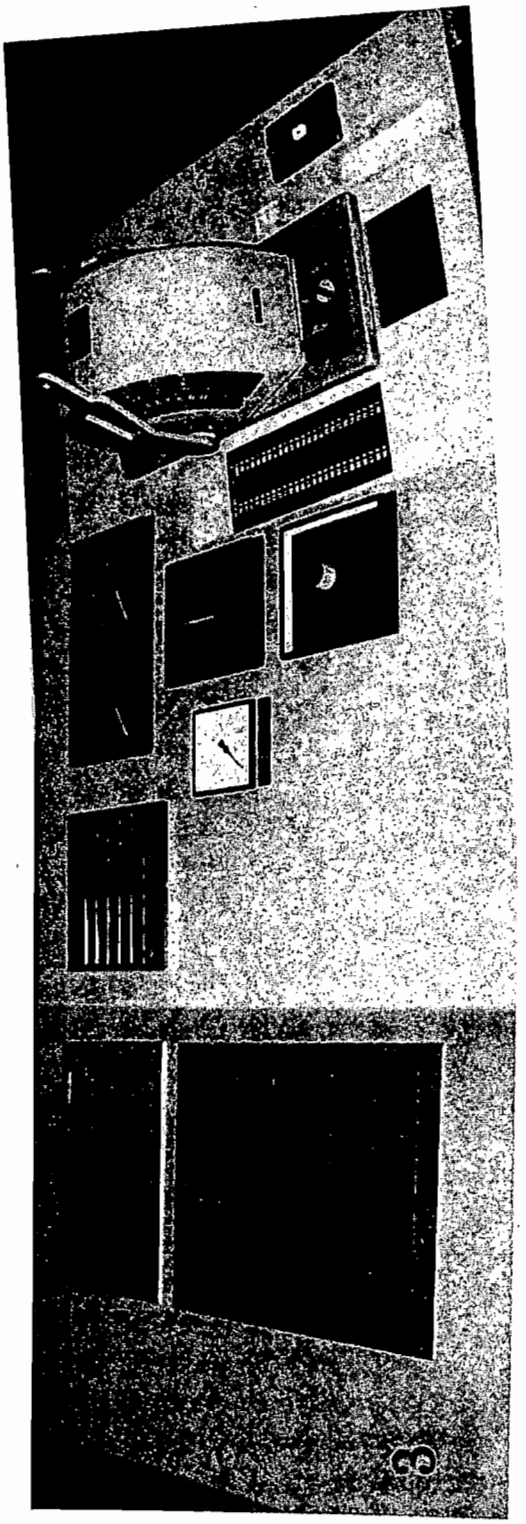

Figure 7.--Engine control console.

- a ground track speed indicator showing ship's speed forward or reverse and vessel heading,
- an analog rudder angle indicator,
- a shaft rpm analog indicator,
- a Sperry digital doppler speed log,
- a digital fathometer with an illuminated display and audible alarm (with the transducer located in the forepeak tank bottom plating),
- a rate of turn indicator showing degrees per second,
- a wind indicator showing wind direction and velocity.

The ship was propelled by an eight-cylinder, reversible, slow-speed Sulzer marine diesel engine, model 8-RTA-84. The main engine was rated at 31,650 brake horsepower (bhp), which sustained a sea speed of 16.25 knots at the engine's maximum continuous rating of 79 rpm. The main engine was designed to operate on No. 2 diesel oil or heavy fuel oil with a viscosity of 6,000 Redwood at 100^{0} F. The main engine crankshaft was directly coupled to the propeller shaft driving a single, five-blade propeller.

The propulsion control system was designed for remote starting, controlling, and stopping of the main engine from the control console in the machinery control room located in the engineroom or from the propulsion control console on the bridge. The control system also provided for emergency operation of the main diesel engine from a local control station at the main engine. In the case of an emergency, the main engine could be stopped remotely by pushing the EMERGENCY STOP button either at the bridge engine control console or at the machinery control room console, or it could be stopped manually at the engine emergency local control station.

Normally, the main engine was started, controlled, and stopped from the control console on the bridge. Provision was made on the bridge control console for automatic acceleration from the maneuvering speed (55 rpm) to sea speed (79 rpm) and for automatic deceleration from sea speed to maneuvering speed. The full-ahead order was programmed so that the engine would slowly increase its speed to the preselected sea speed when the automatic "load program up" button was pushed. The acceleration time, normally about 43 minutes, could be varied between 30 and 120 minutes. The engine speed could be similarly reduced by pushing the automatic "load program down" button, which would cause the engine speed to slowly drop back to the maneuvering speed. By pushing the automatic "load program off" button, the automatic acceleration/deacceleration could be stopped at any time. The engine speed reached when the "load program off" button was pushed would then be kept constant.

The steering system, which consisted of steering equipment and a control system, was located in the steering gear room on the 68.5-foot flat between frames 101 and 107. The steering gear consisted of two (one port and one starboard) independent electrohydraulic pumping units with associated piping and valves, two sets of hydraulic rams (pistons, rods, and cylinders) positioned athwartship, and a tiller and rudder installed on the centerline. When energized, the selected hydraulic pump supplied pressurized hydraulic oil to the rams for left and right movement of the rudder. Limit switches prevented the rudder from moving more than 35^{0} right or left from the midships position.

A Sperry SRP-2000 steering control system was installed in the vessel. According to a description in the Sperry manual:

> The [control] system permits route planning and continuous readout of the tankship's position based on inputs from the ship's gyrocompass, speed log (dead reckoning) and position fixes from satellite navigation (SatNav), global positioning satellite system (GPS), shore-based Loran C and Omega units. The ship [SRP-2000] steering control system provides precise changes in original heading with minimal rudder movement, thus allowing maneuvers with minimal loss of speed and the most economical operation. Course keeping adaptive capability evaluates ship's yaw and rudder motion and automatically alters values to optimize rudder activity.

The SRP-2000 was a centralized, multicomputer, integrated steering control system that furnished communication between the electronics in the bridge steering control console and the electronics in either the port or starboard rudder control unit (depending on which unit was selected) that energized the solenoid control valve of its associated hydraulic pumping unit in the steering gear room. The selected rudder control unit, upon receiving an electrical command from the computer located in the SRP-2000 console on the bridge, energized the solenoid control valve associated with the selected hydraulic steering pump to direct pressurized hydraulic oil to the rams to move the rudder.

The SRP-2000 console had the following four steering modes:

(a) Helm, or hand steering--This was the mode normally used to steer the vessel when it was entering and leaving port. In this mode, the steering wheel was turned by a helmsman to the desired rudder angle, as indicated by a mechanical indicator on the vertical front of the SRP-2000 console, and the rudder quickly moved to the angle set by the wheel. About 1 3/4 turns of the wheel would cause the rudder to move from 0^{0} (midships) to 35^{0} (hard right). The helm mode was selected by pressing the HELM button on the console.

- Turning the wheel caused an electrical command to be transmitted to the rudder control unit, which in turn energized the solenoid on the selected pump to direct oil to the rams to move the rudder. When the rudder reached the angle set by the steering wheel, the unit deenergized the solenoid control valve and the valve closed, hydraulically locking the rudder at the desired angle. The automatic matching of the rudder and the angle set by the steering wheel is referred to as a followup system.

(b) Gyro, or automatic pilot--In this mode, the SRP-2000 received input from the gyrocompass and then generated commands to the rudder control unit to keep the vessel on the selected course. The gyro mode was normally selected by steadying the vessel on the desired course and then pressing the GYRO button. While in the gyro mode, the course could be changed by pressing the left or right arrow switches to select a new heading order, followed by pressing the ACCEPT switch. The vessel would then turn to the new course. The amount of rudder that would be used to keep the vessel on course or to make a turn could be selected. According to the vessel's second mate, the maximum rudder setting was normally 7 to 10 degrees. The steering wheel is electrically disconnected during gyro mode operation and may be turned without affecting the steering or causing any alarms to sound.

(c) NAV mode--In this mode, an integral computer calculated the course to steer from one preselected geographical location or waypoint to the next one and kept the vessel on course until that waypoint was reached. The SRP-2000 normally received position information from passing satellites (SatNav) or from shore-based Loran stations. The SRP-2000 computer determined any needed course corrections to keep the vessel headed toward the next waypoint. As the vessel approached the waypoint, the SRP-2000 console would sound an alarm to alert the navigation watch. Also, it could be programmed to make a course change to head the vessel toward a subsequent waypoint. As many as nine waypoints could be entered in the SRP-2000.

(d) Rate-of-turn mode--This mode enabled a turn to be made at a constant rate. The SRP-2000 monitored the rate of turn and transmitted command signals to the rudder control unit to keep the vessel turning at the selected rate despite any external forces, such as seas and winds.

The SRP-2000 also provided emergency control of the rudder by means of a hand-operated rocker-switch on the front of the console. Pressing either the port or starboard side of the rocker-switch resulted in electrically energizing the solenoid valve of the hydraulic steering pump to direct oil to the rams. The rams moved as long as the rocker-switch was pressed. Releasing the rocker-switch deenergized the solenoid control valve, stopping the rudder. Thus, to move the rudder to the desired angle, the rocker-switch had to be depressed until the rudder, as indicated by the rudder angle indicator, reached the desired angle. This system was referred to as a nonfollowup system.

The console, rudder control unit, and steering pump were activated when the system (pump selector) switch, located on the upper right front of the steering console, was moved from the center, OFF position to either the left (port) or right (starboard) steering system rudder control unit and pump unit. The bridge steering control console received inputs of the following data: **heading** from the ship's gyrocompass, **speed** from the speed log or manual speed input, **position** from SatNav or Global Positioning System (GPS) (not installed) or Loran C or Omega (not installed) units, **rudder angle** order signals from the rudder angle transmitter, and **feedback** signals from the rudder repeat back units, the rudder control unit, and keypad entries.

The SRP-2000 control console provided ship steering control and position information on a cathode ray tube (CRT) display. The information included rudder angle and rate of turn. Also, the steering control mode selected (HELM, GYRO, NAV, etc.) was automatically shown, as were the operating instructions for that mode. The lower portion of the CRT displayed operating instructions for operator-selected parameters of speed, navigation source, turn rate, heading, load, weather adjustment, system status, and ship parameter information.

The pilot stated that all navigation and steering equipment had operated satisfactorily while he was piloting the vessel.

Vessel Damage

An inspection of the vessel in drydock at the National Steel and Shipbuilding Company shipyard in San Diego was conducted on August 29, 30, and 31 and September 1, 1989. The inspection revealed that the forepeak tank was severely holed and that center cargo tanks Nos. 1, 2, 3, and 4 were ripped open over almost their entire lengths. Although holed, center cargo tank No. 5 sustained the least damage. Starboard cargo tanks Nos. 1, 3, and 5 also were severely holed, as was starboard ballast tank No. 2. Starboard ballast tank No. 4 sustained minor damage, resulting in a small opening at

the bottom of the forward bulkhead near the turn of the bilge caused by a separation of the bulkhead from the bottom plating. The void (double bottom) below the starboard slop tank was also ripped open. (See figure 8.)

The greatest loss of plating occurred in the forward starboard side of center tank No. 3 and in the forward half of starboard cargo tank No. 3 and the after one-quarter of starboard ballast tank No. 2. The frames[10] and longitudinals[11] that were exposed by the loss of bottom plating in cargo tanks Nos. 3 (center and starboard) were bent upward about 4 to 6 feet. The turn of the bilge and lower side of the hull at starboard cargo tank No. 3 were compressed upward.

The Safety Board found that the maximum vertical damage was 10.9 feet above the bottom of the vessel at two locations in the after half of starboard cargo tank No. 1. The most forward of the two locations was between frames Nos. 10 and 11, where a large boulder had lodged in the ship's hull structure, causing a longitudinal to break loose at frame No. 11 and curve upward to a height of 10.9 feet. The highest point of the boulder was about 8 feet. Upward bending and breaking of longitudinals near the after end of the tank between frames Nos. 12 and 13 resulted in the second 10.9 feet of vertical damage. In starboard ballast tank No. 2, frames Nos. 15 and 17 near the middle of the tank sustained deformation up to about 15 feet. There were two locations in the forward part of starboard cargo tank No. 3, between frames Nos. 23 and 24 and Nos. 24 and 25, where the vertical damage reached 9.9 feet. The maximum vertical damage in center cargo tank No. 3 was 9 feet in the forward part of the tank between frames Nos. 23 and 24 and Nos. 24 and 25. The vertical damage in the other cargo tanks ranged from less than 1 foot to 8 feet in a few locations.

The center vertical keel had broken loose from the after bulkhead of center cargo tank No. 2 from the tank bottom to a height of about 9 feet, and a small crack in the weld extended to a height of about 11 feet. On the other side of this bulkhead, which was the forward bulkhead of center cargo tank No. 3, the center vertical keel had broken loose from the bulkhead from the tank bottom to a height of about 9 feet.

There was no damage to the port tanks and except for the after part of the void under the starboard slop tank, which is outboard of the pumproom, all damage occurred forward of the pumproom.

Other Damage

Most of the loss of cargo from the EXXON VALDEZ occurred during the first 8 hours. Initial measurements by the chief mate about 30 minutes after

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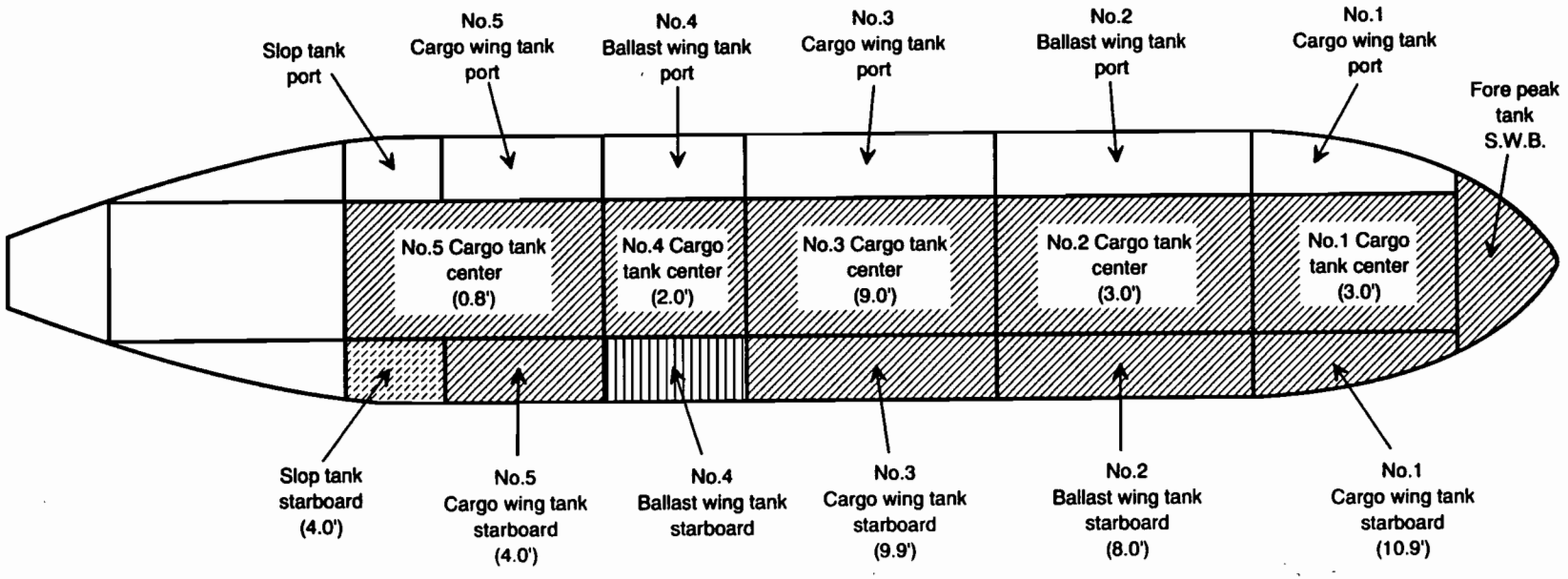
[10] Ribs or girders extending transversely from side to side of the hull and from the keel to the highest continuous deck.

[11] Structural members, or girders, running fore and aft.



Breached tanks (Max. vertical damage)

Flooded due to internal damage

Only void below (slop tank was breached)

Not to scale

Figure 8.--Plan view showing damaged tanks.

the grounding indicated that 115,000 barrels of the 1,263,000 barrels loaded had been lost. These calculations were based on gauge readings made in the cargo control room. By 0600, gauge readings indicated about 215,000 barrels had been lost.

On the morning of March 25, ullage measurements[12] were taken of all cargo tanks, the forepeak tank, and the ballast tanks. The ullages showed that considerable cargo had been lost from all center cargo tanks and from starboard cargo tanks Nos. 1 and 3. The ullage readings also revealed that there was a substantial amount of water in the bottom of these tanks. In addition, three previously empty ballast tanks, the forepeak tank, starboard tank No. 2, and starboard tank No. 4, were found to contain oil as well as water. The changes in the cargo and ballast tanks by the morning of March 25 are shown in the following tables:

Table 1.--Barrels of cargo lost from damaged cargo tanks.

Tank No.	Cargo departing Valdez	Cargo after grounding	Cargo lost from tanks
1 Center	136,061	82,870	53,191
1 Starboard	60,257	36,552	23,705
2 Center	172,095	111,092	61,003
3 Center	189,441	124,200	65,241
3 Starboard	107,107	62,397	44,710
4 Center	79,051	70,910	8,141
5 Center	173,132	124,490	48,642
5 Starboard	61,978	44,790	17,188
Total			321,821

Table 2.--Barrels of cargo gained in damaged ballast tanks.

Tanks	Cargo gained
Forepeak	30,428
No. 2 Starboard	65,645
No. 4 Starboard	935
Total	97,008
Net Loss	224,813 (by March 25, 1989)

A rupture in the forward bulkhead of center cargo tank No. 1 allowed oil from that tank to enter the forepeak tank. Ruptures in the after bulkhead of starboard cargo tank No. 1 and forward bulkhead of starboard cargo tank No. 3, together with the separation of the starboard longitudinal bulkhead from the bottom plating in tanks Nos. 1, 2, and 3, permitted oil to enter No. 2 starboard ballast tank. The holes in the bottoms of the center cargo tanks also may have contributed to the oil gained in the forepeak tanks and

[12]Measurements from the deck or top of the cargo hatch down to the level of the cargo. Also called outages.

starboard ballast tank No. 2. There was some loss of cargo after the ullage measurements on March 25. Exxon calculated that the total cargo lost was about 258,000 barrels. The value of the lost cargo was estimated at $3.4 million. Exxon expended approximately $1.85 billion on cleanup operations in 1989.

Crew Information

Master.--Personnel records provided by Exxon show that the master of the EXXON VALDEZ, age 42, received a Bachelor of Science degree in Marine Transportation from the State University of New York Maritime College in May 1968. At that time he also received a Federal license, which qualified him to serve as a third mate of steam and motor vessels of any tonnage upon oceans.

He was employed by Humble Oil and Refining Co. (the predecessor company of Exxon Shipping Company) as a third mate on June 10, 1968. During his career with Humble/Exxon, he took numerous marine courses sponsored by Exxon. He upgraded his license to second mate in 1971, to chief mate in 1973, and to master in 1977, making him eligible for promotion to the level of the respective licenses. He obtained a Federal pilotage endorsement to his master's license for Prince William Sound between Cape Hinchinbrook and Rocky Point in Alaska in 1987. He was promoted to second mate in 1978, to chief mate in 1979, to relieving master in early 1979, and to master in 1980.

Since his promotion to master, he had served on nine tankships with no breaks in service except for authorized leave periods. He had served as the alternate master on the EXXON VALDEZ since 1987 and had worked in the Alaskan trade for about 10 years (during this period, the master made well over 100 round trips through Prince William Sound).

Submissions by Exxon provided a seriatim ranking of the master in comparison with other Exxon masters from 1981 to 1988. These rankings are as follows:

Year	Rating/group size	Percentile (100 equals the highest possible ranking)
1988	23/38	39
1987	24/29	17
1986	35/37	5
1985	35/37	5
1984	24/34	26
1983	29/33	12
1982	35/39	10
1981	25/36	36

Each year's ranking was for the performance period of the previous year. The EXXON VALDEZ in the West Coast Fleet and the EXXON GALVESTON in the Gulf Coast Fleet were selected as the best performing vessels in 1987. In 1988 the EXXON VALDEZ was the sole winner of this award. The master was one of

two masters of the EXXON VALDEZ when the vessel was judged to be the best performer in the fleet in 1987 and 1988.

In addition to the employment history shown in Exxon and Coast Guard records, the master told Safety Board investigators that he had served as a lightering superintendent in the Gulf of Mexico for about 3 1/2 months and had acquired additional seagoing experience in the Esso foreign flag fleet.

Additional employment information on the master is contained in appendix C.

About 13 hours before the accident, the master, accompanied by the chief engineer and the radio electronics officer, went ashore while the EXXON VALDEZ was loading cargo at the Alyeska Marine Terminal. The Alyeska security logbook shows that they departed the terminal gate at 1059. They were met by the ship's agent, who drove them to the agent's office at Alaska Maritime Agencies, Inc., in Valdez. The agent's supervisor recalled that the three men arrived shortly after 1100 and that the master and chief engineer conducted routine ship's business in a meeting that lasted about 45 minutes. The agent informed investigators that the master seemed "more relaxed" than when she had seen him on previous trips. She explained by saying that she had worked with the master for 8 to 10 years. After the meeting, the pilot who had conducted the inbound transit of the vessel to Valdez picked up the three men at the agent's office in his automobile and drove them to a nearby restaurant, where the four had lunch together. The chief engineer said that they spent about 1 1/2 hours at the restaurant. The chief engineer and the radio electronics officer told investigators that the master and pilot had nonalcoholic beverages with their lunch. However, the master told the Coast Guard investigating officer that he had had a beer at lunch.

After lunch, the pilot drove the three men to a small shopping center, and the three separated to run personal errands. The three men had agreed to meet again at a town bar later in the afternoon. Safety Board investigators located a gift store where the master had ordered flowers sent to his family. The owner of the gift shop recalled having a pleasant conversation with the master and stated that he did not appear to have been drinking. The chief engineer recalled walking to several newsstands, looking unsuccessfully for a newspaper, and then going to the bar, arriving alone about 1600. He said that the master arrived about a half hour after he did. However, the master told the Coast Guard investigator that he arrived at the bar about 1500. The radio electronics officer said that when he arrived at the bar about 1630, the master and chief engineer were already there. According to the radio electronics officer, they played darts with local residents and otherwise enjoyed themselves while each purchased one or more rounds of drinks. The radio electronics officer said that he drank beer while the master was drinking a "clear" beverage and the chief engineer was drinking gin and tonic. The chief engineer told Safety Board investigators that he had three gin and tonics and that he did not recall how much the master had.

The chief engineer said the three men left the bar about 1900 and returned to the restaurant where they had had lunch. They ordered two pizzas to take back to the ship and then went next door to an adjacent bar to await

the preparation of the pizza. The chief engineer and the radio electronics officer in separate interviews agreed that each man, including the master, had one drink while they waited. The radio electronics officer stated that he believed the master had a vodka while they waited. The chief engineer said that about 1930 their pizza order was ready and they called a cab to return to the ship.

According to the cab driver who transported them back to the Alyeska terminal, a fourth person from an ARCO tanker joined them in the cab for the trip to the terminal. He said that no one in the group appeared to be "under the influence of alcohol." The security log at the terminal gate showed that the cab arrived there at 2024. Terminal security officers stated that all persons arriving in cabs were required to check in to the office and walk through a metal detector and that they did not believe any of the men arriving at that time were intoxicated. The cab was permitted to proceed to the dock without delay.

The chief engineer said that they had expected the vessel to depart later in the evening and were surprised that it was ready to get under way. He also said that during the afternoon, the master had discussed the presence of ice in the traffic lanes and was considering delaying departure until daylight.

According to the radio electronics officer, the three men boarded the ship together. The ship's agent was aboard the vessel in the wheelhouse when the master arrived. She said that she met with him there to discuss cargo and ship's fuel. She said that he was in a good mood and did not appear to be intoxicated, although his eyes were watery. The agent and the master agreed that they would talk further on the VHF/FM radio to confirm cargo quantities after the vessel got under way.

The pilot conducting the outbound transit from the Alyeska terminal told Safety Board investigators that he smelled alcohol on the master's breath when the master returned to the ship from Valdez. However, it was his impression that the master's behavior and speech were unimpaired. The pilot said that the master left the bridge after they had gotten under way and remained away until the pilot called him shortly before disembarking at Rocky Point. The pilot said that the master returned to the wheelhouse soon after the call, and he estimated that the master had been gone for about 1 1/2 hours. The pilot stated that he again smelled alcohol on the master's breath, but the master's speech and behavior gave no indication of impairment.

Both the XO and the SIO of the MSO who boarded the vessel after the accident about 0335, smelled alcohol on the master's breath when they met with him on the bridge. The investigating officer described the odor as the very strong smell of "stale" alcohol. In response to a question about the smell of alcohol, the master explained to the investigating officer that he drank two Moussy beers (.05 percent alcohol) after returning to the vessel from Valdez. The investigating officer reported finding two empty Moussy beer bottles in a wastebasket in the master's stateroom.

The XO reported to the Commanding Officer (CO) of the MSO that the master smelled of alcohol, and he requested that someone be sent to the vessel to conduct toxicological testing. The CO then contacted an Alaska State trooper by telephone and requested him to proceed to the vessel to conduct the testing. However, when the trooper arrived about 0630, he had no equipment to conduct any testing or to collect urine specimens for subsequent testing. The XO again called the CO to request someone to conduct the testing. During a later telephone conversation, the CO suggested that the XO check with the master to ascertain if the vessel carried any equipment for collecting toxicological samples. About 1000, the Coast Guard officers learned that kits for obtaining toxicological samples were on board the vessel, and urine specimens were obtained soon thereafter from the third mate and the two ABs on watch when the grounding occurred. The master also was asked to provide a urine specimen at this time, but he said he was unable to urinate.

Meanwhile, ashore, a Coast Guard medical technician from Anchorage, Alaska, who had been conducting an inspection of health records of the MSO, was located at the airport about 0830 and instructed to proceed to the vessel to take blood and urine samples. About 1030, the Coast Guard medical technician boarded the vessel to obtain blood samples for toxicological testing. The master was selected to provide the first blood sample. At this time the master also provided a urine specimen. Blood samples also were taken from the third mate and the two ABs. At this time it was discovered that the urine specimen earlier provided by the AB on lookout was not sealed correctly, and she provided a second specimen.

The results of the toxicological testing by Chem West Laboratories, Inc., of Sacramento, California, of the samples collected on March 24, 1989, are shown in the following table:

Table 3.--Toxicological testing results

	Blood		Urine	
Position	Time	% Ethanol	Time	% Ethanol
Master	1050	0.061	1000[13]	0.094
Third Mate	1100	0	1000	0
Lookout	1140	0	1145	0
Helmsman	1115	0	1000	0

Portions of the blood and urine specimens provided by the master were sent to the Center for Human Toxicology (CHT) for an independent ethanol analysis. The CHT measurement showed the blood contained 0.06 percent ethanol and the urine contained 0.1 percent.

[13]Although the sample container was marked 1000, the urine specimen probably was taken about 1050.

The president of Exxon Shipping Company testified that the master, while on leave, had entered a hospital for treatment of an alcohol problem and that the company learned about the master's hospitalization when a shoreside manager attempted to contact the master. Exxon provided investigators limited medical records for the master's treatment. An Exxon Individual Disability Report, signed by the attending physician and dated April 16, 1985, showed that the master was admitted to a hospital on April 2, 1985, and "remains in residence at the present time." The report stated: "He is a 38 yo W/M who has been depressed and demoralized; he's been drinking excessively, episodically, which resulted in familial and vocational dysfunction." A treatment program was suggested that included a recommendation that he be given a leave of absence to get involved in Alcoholics Anonymous (AA), psychotherapy, and aftercare. The report indicates his first day of disability was April 1, 1985. Further documents show that the master was on sick leave from April 1, 1985, through May 15, 1985, and that disability was terminated on May 16, 1985, at which time he was placed on leave of absence for 90 days starting on May 16, 1985. Exxon did not provide documentation to indicate when he was granted sick leave or what followup monitoring was provided.

The master had made no claims for medical care or health services with the Exxon health care contractor during the last year of his employment before the accident.

The president of the Exxon Shipping Company testified that a fleet manager and a ship group coordinator were given the responsibility to follow up on the master after he was returned to duty following his hospitalization in 1985. According to this testimony, the followup consisted of visits by the ship group coordinator to the master's vessel in the west coast ports of San Francisco and Long Beach about every 2 weeks. The president testified, "I think he [the master] felt he was the most scrutinized employee in our company. I think he felt a little uncomfortable with it."

Early in the investigation, an Exxon representative said the company could find no documents covering this followup period. Exxon later provided documents that included a memorandum dated June 27, 1988, initialed by the master's shoreside supervisor at the time, regarding the master's performance. In this memorandum, the master was complimented for his professional expertise, leadership, and interdepartmental cooperation. Exxon also provided an unsigned and undated document that discussed the supervision of the master during his rehabilitation from October 1985 to April 1987. This document was developed from memory, after the accident, by a former shoreside supervisor of the master. The frequency of the visits and the outcome of these visits were not detailed in the document, except for a statement that no evidence of alcohol use by the master could be found and that it was concluded that he was "clean."

The Safety Board made a 50-State search of the National Driver Register (NDR) to investigate the master's driving record. This check revealed that the master had one "driving while intoxicated" (DWI) conviction in Huntington, New York, in 1985, and a second DWI conviction in Conway, New Hampshire, in 1988. The police report for the first DWI conviction showed

that on September 21, 1984, he ran a red light, struck another vehicle, and left the scene without providing information to the driver of the other vehicle. The investigating police officer subsequently met the master in the driveway of his residence and reported that the master smelled strongly of alcoholic beverage, was unsteady on his feet, and that his speech was slurred. The master refused to take a Breathalyzer test. The master's second DWI conviction, on September 15, 1988, resulted from his being stopped for driving 44 mph in a 30 mph zone. The reporting officer reported that he smelled strongly of alcoholic beverage, had difficulty getting his driver's license out of his wallet, and was unsteady on his feet. The master submitted to a Breathalyzer test that gave a blood alcohol level of 0.19 percent.

The chief engineer and the radio electronics officer stated that the master was going through divorce proceedings at the time of the accident. The radio electronics officer on the EXXON VALDEZ stated that the master appeared to undergo noticeable changes in mood.

The radio electronics officer said that he witnessed the master drinking alcohol on board the EXXON VALDEZ during the last voyage of the vessel at the end of February 1989. The master had called him about a design for a ship's T-shirt, and in the course of the conversation, the master asked him to come to the lounge to "destroy a bottle." When the radio electronics officer arrived, the third mate was already there and the master removed a bottle or a flask from his jacket. Soon thereafter, the master sent the third mate to the galley for some ice, and the radio electronics officer went to bring some orange juice to the lounge. He said that the chief mate came into the lounge while the drinking was going on but did not participate. According to the radio electronics officer's recollection, the incident took place in the morning or early afternoon. The radio electronics officer said that one or two other persons were in the lounge watching a concert video, but he could not recall who they were. He said that the bottle was placed on the deck while he, the master, and the third mate watched the video. He did not recall tasting alcohol in any beverage he drank during the incident. He said the contents of the bottle were clear. It was his impression that the master had been drinking before he was called to the lounge, but no one appeared to be intoxicated during or after the incident.

Third Mate.--The third mate told Safety Board investigators that he had begun sailing in 1977 on National Oceanic and Atmospheric Administration (NOAA) vessels as an ordinary seaman after having worked several years as a shipfitter and a hull inspector. He said that he had served 3 years on NOAA vessels and in 1980 had begun sailing with Exxon as an AB. Coast Guard records for his sea duty with Exxon show that he worked as an unlicensed seaman from December 1980 to January 1987, principally as an AB. The third mate said he had attended a Page Navigation School course in New Orleans to prepare for the third mate's license examination. He obtained a third mate's license in March 1986. Since January 1987, he had served as third mate on five Exxon vessels with no breaks in service of more than 3 1/2 months. He told investigators that he had made six round trips to the port of Valdez with the current master and had served one previous tour on the EXXON VALDEZ. Company records show that he joined the vessel on February 20, 1989. He

obtained a second mate's license on January 12, 1989. Information provided by the company showed that the third mate had made 18 voyages through Prince William Sound, but the information did not indicate how many were as an AB and how many were as an officer.

Exxon provided four performance appraisals for the third mate to the Safety Board. The lowest rating given to the third mate was in 1986 while he was serving as an AB on the EXXON JAMESTOWN; it was "above normal" in the rating category of "Steers In Confined Waters." The same rating category was "outstanding" on two earlier appraisals of his service on the EXXON NORTH SLOPE. The third mate's overall performance as an AB was rated as "outstanding" on three of the Exxon performance appraisals.

In one performance appraisal as a third mate, his "overall effectiveness" had been evaluated as "high," one rating below "outstanding." The two lowest ratings he received as a third mate were given to him while he was on the EXXON JAMESTOWN in 1987 and contained the following comments: "performs adequately" in the rating categories of "seeks advice or guidance at the appropriate time and informs supervisor when appropriate" and "demonstrates thorough knowledge of ship and its handling characteristics." In a summary of employee weaknesses, the evaluator wrote, "He [third mate] seems reluctant or uncomfortable in keeping his superior posted on his progress and/or problems in assigned tasks."

During the third mate's initial interview by the Coast Guard investigating officer, he stated that he began work on March 23, 1989, at 0800, had a "cat nap" at 1330, relieved the chief mate for supper and worked thereafter until the grounding. He testified that he had been on watch when the EXXON VALDEZ approached the terminal dock on the day preceding the accident. The third mate said that after his watch ended, he had a brief conversation with the chief mate about how he [the chief mate] "starts up the cargo." He also testified that he had gotten to sleep at 0100 and was called at 0720 for his watch on the morning of March 23.

The crew on the EXXON VALDEZ did not normally break sea watches while they were transferring cargo or ballast. Since the chief mate oversaw cargo handling operations, the second mate and the third mate stood watch extra hours to enable the chief mate to rest. The second mate said that in addition to relieving the chief mate, the two mates tried to "cover one another when needed." The second mate told Safety Board investigators that on this trip to Valdez, the two mates began their extended watches at midnight on March 23. He indicated to Safety Board investigators on board the vessel on March 26, 1989, that he and the third mate essentially stood watches 6 hours on and 6 hours off during cargo operations.

The third mate testified that he went to the engineroom to conduct a "salinity test" after lunch on March 23 and then went to his room for a nap between 1300 and 1350. According to the testimony of an Exxon Seaman's Union officer, it was "common practice for the mates off watch to assist in the cargo operations." The pumpman told Safety Board investigators that he had seen the third mate walking forward on the main deck early during the afternoon watch on the day preceding the accident.

At 1700 on March 23, the third mate relieved the chief mate for the evening meal, and about 1730, he was in turn relieved by the chief mate. About 1800, he assisted the chief mate with completing the cargo loading. The third mate checked navigation gear on the bridge about 1848 and remained on the bridge until he was relieved by the chief mate, probably sometime prior to 1900. The third mate was next reported by an AB as standing by at his usual location at the aft mooring lines during undocking about 2100. The third mate then returned to the pilot house about 2150 to relieve the chief mate. He said that he relieved the chief mate early because the chief mate had been up for a long time and needed rest. The pumpman who met and talked briefly with the third mate immediately before he returned to the bridge stated that the third mate appeared to be fatigued. Another AB also told Safety Board investigators that he had heard on the night of the grounding that the second mate was tired and this explained why the third mate had remained on watch after midnight. The third mate remained on duty until sometime after the Coast Guard boarding officers arrived about 0335.

Helmsman.--Coast Guard records show that the AB serving as helmsman when the grounding occurred had obtained his first seaman's document in 1965. Between 1965 and 1970, he had acquired only 25 days of documented marine work, all of which was in the steward's department for Boatel, Inc., an offshore catering company. The helmsman had no further documented shipping time until he began working for Exxon in April 1975. He initially worked in the steward's department on Exxon vessels for about 1 year and then began working regularly as an ordinary seaman. He obtained a lifeboatman endorsement in April 1980 and an unlimited AB rating in October 1981. Coast Guard records indicated that he had worked each year without remarkable breaks in service except in 1978 and 1987, when he sailed 1 month and 1 1/2 months, respectively. Since joining Exxon, he had served on 19 vessels, including the EXXON VALDEZ.

Since acquiring his AB rating, the helmsman had acquired about 7 1/2 months of documented time as an AB, according to Coast Guard records. Those records show that the helmsman had worked primarily as an ordinary seaman and in other unrated positions. On January 18, 1989, he was assigned to the EXXON VALDEZ as an AB.

Exxon provided seven performance appraisals for the helmsman from February 1986 to August 1988. No performance appraisal for the helmsman referred to an AB-specific job classification, and for the corresponding periods in Coast Guard records he was shown as an ordinary seaman. Five performance appraisals were for the position of maintenance seaman,[14] one was

[14]Maintenance seaman is a designation for a crewman having cross responsibilities in deck, engine, and steward's departments.

for ordinary seaman corrected to read "MS," and one was for wiper.[15] Safety Board investigators could not locate any Coast Guard record for the periods during which the helmsman was evaluated as wiper.

The performance appraisals for the helmsman included at least one evaluation from the deck, engine, and steward's departments. In May 1986, he received ratings from a chief mate with whom he had worked on two vessels successively. This evaluator indicated a "cannot rate" for the "steers in confined waters" category and commented that the helmsman "needs to practice [helmsmanship] before sailing AB." The chief mate listed the helmsman's strengths as "a hard worker who was thorough in cleanup operations" but stated "[the helmsman] must prove himself capable [of an AB's position] by steering in confined waters ... and other skills required of an AB." A chief mate on the EXXON NEW ORLEANS rated the helmsman as a "normal" overall performer but commented that "[he] must concentrate more on the task at hand." In 1987, the helmsman's performance appraisal on the EXXON CHARLESTON included an "above normal" for the category "steers in confined waters" with the comment, "steers well to pilot's orders." The chief mate commented that "[he] is not ready at this time to sail as AB." In January 1988, the first assistant engineer on the EXXON BALTIMORE rated him less than the midpoint for overall performance, "needs improvement." The helmsman noted on the same performance appraisal that his ambition was to "sail on my AB's papers and/or obtain my oiler's endorsement and sail in the engine department." The helmsman also received a performance appraisal for his duties in the steward's department on the EXXON BALTIMORE and was given an overall assessment of "generally meets requirements," a midpoint rating. In August 1988, the helmsman received a performance appraisal for his maintenance duties in the engine department on the EXXON BALTIMORE and was rated with an overall assessment of "generally meets requirements."

The helmsman indicated that from March 17 through March 23 he had experienced a normal routine at sea, adhering to 4-hour watches with the customary 8 hours off. The helmsman indicated that he usually slept from about 0400 until called some time after 1100 in time for lunch before his afternoon watch. After the watch, he remained awake to eat supper about 1700 and then returned to his room to sleep about 1800 until called at 2320 for the next morning watch. He indicated that on March 23, he obtained his usual sleep between the morning watch and an unusually early call for lunch at about 1030. He then worked from noon to about 1600 loading cargo, ate supper, and went to bed. The helmsman indicated that he assisted during the undocking from the terminal from about 2000 until 2200. He indicated that he returned to his room for a nap until called for watch at 2320. The helmsman declined most voluntary opportunities to work in excess of 8 hours a day.

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[15] An entry-level position in the engineering department on board a merchant ship. A wiper assists in the performance of general work in the engineroom and is so named because he is commonly occupied in cleaning machinery, etc.

Operations Information

The EXXON VALDEZ was one of two very large crude carriers designed for transporting Alaska North Slope crude oil from Valdez, Alaska, to Panama for transshipment by pipeline to other tankships on the Atlantic side of Panama. Beginning in 1988, the vessel was used primarily for carrying reduced loads of North Slope crude oil to the West Coast ports of Long Beach and San Francisco, California.

Minimum manning for the EXXON VALDEZ, according to the vessel's Certificate of Inspection issued by the Coast Guard, was 15 persons as follows:

Master	1	Chief Engineer	1
Chief Mate	1	First Assistant Engineer	1
Second Mate	1	Second Assistant Engineer	1
Third Mate	1	Third Assistant Engineer	1
Radio Officer/Operator	1		
Able Seaman	3		
Maintenance Persons[16]	3		

The Coast Guard allowed the vessel's operator or owner to determine the number of persons comprising the steward's department.

The normal complement on the EXXON VALDEZ was 19 persons, including the master. In addition to the crewmembers listed in the Certificate of Inspection, the crew normally included two cooks and two qualified members of the engineering department (QMEDs). One QMED was assigned as the pumpman. At the time of the grounding, there was an additional QMED on board, for a total of 20 persons. A relieving QMED had reported on board, but the QMED who was to be relieved desired to remain on board for one more trip and was allowed to do so.

The chief mate was assigned to the 4-to-8 watches, the second mate to the 12-to-4 watches, and the third mate was assigned to the 8-to-12 watches. Two ABs were assigned to each watch. In addition to their navigation watchstanding duties, each mate was responsible for supervising cargo/ballast operations during his watches in port. The chief mate had overall responsibility for loading and discharging cargo and ballast and was

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[16] Maintenance persons are designations for positions in a "Maintenance Department" that had not been fully implemented in the Exxon fleet. The department, when implemented on the EXXON VALDEZ, was to consist of three able seamen, although two ordinary seamen could be substituted for two ABs, provided the ordinary seamen were specially trained. The department had not been implemented, according to Exxon, because concurrence of the unlicensed employees labor union (Exxon Seamen's Union) had not been negotiated. The Coast Guard, pending implementation of the Maintenance Department, had directed that ABs would be required in lieu of the specially trained ordinary seamen. Special training for the ordinary seamen was to consist of a period of vessel indoctrination.

present during starts and stops. He was also responsible for the maintenance of the vessel, including directing the deck maintenance work of the ABs during the working day at sea from 0800 to 1700. The second mate was responsible for ensuring that the vessel's navigation equipment was operating satisfactorily, that all necessary charts and navigation publications were on board, and for correcting the navigation charts. The second mate was also responsible for ordering food and supplies for the ship. The third mate was responsible for all emergency equipment, including lifesaving and lifeboat equipment and firefighting equipment.

The engineroom was approved by the Coast Guard for periodic unmanned operation. Thus, watches were not normally stood in the engineroom while the vessel was under way at sea. From 0800 to 1700 at sea, engineering department personnel were in the engineroom, except on Sundays, performing maintenance work. After 1700, one engineer was assigned as the duty engineer and responded to any equipment malfunction alarms that might sound between 1700 and 0800. Another engineer was assigned as the alternate duty engineer and was responsible for tank soundings, checkoff lists, and logs, as well as for assisting the duty engineer as needed. Watches were stationed, however, while the vessel was operating in confined waters, such as entering and leaving port.

An engineering watch consisting of the first assistant engineer was stationed in the engineroom before the vessel's departure from the Alyeska Marine Terminal on March 23. The chief engineer also was in the engineroom. The chief engineer stated that he was not on watch and that his presence in the engineroom was not required, but that it was his custom to be there when the vessel was entering and leaving port. The first assistant engineer was being relieved by the third assistant engineer at the time of the grounding.

Two Federal statutes, one pertaining to rest for the navigation watch officer and one pertaining to watchstanding, applied to the EXXON VALDEZ crew. Title 46 U.S.C. 8104(a) identifies an interval of off-duty time required for deck officers before leaving port:

> (a) An owner, charterer, managing operator, master, individual in charge, or other person having authority may permit an officer to take charge of the deck watch on a vessel when leaving or immediately after leaving port only if the officer has been off duty for at least six hours within the 12 hours immediately before the time of leaving.

Title 46 U.S.C. 8104(d) identifies conditions for work in excess of 8 hours in 1 day for licensed personnel or seamen:

> (d) On a merchant vessel of more than 100 gross tons ...the licensed individuals, sailors, coalpassers, firemen, oilers, and water tenders shall be divided, when at sea, into at least three watches, and shall be kept on duty successively to perform ordinary work incident to the operation and management of the vessel.... A licensed individual or seamen in the deck or engine department may not be required to work more than eight hours in one day.

A Coast Guard representative from the Merchant Vessel Personnel Division of Coast Guard Headquaraters testified that this statute is intended to "ensure that the individual has adequate rest or at least has the opportunity for adequate rest." He attributed responsibility for compliance with the statute to a vessel's operating management. An Exxon spokesperson, who had previously sailed as a master of Exxon tankships, testified that the company does not have any program to give 6 hours of rest to any deck officer before getting under way. He stated that it was the master's responsibility to ensure that the officers obtained appropriate rest. He also said that on vessels under his personal command, he would stand a bridge watch after departure until someone had had "enough rest" to assume the watch.

Safety Board investigators obtained information about procedures for reducing traditional crew complements on U.S. merchant vessels from interviews with several Coast Guard officers working in supervisory positions in the offices of the Merchant Vessel Personnel Division at the Coast Guard's Washington, D.C., headquarters. Similar information was obtained in testimony from the Coast Guard civilian witness from the Merchant Vessel Personnel Division during the Safety Board's public hearing into the accident. According to these sources, the manning levels on reduced crew vessels in the Valdez trade were typical of manning levels on tankships throughout the U.S. fleet. They stated that the current crew levels were the result of a gradual reduction in crew size since World War II, coinciding with the increase in reliability of automated monitoring and controlling systems.

The Coast Guard officers said that the Coast Guard has responsibility for balancing minimum manning levels between the realities of commercial maritime economics and the need for vessel safety. They defined "minimum crew level" for any given vessel as a crew complement that cannot be further reduced and still provide for the safe operation of the vessel, and it is this level that is indicated on each vessel's Certificate of Inspection. The officers explained that there is no standard for determining the manning of merchant vessels and described their conception of reduced crew levels as complements that are "appropriate to the vessels" rather than as "reduced manning" levels. The civilian witness referred to the term "reduced manning" as a misnomer. Instead, he said that the Coast Guard is trying to set "designed manning" or "proper manning."

The Coast Guard officers referred to eight factors that are considered in setting minimum manning requirements:

(1) emergency situations (used more frequently for passenger vessels, where the crew is required to assist passengers with abandon ship duties),

(2) size and type of vessel,

(3) equipment installed on the vessel,

(4) proposed routes of operation, including frequency of port calls (longer trips permit more maintenance and crew rest after peak workload times during cargo handling),

(5) type of service in which vessel is employed,

(6) degree of automation,

(7) use of labor-saving devices, and

(8) organizational structure of the vessel, such as whether there is a maintenance department of persons that could be assigned to duties in the deck or engineroom spaces at the discretion of the master.

According to the Coast Guard Officers, the Coast Guard reviews of minimum crew levels have not been limited to these factors, and no single factor must be considered, according to statute. The Coast Guard officers said that although each vessel must be evaluated individually when several vessels are similarly equipped with automation, evidence of successful operation for one ship can be used in support of minimum crew complements for the newer vessels of the same class. According to the Coast Guard officers, the most important factor used for determining minimum manning levels is the type of equipment installed on board the vessel and its operational reliability. They said that as a general rule, the greater the automation of installed equipment on vessels, the lower the crew complements are for operation of those vessels.

In addition, the Coast Guard officers said that minimum manning for any vessel should always be based on the minimum number of persons required to accomplish essential work tasks under the most serious conditions that could reasonably be encountered, i.e., a "worst case analysis." The civilian witness elaborated on this factor as follows:

> [Coast Guard concern is for] the ability of the ship ... to react to emergencies that we can anticipate. Are there enough people to fight a fire within the limits that we feel a crew should be able to fight. Are there enough people to set watches, [and] additional people in the watches so that if we are in reduced visibility for an extended period of time, [we can] have an augmented bridge watch.... If the automation in the engine room failed, can we set up engineroom watches.

According to the civilian witness, the Coast Guard does not consider adequate maintenance of shipboard equipment as a criterion for determining manning levels. Similarly, in his view, inadequate maintenance is not necessarily indicative of an undersized crew. He explained that maintenance on reduced crew vessels may be the responsibility of temporary riding crews or contractors who are hired by the ship operators and are aboard the vessels only to perform required maintenance tasks.

Coast Guard officers indicated that a review to determine the minimum crew complement for any given vessel normally begins with a shipowner's request in writing submitted to the Officer in Charge of Marine Inspection (OCMI) in the local MSO. The request letter serves as a formal proposal indicating the shipowner's preference for the minimum crew complement on the vessel under consideration. The OCMI is required to refer the review process to Coast Guard headquarters. Normally, when the OCMI makes his referral, he includes his own recommendations for the change in manning and forwards the requested recommendations and supporting documents with his recommendation via the District Commander to the Vessel Manning Branch of the Merchant Vessel Personnel Division at Coast Guard headquarters.

Coast Guard officers in the Vessel Manning Branch typically begin their review of requests for reduced manning with a determination of whether the requested manning is consistent with existing Federal statutes (46 U.S.C. 8104), Coast Guard regulations, the Marine Safety Manual Chapter 23, and Coast Guard policy. Then they consider supporting documentation submitted with the shipowner's request, including identification of equipment installed on the ship, maintenance records, and overtime information about the crew. If the vessel is new, it is initially manned with a traditional complement regardless of the reduced-crew manning that was intended when the vessel was designed. The traditional complement, excluding the steward's department, includes six ABs, three QMEDs, and eight licensed officers. Next, a Coast Guard officer is assigned to ride the vessel for one trip to evaluate the performance of the new vessel with the traditional crew complement. After the new ship has completed one or more voyages, the Coast Guard tentatively implements the shipowner's proposals for crew reductions or crew adjustments. A distinction is made between reductions and adjustments. A reduction takes place when the total complement of crew is reduced in number, and an adjustment occurs when the descriptions of crew duties and crew qualifications are changed, such as the creation of a maintenance department consisting of ordinary seamen in place of able seamen. When the new vessel has been operating with a reduced crew for several trips, a Coast Guard officer rides the vessel again, evaluating the crew's activities and the reliability of the automated systems that were intended to enable the reduction. When this evaluation is complete and indicates that the reduced crew is sufficient, the Vessel Manning Branch transmits its approval through the District Commander to the OCMI who initiated the review. The OCMI then implements the approval for the intended minimum manning requirement in the Certificate of Inspection issued for the vessel. During the public hearing, the civilian witness said that Coast Guard followup for monitoring reduced crews is accomplished during a reconsideration of the Certificate of Inspection every 2 years and by the midyear (off-year) inspection to ensure that all automation is operating correctly.

The Coast Guard officers were asked about the value of crew overtime records as an accurate and meaningful measure of crewmember workload. They

stated only that it was necessary to distinguish between penalty time[17] and overtime paid for work in excess of 8 hours for this information to be used effectively in the evaluation process. Safety Board investigators asked the officers about Exxon's alleged manipulation of records that supported its reduced manning requests (i.e., minimizing overtime and deferring maintenance during the evaluation period). The officers said that evidence of these practices was provided to the Coast Guard by the Exxon Seamen's Union after the grounding of the EXXON VALDEZ. (The evidence consisted of three Exxon memoranda from a ship group coordinator (a shoreside manager) to the masters of four tankships directing that overtime be curtailed until after the Coast Guard had completed a review of the workload on certain vessels to determine whether reduced manning in the enginerooms of those vessels was justified. These memoranda were marked for distribution to other Exxon managers.) As a result, the Vessel Manning Branch is now requiring masters and chief engineers to include an additional letter with their documentation of overtime certifying that the records are "representative."

The Coast Guard officers interviewed by Safety Board investigators said that both the EXXON VALDEZ and her sister ship, the EXXON LONG BEACH, were designed to operate with smaller crew complements than ships of earlier vintage. The officers explained that the crew reductions were possible primarily due to the installation of "automated systems" in the engineroom and "labor-saving devices" for the deck department. The officers said that after the EXXON VALDEZ had been placed in regular service, a revised Certificate of Inspection was issued by the San Diego OCMI at Exxon's request. This revision eliminated the three QMEDs included in the original Certificate of Inspection as part of the required "traditional" crew complement. The Coast Guard officers did not discuss personnel in the steward's department.

According to the Coast Guard officers and an official of the Exxon Seamen's Union, this deletion of the QMEDs from the Certificate of Inspection involved two departures from procedures required for reducing crew complements. First, the review for the deletion of QMEDs should have been referred to the Vessel Manning Branch at Coast Guard headquarters. Second, according to the Exxon Seamen's Union official, the deletions were linked to the company's request to obtain periodically unmanned status for the engineroom. According to the union official, the company's rationale for the deletions was that since watches were no longer required for operation of the machinery spaces and all engine department personnel were placed on day work, QMEDs were unnecessary crewmembers and should be deleted from the Certificate of Inspection. Correspondence provided to Safety Board investigators by the Coast Guard and the Exxon Seamen's Union indicated that the Vessel Manning Branch had upheld the original decision of the OCMI to delete the QMEDs from the Certificate of Inspection. The union official

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[17] Penalty time is a rate of extra pay for watchstanding during weekends and holidays or for performing certain duties determined to justify an overtime rate. Hence, penalty time has little impact on the Coast Guard evaluation process to assess proper tasking of crewmembers.

said that to his knowledge, the EXXON VALDEZ continued operating with QMEDs on board regardless of the approval for their deletion.

The chief engineer on the EXXON VALDEZ testified that he was assigned to the vessel when it was delivered to the company. He said that before the present COI was issued, the EXXON VALDEZ was manned with two additional oilers [QMEDs] in the engineroom and an additional third engineer. The chief engineer testified that the crew complement was, in fact, reduced after the certification for periodically unmanned status for the engineroom was granted by the Coast Guard. He recalled that one oiler was initially removed after the certification for periodically unmanned status was obtained and that some months later, a second oiler was removed, leaving one oiler aboard. He said that a third engineer was removed from the ship 1 year after the periodically unmanned status certification. The chief engineer also testified that he had not been instructed to reduce overtime and that the Exxon management memoranda obtained by the Safety Board directing ships' officers to reduce overtime was not written by his vessel's supervisor.

The president of the Exxon Shipping Company testified that he was "comfortable" with the manning scales aboard vessels in the Exxon fleet. He identified a "national standard" for crew size on U.S. ships as 21 persons and later substantiated the assertion with a manning summary document sent to the Safety Board. He stated that newer Exxon vessels were being built with "full automation" in order to attain engineroom personnel reductions on more vessels. He characterized the Exxon policy of updating its fleet with the reductions of crew size as consistent with trends in the rest of the shipping industry. He noted that the chemical specialty vessels operated by Exxon carry an additional mate and an additional pumpman.

The president of the Exxon Shipping Company testified that the mates were considered part of management and that the management status enabled Exxon to eliminate payment of overtime for officers on Exxon vessels. He said that instead of receiving overtime pay, the mates and masters received higher base salaries to offset the loss of direct payment for overtime. He explained that the exemption of officers from overtime pay was done to put them "more on a total supervisory footing."

Exxon submitted two graphics to the Safety Board as evidence of safer operation of Exxon vessels using reduced crews. One figure showed "average manning per vessel" and "number of oil spills per vessel" plotted over time from 1974 through 1988. The second figure showed "average manning per vessel" and "injuries per million workhours" plotted over time from 1973 through 1989. No breakdown of information pertaining to training or crew composition, duty/tour length, crew overtime, age or models of shipboard equipment, or indications of specific types of casualties was indicated. (See appendix D.)

Three Exxon Seamen's Union officers expressed concern for maintenance that was being regularly deferred on Exxon vessels. One union officer said that he had great concern about work on the older ships that "just isn't being done." He explained that the deferring of work on the ships was a result of two factors: insufficient manning levels on Exxon vessels and

Exxon's intent to demonstrate to the Coast Guard by not authorizing overtime that existing manning levels include unnecessary crewmembers.

Exxon union officials testified that fatigue was reported frequently to the union by licensed and unlicensed crewmembers and that the company regularly used incentives to get crewmembers to work more than 8 hours a day. The senior union official testified that two factors were contributing to the fatigue reported by crewmembers on Exxon vessels. The first was the lengthening of the tours for crewmembers from the usual 60 days to 90 and 100 days because the company could not obtain relief seamen. He said that daily work for seamen on the reduced crew vessels often includes overtime.[18] Statements from ABs on the EXXON VALDEZ and the EXXON BATON ROUGE, which lightered the stranded EXXON VALDEZ, indicated that crewmembers worked 20 or more hours daily during routine cargo handling operations.

The senior union official identified the second major factor causing fatigue as the shortness of the trade routes, which require peak workloads for loading or discharging cargo every 4 to 5 days. He said that the current minimum crew requirements for the EXXON VALDEZ and EXXON LONG BEACH were intended for the Panamanian run from Valdez and that the length of the run to Panama provided more time for the crew to rest and perform maintenance between ports. It was his understanding that some time after the crew reductions were granted by the Coast Guard, the EXXON VALDEZ was removed from the Panamanian run and assigned to the Long Beach/San Francisco run, a run that is several days shorter.

Two research efforts were identified by Coast Guard officers for the study of reduced crews and safety, both of which were receiving Coast Guard sponsorship and partial funding. A joint U.S. Maritime Administration (MARAD) and Coast Guard study, Shipboard Crew, Fatigue, Safety, and Reduced Manning, is intended primarily to be an assessment of fatigue on merchant vessels with practical recommendations for shipping company management on how to assess crew fatigue. The work is being carried out with the Transportation Systems Center at Cambridge, Massachusetts, the principal research facility for DOT. The first of two phases has been completed and an interim report has been published in draft form, Shipboard Crew Fatigue, Safety and Reduced Manning - Draft Report: Fatigue. The next phase will involve direct assessments of crew fatigue on operating vessels.

The second study is being conducted by the Marine Board of the National Research Council and is entitled Effect of Smaller Crews on Maritime Safety. The purpose of the project is to provide the Coast Guard with guidelines for determining minimum crew complements and crew composition for merchant vessels. The advisory board or study group for the project included the president of Exxon Shipping Company, representatives from major maritime unions, and other participants. According to the director of the project,

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[18] All reference to overtime is for hours worked in excess of 8 hours per day. Payment for certain kinds of work performed on watch after normal working hours or on holidays is not included.

interim results of the study have not been made public at the time of this report.

Waterway Information

The Gulf of Alaska is located along the southern coast of Alaska and is bordered by the Alaskan Peninsula on the west and Canada on the east. Prince William Sound, which is entered through the Cape Hinchinbrook entrance, is a main artery leading northward to the port of Valdez.[19] The distance from the entrance at Cape Hinchinbrook to the terminal in Valdez is about 67 miles. Prince William Sound has a traffic separation scheme (TSS) with inbound and outbound traffic lanes from Cape Hinchinbrook to within about 6 miles of Valdez Narrows (the entrance to Port Valdez). The traffic lanes are each 1,500 yards wide from Hinchinbrook Entrance to the vicinity of Bligh Reef at the southeast end of Valdez Arm, then gradually decrease to a width of 1,000 yards at the terminus located at Rocky Point. The separation zone between the two traffic lanes is 2,000 yards wide between Cape Hinchinbrook and Bligh Reef and then gradually decreases in width to 1,000 yards and terminates at Rocky Point. The eastern perimeter of the TSS passes within 1 mile of Bligh Reef buoy.

The most restrictive section of the passage is Valdez Narrows, which is about 0.8 mile wide and about 2 miles long. Potato Point Light on the west bank and Entrance Point on the east bank mark the southern entrance to Valdez Narrows. At Middle Rock, a shoal near the north end of the Narrows, Valdez Narrows accesses Port Valdez. Valdez Narrows is restricted to one-way traffic by tank vessels of 20,000 deadweight tons or more[20] and loaded tank vessels are restricted to a maximum speed of 6 knots.[21]

Prince William Sound and Port Valdez have a diurnal range of tide of 12 feet; however, tidal currents in Valdez Arm are too weak and variable to be predictable. Depths in Prince William Sound within the TSS range from 125 to 250 fathoms (750 to 1,500 feet) from Cape Hinchinbrook to Valdez Narrows. In the Narrows, the navigable waters are less than 100 fathoms (600 feet). Depths then increase to more than 125 fathoms (750 feet) in the Port Valdez area. Alongside the Alyeska Oil Terminal berths in Port Valdez, depths range from 85 to 150 feet.

Vessels proceeding outbound from the Alyeska Marine Terminal in Port Valdez steer about 270^{0} for about 6 miles to the northern entrance to Valdez Narrows, which is marked by a navigation light on Entrance Island. The course is then in a southerly direction into the Valdez Narrows. Upon transiting Valdez Narrows, the outbound vessel enters the wider Valdez Arm and steers 219^{0}. The waterway through Valdez Arm is marked with navigation aids, and the land masses provide good radar returns for accurate radar

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[19] U. S. Coast Pilot 9.

[20] Title 33 Code of Federal Regulations (CFR) 161.370(a).

[21] Title 33 CFR 161.376(b).

navigation. Valdez Arm is about 2.5 miles wide at the start of the traffic lanes about 6 miles southwest of Potato Point and increases to about 5 miles wide adjacent to Bligh Reef buoy. Until April 12, 1989, the pilot station was located west of Rocky Point.

Busby Island Light, about 3 1/2 miles south-southwest of Rocky Point, is the next prominent fixed navigation light. Busby Island Light shows a white and red sector; the red sector shows across the area of Bligh Reef. Columbia Bay is west of the traffic lanes. Icebergs and smaller ice pieces that calve from the Columbia Glacier flow into the Valdez Arm. Bligh Reef is east of the traffic lanes opposite Columbia Bay. Bligh Reef lighted bell buoy No. 6 marks the shoals, which are east of the buoy. (The Coast Guard plans to install a tower with a navigation light, radar reflector, and a day marker to mark Bligh Reef.) Bligh Reef, a shoal area of 10 fathoms or less, extends northeast 1.8 miles and southeast 1 mile from the buoy. Upon reaching a point about 60°50'N latitude and 147°02.5'W longitude with Bligh Reef buoy bearing 083°, distance 4 miles, the outbound vessel steers 186° to remain in the traffic lane. About 1 mile south of this juncture is the new pilot station, about 3.6 miles 246° true from Bligh Reef Buoy at position 60°49'N latitude and 147°01'W longitude.[22] This location is about 9 miles seaward of the previous pilot station.

Though ice calves from the Columbia Glacier into Columbia Bay throughout the year, the Coast Guard stated that the greatest number of and the largest icebergs generally appear during the late summer and early fall. Testimony and statements by pilots, traffic watchstanders, and Coast Guard correspondence indicated that the number of vessels reporting ice in the traffic lanes in the vicinity of Bligh Reef has steadily increased since the VTS was first established in 1977. The ice, consisting mainly of brash,[23] bergie bits,[24] growlers,[25] and icebergs,[26] is propelled by wind and current out of Columbia Bay and moves across the open waters of Valdez Arm toward

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[22] Title 12 AAC 56.120. Pilot Stations.

[23] A collection of small fragments and rounded nodules of ice frozen together, which a ship can easily force its way through.

[24] Medium-size pieces of ice that are detached and rounded on the top. May originate either from a glacier or from disrupted hummocky ice.

[25] A low-lying mass of field ice that is not easily seen by approaching vessels owing to its dark indigo color. It is therefore a menace to shipping. It is usually caused by the capsizing and disintegration of an iceberg.

[26] A large floating mass of ice detached from a glacier at sea level. The movement of a glacier downward causes it to protrude into the sea, by which it is in part supported until the weight becomes so great that more or less of it breaks off (calving) from the glacier.

Bligh Reef. According to the U.S. Coast Pilot,[27] "Large bergs may be found at any time along the north shore from Point Freemantle to Glacier Island." The Coast Guard has reported that vessels en route to and from Port Valdez often have been forced to take action such as reducing speed, deviating from one traffic lane to another, deviating from the TSS altogether, or awaiting daylight before transiting on account of the ice choking the traffic lanes.

The VTC watchstanders monitor the ice situation in the Valdez Arm by requesting that participating vessels make ice reports to the VTC. Ice reports, however, are not mandatory. As a result, not all vessels participating in the VTS provide ice reports. According to the Prince William Sound Vessel Traffic Center Manual (November 1988):

> (Section 4.9.4.a.) Ice conditions change rapidly and there is a continuing need to have up-to-the-minute information. Ice reports should be requested from any vessel transiting the area where ice conditions may exist. Ice reports should be received from any vessel if the latest ice report is over 2 hours old.

The VTC Manual states that the VTC shall pass along ice reports to vessels entering the system. According to the VTC Manual:

> (Section 4.9.4.c.) Ice reports shall be passed to vessels upon request and when an inbound vessel reports at Naked Island, and when an outbound vessel reports underway from Valdez.

The VTC watchstanders were required to log all ice reports onto the Vessel Data Sheets. They were also required to list the area congested by ice, as well as the concentrations and approximate size of ice reported, and to note all actions taken by vessels to alter course, speed, or depart from the normal traffic routes on account of the ice.

During the morning of March 23, the tankship BROOKLYN transited the Valdez Arm outbound. (See figure 9.) During that time, the BROOKLYN departed from the TSS to avoid ice and passed within 1.4 miles west of the portion of Bligh Reef where the EXXON VALDEZ later grounded. Shortly thereafter, the vessel passed within 0.35 mile (about 2,100 feet) west of Bligh Reef buoy before returning to the TSS.

About 1904, during the evening before the accident, the ARCO JUNEAU altered course to about 180° and departed from the traffic lanes to avoid the ice. During this time, the vessel passed within 3,900 feet (about 4.5 ship lengths) west of the portion of Bligh Reef where the EXXON VALDEZ later grounded. Shortly thereafter, the vessel passed within 0.4 mile

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[27] Volume 9 - Pacific and Arctic Coasts of Alaska: Cape Spencer to Beaufort Sea, 1987. Published by the U.S. Department of Commerce (National Oceanic and Atmospheric Administration).

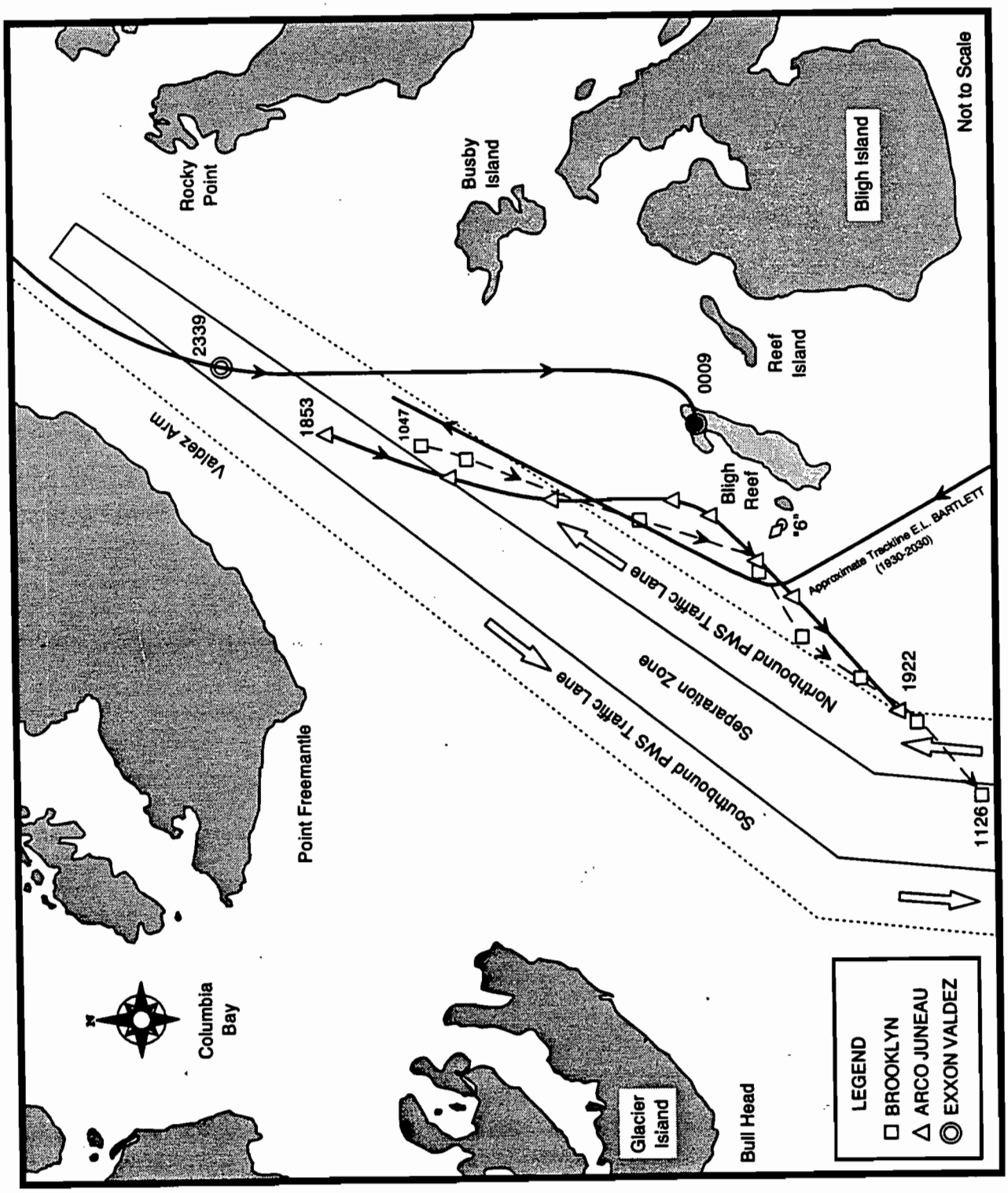

Figure 9.--Vessels departing the TSS.

(about 2,400 feet) west of Bligh Reef buoy before returning to the TSS about 1922.

About 1930 on March 23, 1989, the passenger vessel E.L. BARTLETT,[28] which was en route to Valdez, was approaching the TSS in the vicinity of Bligh Reef. According to the chief mate of the E. L. BARTLETT, who was on watch at the time, visibility was very poor because of snow squalls. As the vessel approached Bligh Island, he stated that the radar indicated an "extremely heavy concentration of ice all across Valdez Arm from Point Freemantle to Bligh Reef buoy and extending north to south from Busby Island to the south end of Glacier Island." The master was called to the bridge, and the speed of the vessel was reduced. Between 2000 and 2025, with the aid of radar and searchlights, the vessel worked its way through the ice in the vicinity of Bligh Reef until it was clear of the ice (in the vicinity of Busby Island). According to the chief mate, "It was some of the thickest ice I have seen in that area in the years I've worked the BARTLETT." The E.L. BARTLETT was required to participate in the VTS. On the night of the accident, however, the vessel did not transmit an ice report to the VTC, nor was it requested to do so. The vessel later made a stop at Ellamar, Alaska, (located east of Busby Island) to pick up passengers and then continued on toward Port Valdez where it arrived without incident about 2230.

As early as September 1, 1975, ice in Valdez Arm was recognized as a potential hazard to navigation. At that time, the CO of the Marine Safety Detachment[29] reported to the Commander, Seventeenth Coast Guard District, that the tug POLAR MERCHANT had sighted considerable ice in the shipping lanes west of Bligh Reef buoy and that some of the icebergs were reported to be as large as the 115-foot long tug. Records kept by the Coast Guard following the commencement of oil shipments in 1977 indicate that ice did affect the ability of vessels to navigate in the TSS in Valdez Arm. For example, from July to October 1981, a total of 634 transits by tankships were monitored by the VTC. Of these transits, 72 tankships reported sizable ice, 12 had to reduce speed because of ice, and 18 tankships departed the TSS to avoid ice. Because of the ice, two oil companies (Exxon and Mobil) for a period of time limited their vessels to daylight transits of Valdez Arm. Another oil company, SOHIO, for some time restricted the speed of its vessels to 6 knots when ice was present.

From July 23 to October 31, 1984, there were at least 403 vessel transits of Valdez Arm, and records indicate that in 131 of these transits the vessels (38 percent) were forced to reduce speed and/or maneuver around ice in the TSS. Of the 131 vessels affected by ice, 76 were forced to depart the TSS. One such vessel, the GLACIER BAY, reported on July 24, 1984, that

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[28]The E.L. BARTLETT was a passenger vessel owned and operated by the State of Alaska (Department of Transportation). The 168-foot vessel, which was constructed as a RO/RO combination cargo/ferry and was capable of carrying up to 236 passengers, provided regular ferry service between Cordova, Ellamar, and Port Valdez, Alaska.

[29]The activity became a Marine Safety Office in 1977.

ice extending across the traffic lanes to within 0.5 mile of Bligh Reef buoy forced the vessel to depart the TSS and to pass within about 500 yards of the buoy.

The CO of MSO Valdez, on December 1, 1984, in correspondence with the Commandant, proposed the installation of a radar site either on Glacier Island or Bligh Island to monitor the glacial ice flowing out of Columbia Bay. The CO cited the U.S. Geological Survey prediction at the time, which reported that calving of ice from the Columbia Glacier was expected to increase over the next 10 to 30 years. Further justification, according to the CO, was that the radar could assist vessel traffic control during the adverse weather extremes experienced during the winter months. The proposed radar site, however, was not approved by Coast Guard headquarters.

The 1984 ice conditions resulted in a meeting on August 22, 1984, between the CO of MSO Valdez and representatives of the oil companies, Southwest Alaska Pilots, and U.S. Geological Survey personnel. The meeting addressed the need of tankship masters for better reports on ice conditions and the potential impact of the retreat of the Columbia Glacier, which, according to the U.S. Geological Survey, would result in increased ice floes. The oil companies expressed their belief that the masters of their vessels could be relied on to avoid the ice. The Coast Guard and the industry generally agreed that operations would continue as before.

The CO (at the time of the grounding) stated that although he was aware of vessels being forced out of the lanes because of ice during the summer of 1984, he was unaware of the exact number of incidents or the number of vessels involved. He also admitted that he had not been aware that some oil companies had previously decided that ice in the Valdez Arm posed a sufficient threat to their vessels, cargoes, and crews that they had, on occasion, ordered their vessels to operate at reduced speeds or to transit Valdez Arm only during daylight. As far as the CO was concerned, there was not sufficient concern on the part of the Coast Guard to take steps other than requesting that vessels provide regular ice reports to the VTC. When asked whether he considered the presence of ice in the traffic lanes a hazard, he stated that "any ice is a hazard to navigation." See appendix E for further information on the effects of ice on vessel operations.

Meteorological Information

At 2300 on March 23, there was a low pressure area over the southern Yukon Territory with a stationary front extending west-northwest from the low into Alaska and passing about 200 miles north of Valdez. There was a weak high-pressure area over Ketchikan with a ridge extending west-northwest through Valdez.

In the vicinity of Valdez the skies were overcast, visibility was restricted by light snow and fog, and winds were calm. For surface weather observations at Valdez from 2100, March 23, through 1200, March 24, see appendix F.

Columbia Bay, which contains the terminus of the Columbia Glacier and is the source of icebergs in the Valdez Arm and Prince William Sound, is immediately to the west of the Valdez Arm. The Columbia Glacier has been stable throughout recorded history with the terminus at a terminal moraine[30] in the bay. During the 1970s, the glacier began to retreat from the terminal moraine into the deeper waters of the fjord.[31] At that time, it was predicted that once the terminus retreated into deeper water, it would begin a rapid or catastrophic retreat, a phenomenon that had already been observed in several other Alaskan glaciers.

When the Port of Valdez first opened as an oil terminal, the Columbia Glacier was being closely monitored by the U.S. Geological Survey, but since that time the level of effort has been reduced to a periodic aerial observation of the glacier terminus

Based upon recent observations, the Columbia Glacier is receding as predicted. Since 1982, it has receded at a rate of 500 to 1,000 meters per year, and the terminus is now about 4 kilometers (2.5 statute miles) from the terminal moraine. It is expected to retreat about 30 kilometers (19 statute miles) in 30 to 50 years and then to stabilize. As the glacier recedes, it expels a large number of icebergs. About 5 cubic kilometers (1.2 cubic miles) of ice currently calves from the glacier each year, a significantly larger amount than was calved from the glacier when crude oil shipments from Port Valdez commenced in 1977. The iceberg discharge is expected to continue at about the current rate until the glacier stabilizes in 3 to 5 decades. The size of the icebergs from the glacier that can exit the fjord is limited by the depth of the terminal moraine, which is about 27 meters (89 feet).

Once icebergs depart the fjord, their movement is controlled by the currents and the wind. The majority move to the west of Glacier Island away from the Valdez Arm, but a significant number move into Valdez Arm. Although ice calves from the glacier throughout the year, the greatest activity is in the late summer and early fall, when both the greatest number and the largest icebergs are formed.

Icebergs emanating from the Columbia Glacier frequently occur in groups or plumes of icebergs. Based upon a study conducted in 1983,[32] it was estimated that approximately 121 plumes occur in Columbia Bay per year and of these, 43 enter the Valdez Arm. Normally, less than 3 plumes cross

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[30] A shoal or bar across the front of the glacier built up by earth and stone deposited from the glacier.

[31] A narrow steep walled inlet of the sea formed either by the submergence of a mountainous coast or by entrance of the sea into a deeply evacuated glacial trough after the melting away of the glacier. A fjord (fiord) may be several hundred fathoms deep and often has a relatively shallow sill (terminal moraine) of rock or gravel across its entrance.

[32] A. R. Klingle, U.S. Department of Interior, Geological Survey, October 20, 1989.

Valdez Arm each year, but it was estimated that with the glacier in full retreat, about 21 plumes could be expected to cross the Valdez Arm every year. A plume might consist of 10,000 icebergs, of which, according to the 1983 study, 1,000 might have a mass greater than 3,000 tons, 153 a mass greater than 24,000 tons, and 25 a mass greater than 50,000 tons.

The life span of icebergs was considered during the 1983 study. About one-half of the icebergs lasted less than 12 hours and two-thirds lasted less than 24 hours. Most icebergs were gone after 48 hours, although some larger ones moved out of the Valdez Arm into Prince William Sound and could not be tracked throughout their life spans. The life span varied, in decreasing order of importance, with water temperature, iceberg type (essentially the density), and iceberg mass.

Tests and Research

Computer Simulation.--The Computer Aided Operations Research Facility (CAORF),[33] National Maritime Research Center, at Kings Point, New York, conducted a study of the preaccident maneuvers of the EXXON VALDEZ using the facility's ship simulator. The computer for the simulator was programmed to replicate the hydrodynamic characteristics[34] of the EXXON VALDEZ so that the simulator would duplicate graphically the maneuvers of the EXXON VALDEZ in response to rudder and engine speeds. Once programmed, the computer was used to develop a graphic presentation of the trackline probably followed by the EXXON VALDEZ from Middle Rock in Valdez Narrows to the site of the grounding.

Fine tuning and iteration resulted in generating a trackline that passed within about 1 ship width (165 feet) of positions plotted by the VTC near Entrance Island at 2220 and near Potato Point at 2253, as well as the 2339 position in the separation zone plotted by the third mate. The trackline passed slightly less than 0.9 mile from Busby Island Light, as the third mate had indicated. Although the simulated trackline did not pass through the fixes plotted by the third mate at 2306 and 2312, it passed within 0.1 and 0.14 mile, respectively, of these two fixes. The simulated trackline, based on a turn using 4^{o} of right rudder, placed the vessel within 2 1/2 ship widths of the grounding site on Bligh Reef as determined by the Coast Guard (latitude 60^{o} 51.3′ N; Longitude 146^{o} 52.37′ W).

The simulator study resulted in following findings:.

(a) The EXXON VALDEZ passed abeam of Busby Island Light at 2355 on March 23 at a distance of about 0.9 mile.

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[33]Operated for the MARAD by Marine Safety International, Inc.

[34]Such information included the advance and transfer for the vessel. The advance is the distance the vessel travels ahead until its heading changes 90^{o} (about 0.6 mile). Transfer is the lateral distance the vessel travels right or left of its original trackline by the time its heading has changed 90^{o} (about 0.3 mile for a right turn).

(b) The turn from 180° toward Bligh Reef began at 0001.5 on March 24 about 1.4 miles past Busby Island Light.

(c) Right 10° rudder was used for about 1/2 minute at the start of the turn, and then the rudder was eased one or more times to produce a slow turn. A change in the rate of swing at time 0006 indicates that little right rudder, or possibly counter rudder, was being applied. The rudder changes resulted in a turn that could have been made using about 4° to 5° of rudder. There was no evidence that right 20° or hard right rudder was applied between the start of the turn and the time that the vessel's heading reached 245°.

(d) The vessel passed over the 50-fathom oval-shaped depth contour centered at latitude 60° 51.5′ N, longitude 146° 51.3′ W. (This was also confirmed by the vessel's fathometer trace.)

(e) A reduction in rate of turn occurred at 0007 that could have been caused by a reduction in rudder angle or counter rudder, or possibly by the ship coming under the influence of external forces such as shallow water effect, bank cushion, or impact with the reef.

Trial turns conducted on the simulator yielded the following information:

(a) If 10° of right rudder had been used continuously throughout the turn, the vessel probably would have passed safely north of Bligh Reef about 0.1 to 0.2 mile from the 10-fathom curve.

(b) Using 4° of right rudder when Busby Island Light was abeam would have resulted in a gentle turn, causing the vessel to pass approximately 0.9 mile north (20-fathom curve) of Bligh Reef. Other turns, begun at the same time, with increased rudder were run to determine what additional clearance from the reef would result. The results of these trials are shown in the following table:

Rudder (degrees)	Distance from Bligh Reef (miles)
4	0.90
5	1.00
10	1.20
20	1.36
35	1.40
10-20-25	1.25

The course recorder trace showed that the vessel was on course 180° for about 18 minutes. The 180° portion of the course recorder trace was very straight until 0001.5, when the vessel commenced a right swing. After the vessel steadied briefly on a heading of 247° at 0007, it resumed a slow right swing, which continued until about 0009, when the vessel's rate of swing increased significantly between 280° and 290°.

Other Information

Alcohol and Drug Policies.--The Exxon Shipping Company had a written policy on alcoholism at the time that the master was undergoing treatment for alcohol dependency in 1985. This policy, dated September 28, 1984, recognized that alcoholism is a treatable illness and that alcoholism does not, by itself, represent grounds for dismissal. However, failure to perform owing to alcohol use was sufficient cause for termination. The policy instructed supervisors to refer to the medical department those employees whose unsatisfactory job performance was owing to the perceived use of alcohol. However, no records were provided that indicated the medical department was involved in the oversight or supervision of the master. The report from the substance abuse treatment program in which the master participated during his hospitalization in 1985 was part of Exxon records on the master. The report, which was on Exxon Shipping Company forms, included a recommended treatment program. However, no documents were provided that discussed his progress or the degree to which he was following the suggested treatment program.

A more recent written policy, dated March 11, 1987, on the use of alcohol and drugs by Exxon employees was provided to the Safety Board. This policy basically prohibits the use, possession, distribution, or sale of drugs and alcohol on company premises. Furthermore, being unfit for duty because of the use of drugs or alcohol is forbidden. The program provides for:

1. preemployment drug and alcohol testing;
2. drug and alcohol testing for cause;
3. unannounced searches on Exxon-owned and -controlled property;
4. substance abuse treatment and rehabilitation through an Employee Health Advisory Program (EHAP);
5. no termination for voluntarily seeking help for a dependency problem; and
6. disciplinary action that may include termination if an employee's use of alcohol or drugs is discovered before voluntary action is taken.

Based on testimony of EXXON VALDEZ crewmembers, crewmembers were clearly aware of the Exxon policy on alcohol and drug use and knew that their employment was subject to termination for possession and use of alcohol while on the job or for reporting for duty while under the influence of alcohol. The president of the Exxon Shipping Company testified that the company did not have any procedures, such as a hot line, for crewmembers to report infractions.

The applicable DOT Coast Guard regulation for the control of intoxicant(s) in commercial vessel operation in effect at the time of the grounding is contained in 33 CFR Part 95 and is entitled "Operating a Vessel While Intoxicated." The regulation authorizes the marine employer or law enforcement officer, including a Coast Guard official, to direct a person operating a vessel to undergo a chemical test when a reasonable cause exists (Section 95.035). Reasonable cause exists when: the person was directly involved in the occurrence of a marine casualty as defined in Chapter 61 of Title 46, United States Code, or is suspected of being in violation of the "Standards of Intoxication" as defined in Section 95.020. Section 95.020 states that a person operating a vessel other than a recreational vessel is intoxicated when (1) the person has a blood alcohol concentration of 0.04 percent or (2) the person is operating any vessel and the effect of the intoxicant(s) on the person's manner, disposition, speech, muscular movement, general appearance or behavior is apparent by observation. Section 95.040 states: "A crewmember (including a licensed individual), pilot, or watchstander not a regular member of the crew: (a) shall not perform or attempt to perform any scheduled duties within 4 hours of consuming any alcohol." The marine employer is responsible for ensuring compliance with this rule.

A new final rule[35] on drug and alcohol testing for commercial vessel personnel was published on November 21, 1988, in the Federal Register. This rule also calls for toxicological testing after a marine casualty or accident involving death, injury, property damage, or loss and discharge of oil and hazardous substance in navigable waters of the United States. This regulation includes testing for alcohol and drugs in urine and blood and for alcohol on the breath. Urine specimens must be tested according to U.S. Department of Health and Human Services (DHHS) guidelines in 49 CFR Part 40. The prohibition against assuming duties within 4 hours of consuming alcohol has been retained. The date for implementation of the new drug testing program depends on the number of employees in the company. Testing after serious incident and reasonable cause testing had to be implemented by December 21, 1989, by all employers who employ 11 or more employees. The drug testing program must be implemented by December 21, 1990, by employers who employ 10 or fewer employees.

The new regulation states that the urine must be tested according to guidelines in 49 CFR Part 40, which does not address alcohol testing.

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[35]"Programs for Chemical Drug and Alcohol Testing of Commercial Vessel Personnel," 46 CFR Parts 4, 5 and 16, Federal Register, Vol. 53, No.224, Monday, November 21, 1988, FR 47064.

However, breath analysis for alcohol and the collection of blood is permitted. This regulation does not contain guidelines concerning how the blood is to be tested or for what drugs.

Both regulations state that in the case of postincident/accident investigations the marine employer has the responsibility to implement the regulation (46 CFR Part 40) by determining who is to be sampled and to ensure the specimens are collected in a timely manner.

The Coast Guard drug testing program as it applies to DOT civilian employees was established and set forth in the DOT directive entitled, "Drug Free Departmental Workplace" (DOT Order 3910.1), dated June 29, 1987. As an implementation resource for supervisors, the DOT issued a "Drug Testing Guide" in March 1988. A revision to the Guide concerning postaccident testing procedures was issued on July 1, 1988. The DOT's drug testing program is based on Executive Order 12564, "Drug-free Federal Workforce" signed by President Reagan on September 15, 1986. This order applies only to Federal civilian employees. The DOT drug testing program, including laboratory testing, as outlined in this document and as explained in testimony by the DOT Deputy Assistant Secretary for Administration, is to be executed in strict accordance with procedures contained in the DHHS "Scientific and Technical Guidelines for Drug Testing Programs." According to these guidelines (49 CFR Part 40), only urine specimens are tested, and the testing is generally limited to five specific drugs or their metabolites. Alcohol is not included. The five specific drugs or drug classes are: (1) opiate metabolites; (2) cocaine metabolites; (3) marihuana metabolites; (4) phencyclidine (PCP); and (5) amphetamines. The DHHS guidelines specify lower threshold cut-off values for reporting the presence of each of these five drugs or their metabolites.

The DOT employees covered in the policy are those in safety- and security-sensitive positions, including vessel traffic controllers. The policy specifies that testing is to be done when an accident or unsafe practice occurs or when reasonable suspicion exists. The decision to test DOT employees after an accident or incident is a three-step process. First, the determination must be made that a qualifying event has occurred. Second, employees whose work performance may have been a contributing factor are identified. Third, it must be determined that the employee's actions cannot be eliminated as a contributing factor from a review of known facts. The determination that a qualifying event has occurred is made by the operating administration. Once the determination has been made that testing is necessary, the employee must be notified. This decision to test, who to test, and notification of individuals to be tested must be made within 8 hours after the operating administration has received notice that an accident has occurred.

The DOT Deputy Assistant Secretary for Administration testified that postaccident testing has two objectives: deterrence and identification of employees who use illegal drugs. She said, "It is not meant as part of postaccident investigation in the sense that the Board does an investigation" to determine probable cause. However, later in her testimony she stated that the "second objective is to assess the employees' performance at or about

the time of the accident for simple employer/employee relationship, i.e., to determine if it is necessary to take disciplinary action against an employee."

In the EXXON VALDEZ grounding, the determination that a qualifying event had occurred was made, according to the Deputy Assistant Secretary for Administration, by the Coast Guard Pacific Area office in Alameda, California, which ordered that the two VTC watchstanders who were on duty just before and at the time of the grounding be tested for drug use. The order partially was carried out by a Coast Guard officer, who obtained a urine sample from the VTC watchstander on duty at the time of the grounding about 1400 on March 24, about 14 hours after the accident. The VTC watchstander on duty just before the grounding did not provide a urine specimen on March 24.

The first urine specimen obtained from the VTC watchstander on duty at the time of the grounding was tested for alcohol and revealed a blood alcohol concentration (BAC) of 0.2. Statements and testimony indicated that the watchstander was not impaired and had performed properly during his 0000-to-0800 watch, as well as during 4 hours of overtime from 0800 to 1200. He stated that after departing the VTC, he had consumed about three strong drinks at home during lunch and had then gone to bed. He gave the urine specimen about 2 hours after consuming these drinks.

The DOT Deputy Assistant Secretary for Administration testified that the toxicology testing procedures initiated by the DOT resulted in urine being collected from the two VTC watchstanders some time after 2030 on March 26, shortly after the time the collector designated by the DOT toxicology testing contract arrived in Valdez. However, DOT documents do not have the time of collection written on them. The deputy assistant secretary testified that the specimen provided on March 24 by the VTC watchstander on duty at the time of the grounding was not considered to have been collected under the DOT procedures for the employee program since the specimen was not collected by the DOT contractor (Upjohn Health Care Services Incorporated) but was collected by the Coast Guard. The DOT contractual agreement with Upjohn provided that the contractor had 24 hours in which to arrive at the collection site after being notified. Upjohn was notified at 1530 on March 24. The collector who obtained the two specimens in this case came from Atlanta, Georgia, because, as the DOT Deputy Assistant Secretary for Administration stated, "He was available and because he was one of their better collectors."

The urine specimens collected on March 26 were tested according to DOT drug procedures. According to Public Law 101-71 (101 Stat. 391,468-471, July 11, 1987), toxicological results obtained on Federal employees pursuant to Executive Order 12564 (September 15, 1989) can be released only (1) to the employee's medical review official, (2) to the administrator of any Employee Assistance Program in which the employee is receiving counseling, (3) to any supervisory or management official within the employee's agency who has authority to take adverse personnel action against such employee, or, (4) pursuant to the order of a court of competent jurisdiction where required by the U.S. Government, to defend against any challenge against adverse

personnel action. Release of test results to anyone else requires written consent from the employee. Based on this law, the DOT refused to release the urine test findings from the VTC watchstanders to the Safety Board without written authorization from the employees. Written consent to disclose the results of these tests to the Safety Board was received from the employees on May 17, 1989. Both tests were negative for the five drugs or drug classes as tested according to DHHS guidelines. The specimens were not tested for alcohol.

After the urine specimens were tested according to DHHS guidelines, the specimens were obtained by the Safety Board and tested by Chem West Laboratories, Inc., of Sacramento, California, under a broader drug screen that included alcohol and at lower cut-off levels for drugs. Under these conditions, both individuals tested positive for drugs, and the results were inadvertently released. These results are shown in the following table.

Table 4.--Urine toxicology on VTS personnel.

Position	Date	Time	Drug	Concentration
0000-0800 VTC Watchstander	3/26	1500	morphine*	230 ng/ml
1600-2400 VTC Watchstander	3/26	1500	THC-COOH**	7.5 ng/ml

* eating poppy seeds will result in positive urine morphine; the controller stated that he had eaten bread with poppy seeds before the test.

** 11-nor-delta-9-tetrahydrocannabinol-9-carboxylic acid: metabolite of marihuana.

The DHHS guidelines[36] for drug testing in the workplace set a urine screening cutoff for opiates, which include morphine, of 300 ng/ml and for marihuana metabolites of 100 ng/ml. The DHHS confirmation test cutoffs for these two drugs are 300 ng/ml for opiates and 15 ng/ml for marihuana (carboxylic and acid metabolite of THC).

Vessel Traffic Service.--The VTS operated from the VTC that was located in the MSO in Valdez. MSO Valdez performed COTP and OCMI functions for all of Prince William Sound. The CO of MSO Valdez acted as COTP and OCMI and was directly responsible to the Commander, Seventeenth Coast Guard District, Juneau, Alaska, for the operation of the Prince William Sound VTS. MSO Valdez had four departments: Marine Safety, Operations, Administrative, and Public Works. The VTS was part of the Operations Department. Unlike the VTSs in Puget Sound, San Francisco, and Houston/Galveston, Prince William Sound VTS was not a separate command unit. As a result, VTS personnel were utilized to perform collateral duties unrelated to the operation of the VTS. See appendix G for a description of the geographical limits and operational

[36] Federal Register, DHHS. Alcohol, Drug Abuse, and Mental Health Administration; Mandatory Guideline for Federal Workplace Drug Testing Programs; Final Guidelines; pp. 11972-11989, April 11, 1988.

regulations, and for a history pertinent to the Prince William Sound VTS, see appendix H.

The CO of MSO Valdez, as COTP, was assisted in the operation of the Prince William Sound VTS by an XO, an Operations Officer, an Assistant Operations Officer, and a Senior Watchstander.

According to the Coast Guard Marine Safety Manual, COTP responsibilities include the supervision and control of vessel movement and mooring within the port, including vessel traffic control; the supervision and control of anchorages within the COTP zone; and the protection of the navigable waters and resources therein from environmental harm resulting from damage, destruction, or loss of any vessel, facility, or structure. According to 46 CFR 160.111, the COTP has the authority to restrict the movement of vessels through Prince William Sound when he has determined that:

> such order is justified in the interest of safety by reason of weather, visibility, sea conditions, temporary port congestion, other temporary hazardous circumstances, or the condition of the vessel.

The CO of MSO Valdez stated:

> the main reason why the system was designed for the location, is for Valdez Narrows, to protect Valdez Narrows, and I would think that if the folks that envisioned the system wanted coverage all the way out, we would have radars all the way out.

During the evening of March 23, the VTC was manned by a civilian traffic watchstander and an adjoining communications center was manned by an enlisted Coast Guard radioman. (See figure 10.) The VTC watchstander was responsible for communicating with and monitoring all vessels participating in the VTS. The radioman, who was standing the 2000-0800 watch, was responsible for monitoring non-VTS radio traffic on the radiotelephone, single-sideband (HF-SSB), and teletype communications for the unit.

The VTC watchstander reported for duty about 1600. About 1930, the master of the outbound ARCO JUNEAU[37] reported to the VTC that he had detected ice in the TSS. According to the report, the perimeter of the ice extended from Point Freemantle southward to Glacier Island (in the vicinity of Bulls Head at the southeastern part of Glacier Island) and extended eastward across the TSS to Bligh Reef Buoy. The master of the ARCO JUNEAU informed the VTC that he would maneuver the vessel through the ice, and the master also reported that he would head his vessel toward an area of open water

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[37]The ARCO JUNEAU was the last tank vessel to successfully transit the Valdez Arm on the night of March 23. The ARCO JUNEAU was an 850 foot-long tankship capable of carrying a cargo of about 800,000 barrels of North Slope crude oil.

Figure 10.--Vessel Traffic Center.

about 0.9 mile wide near Bligh Reef. The VTC watchstander observed on radar the ARCO JUNEAU deviate from the southbound lane into the northbound lane shortly before losing radar contact with the vessel in the vicinity of Busby Island about 10 to 12 miles southwest of Potato Point.

The VTC watchstander stated that he was concerned about the ice encountered by the ARCO JUNEAU. However, his concern did not prompt him to require the ARCO JUNEAU to make more frequent position reports. According to the watchstander, ice in the traffic lanes is common, and vessels transiting the Valdez Arm often are forced to reduce their speed as they maneuver around the ice. He also stated that because of the ice, most of the masters are granted permission by the VTC to deviate from the southbound traffic lane into the northbound traffic lane if there is no opposing traffic. He said that many tankship masters transiting the Valdez Arm are aware that there is an ice-free stretch of water about 0.5 to 1.0 mile wide to the west of Bligh Reef Buoy. He said that these masters regularly head their vessels into this stretch of water to remain clear of the ice. The watchstander stated that he observed the ARCO JUNEAU alter course toward Bligh Reef and that the master of the ARCO JUNEAU called the VTC, stating that he intended to head toward a small area of open water about 0.9 mile wide near Bligh Reef to remain clear of the ice. The watchstander said that he did not give the master of the ARCO JUNEAU permission to deviate from the TSS; however, he did not tell him that he could not deviate. However, the master stated that he believed his vessel was being tracked on radar by the VTC. The master of the ARCO JUNEAU, like the master of the BROOKLYN, was on the bridge conning his vessel and supervising the navigation watch.

The chart[38] used aboard the ARCO JUNEAU during the evening of March 23 showed that about 1904, the ARCO JUNEAU altered course to 180°, then departed from the TSS, and followed a track that took the vessel through an area about 1.0 mile wide between the Bligh Reef buoy and the traffic lanes.

Coast Guard records indicate that during the transit of the EXXON VALDEZ through the Narrows, the No. 3 (slave)[39] radar console was set on the 3-mile range scale and the range and bearing of the vessel from Potato Point was recorded by the data logger[40] every 3 minutes. The VTC watchstander stated that during the transit of the EXXON VALDEZ between Potato Point and the pilot station at Rocky Point, the No. 1 master radar was set on a 3-mile

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[38]The chart used aboard the ARCO JUNEAU shows the track of the vessel passing within three ship lengths of the location where the EXXON VALDEZ grounded about 4 hours later.

[39]The slave radar received its video display from the No.1 (master) radar.

[40]The data logger is a device that automatically records vessel positions.

range scale and the No. 3 radar was set on the 6-mile range scale (in offset).[41]

The watchstander stated that he began to lose radar contact with the EXXON VALDEZ shortly after the vessel disembarked the pilot near Rocky Point about 2324. In an effort to maintain radar contact, he switched the range scale of the No. 3 (slave) radar to the 12-mile range scale. He could not recall, however, whether he adjusted the range scale of the No. 1 (master) radar at that time. After failing to detect the target on the 12-mile range scale after three or four sweeps, the watchstander switched the No. 3 (slave) radar back to the 6-mile range scale. He stated that with the No. 3 radar (slave) on the 6-mile range scale, he was able to resume monitoring the movement of the EXXON VALDEZ. When asked why he thought the No. 3 radar was capable of picking up the EXXON VALDEZ on the 6-mile range scale but not on the 12-mile range scale, he replied:

> I don't know why. I just thought it was because the radars weren't working as well as they should have been at the time. That was my theory. It just didn't work so I went back to the 6-mile scale.

At 2326, the VTC watchstander observed the EXXON VALDEZ abeam of Rocky Point on a course of about 219°. The watchstander recalled being informed by the master that the vessel was coming to 200° and reducing speed to 12 knots, but he did not consider the course change to 200°, by itself, unusual. He then left the radar console and walked over to the VTC status board,[42] where he estimated without the use of plotting instruments that the VALDEZ, on a course of 200° from its last known position, would pass within 1 mile of the Bligh Reef buoy.

The watchstander stated, however, that by 2330, the VTC had lost all radar contact with the EXXON VALDEZ. The watchstander stated that the VTC radar system was often unable to track vessels transiting the TSS beyond the vicinity of Busby Island because of adverse weather and sea conditions. Neither Bligh Island nor Bligh Reef buoy were visible on radar at that time. The eastern boundary of the TSS passes within 1.1 miles (to the northwest) of Bligh Reef buoy. Shortly after returning from the status board to the radar console (about 2332), he began making preparations for the changing of the watch, which was scheduled to take place about 2345. These preparations

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[41] Offset is a feature built into the Raytheon VTS radar that allows the traffic watchstander to offset the origin position on the radar PPI scope to monitor a greater distance in one direction using the same range scale, thus producing a larger scale presentation than would be obtained by increasing the radar range setting.

[42] The VTS status board is an enlarged chart of Prince William Sound that measures about 8-feet wide and 7-feet tall and is mounted on the wall of the VTC. Magnets in the shape of vessels are moved around the board so that the watchstander can keep track of the approximate location of participating vessels that are not under radar surveillance by the VTC.

included updating the status board and ensuring that all necessary logbooks were up to date.

The VTC manual required the VTC watchstander to "advise the OOD when a vessel deviates due to ice in the lanes." However, during the evening of March 23, the 1600-2400 traffic watchstander did not notify the Officer of the Day (OOD) that the EXXON VALDEZ had deviated from the outbound traffic lane to avoid ice and that the master had reported he would depart the TSS.

The OOD on duty on the day of the accident stated that ice was reported in the traffic lanes earlier in the day (March 23) and that tankships were told by the VTC that "they could maneuver around the ice if need be." The OOD also stated that he frequently checked on the status of those tankers in the system and observed that "they were maneuvering around the ice with no problem."

About 2333, the 0000-0800 VTC watchstander arrived at the VTC and prepared to take over the watch. Neither of the two VTC watchstanders was aware that by 2339, the EXXON VALDEZ had altered course from 200^{o} to 180^{o}. About 2345, the VTC radar watch was relieved.

When the relieving watchstander first arrived in the VTC, he observed that the No. 1. (master) radar was set on the 3-mile range scale and the No. 3 (slave) radar was set on the 6-mile range scale. He did not observe any contacts on the radarscope, nor did he make any changes to the radar such as using a higher range scale to determine whether there were any contacts in the area. Between 2333 and 2345, the off-going traffic watchstander briefed his relief on the events that had occurred during the previous watch. During the briefing, the 0000-0800 traffic watchstander was informed that:

(1) Ice had been reported in the TSS;

(2) The EXXON VALDEZ had disembarked its pilot, was currently maneuvering through ice, and that it was likely that the vessel had deviated from the southbound traffic lane into the northbound lane to avoid the ice;

(3) The VALDEZ was no longer on radar;

(4) The last vessel to go through the Valdez Arm (ARCO JUNEAU) had left the southbound traffic lane and crossed over the separation zone into the northbound lane because of the existence of "a lot of ice" in the TSS;

(5) The remote radio sites located at Naked Island and Cape Hinchinbrook were inoperative and as a result, communications with vessels south of Naked Island (i.e., communications to vessels at anchor or proceeding to and from Knowles Head anchorage) were more difficult; and,

(6) The VTC had requested that the EXXON VALDEZ provide an ice report when it reached the Naked Island check point.[43]

According to 0000-0800 VTC traffic watchstander, the previous watchstander did not relay any information to him that indicated that anything out of the ordinary was taking place as far as the EXXON VALDEZ was concerned. The 0000-0800 traffic watchstander stated that a few minutes after taking over the watch he left the VTC (located on the second floor of MSO VALDEZ) and went to the galley (located on the first floor of the MSO) to obtain a cup of coffee, leaving the Coast Guard radioman, who was standing the communication watch, to also monitor the VTS communications. He stated that as far as he was concerned, "There wasn't anything going on at the moment."

On the way back to the VTC, the VTC watchstander stopped at the National Weather Service office (also located on the second floor) to examine the weather map. About 2355, he returned to the VTC to perform several routine administrative tasks. About midnight, he rewound, removed, and replaced the 24-hour multichannel recording tape for March 23.[44] After the tape was changed, the watchstander spent the next several minutes updating the status board, making log entries, and tallying the vessel data sheets from the previous day. The watchstander stated that it was about 0015 when he first sat down in front of the radar console and proceeded to check the calibration of the radar. To calibrate the radar, it was necessary to set the range scale of the No. 1 (master) radar at the 3-mile range scale and to set the No. 3 (slave) radar at the 1.5-mile range scale. They remained on these range settings until 0027, when the master of the EXXON VALDEZ called the VTC and notified the watchstander that his vessel had grounded in the vicinity of Bligh Reef. The watchstander immediately switched the range scale of the No. 1 (master) radar and the No. 3 (slave) radar (in offset) to the 12-mile range scale and observed the EXXON VALDEZ stationary in the water at Bligh Reef about 13.2 miles southwest of Potato Point.

The **VTS radar surveillance system**[45] consisted of radar transceivers installed at two remote radar sites. The information from the transceivers was transmitted by microwave back to radar consoles in the VTC. One of the sites was located at Valdez Spit, a short distance from MSO Valdez. The second site was located at Potato Point, about 12 miles southwest of the MSO,

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[43]The Naked Island check point is about 10 miles south of Bligh Reef.

[44]The MSO, through the use of a Motorola Magnasync multichannel tape recorder, taped all incoming VHF-FM and telephone traffic that was routed through the VTC. The tape in the recorder was capable of operating for 24 hours before it needed to be replaced with another tape.

[45]The Raytheon ANL/FPS-121 radar is a modified version of the Raytheon ANS/SPS-64V shipboard surface radar currently employed aboard many Coast Guard cutters. The primary difference between the shipboard version (ANS/SPS-64V) and the land-based VTS version is that the VTS radar uses a larger antenna and is fitted with a microwave video link.

near the southern entrance to the Valdez Narrows. For the purpose of providing system reliability, each site was fitted with two radar transceivers[46] and a backup power supply.

The radar system was controlled by a traffic watchstander monitoring three radar consoles in the VTC. Because the consoles were virtually identical, they could be used interchangeably to control and receive data from either the Potato Point or Valdez Spit remote radar sites. According to the VTC watchstanders, the No. 1 and No. 3 radar consoles were normally used to monitor the transits of vessels through the Valdez Narrows and the Valdez Arm utilizing the Potato Point remote radar site. The No. 2 radar console normally was used to monitor the transits of vessels through Port Valdez utilizing the Valdez Spit remote radar site.

Each radar console was capable of tracking up to 20 targets automatically. The offset feature on the consoles permitted the use of a smaller range scale for better resolution and enabled a slightly greater portion of Valdez Arm to be monitored on the No. 3 (slave) radar console when the No. 1 (master) radar console was on the 3-mile or 1 1/2-mile scale to monitor Valdez Narrows. The optimum trackline and the TSS normally could be displayed on both radar consoles (No. 1 and No. 3, respectively) used with the Potato Point radar site. However, the TSS circuit card for the No. 1 (master) radar, which synthetically displayed the TSS boundary lines, had burned out; hence, only the No. 3 radar console was capable of displaying the TSS overlay at the time of the accident.

A data logger, capable of automatically recording the time, range and bearing, course and speed of vessel out to the range of the radar, was connected to the No. 3 (slave) radar console. The data logger was used only to record data on vessels transiting Valdez Narrows; thus, it was not used to record the movement of the EXXON VALDEZ after it exited the Narrows and proceeded toward the grounding site.

Shipboard radars operate on either an X-Band (3 cm) or S-Band (10 cm) carrier frequency.[47] The Raytheon VTS radar in Valdez used an X-Band carrier frequency. The minimum and maximum ranges at which echoes (targets)

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[46]At the time of the accident, however, only one of the transceivers at each of the remote sights could be operated at a time. A modification, known as Field Change No. 2, had been designed to enable both radars at a site to be operated simultaneously. However, this modification, intended for the Potato Point radar site, had not been installed because the electronic technicians at MSO Valdez did not know how to do so.

[47]Carrier frequency is the frequency at which the radio-frequency energy is generated. The principal factors influencing the selection of carrier frequency are expected range of targets and weather conditions.

can be detected depend on the pulse length[48] and the pulse repetition rate (PRR)[49] selected by the VTC watchstander. The Raytheon VTS radar was designed to operate using the following pulse lengths and PRRs:

Table 5.--VTS radar characteristics.

Range Scale	Pulse Length	Pulse Repetition Rate (PRR)
3 miles or under	160 Nanoseconds	3600 Hz
6 and 12 miles	500 Nanoseconds	1800 Hz
24 miles or more	1,000 Nanoseconds	900 Hz

The longer the pulse length, the greater the range capabilities of the radar. For the shorter pulse lengths the range capability is less, but the higher PRR facilitates accurate radar tracking.

According to the Coast Guard project officer who supervised the installation of the Raytheon VTS radar, in order to ensure maximum performance of the VTS radar, the slave radar had to be set on a range scale that employed the same pulse length that was used by the master radar console. If a mismatch occured, the slave radar would pick up only a portion of the returning echoes from the remote radar site and the radar presentation on the slave radar console would be degraded. A degraded radar presentation means that targets may not be detected and/or targets previously detected and tracked could be lost.

The 1600-2400 VTC watchstander stated that he often had to turn the gain control[50] on the VTS radar all the way up in order to maintain radar contact with vessels being monitored. He believed that the radar was not working properly on the day of the accident.

The Operations Officer also stated that, overall, he did not believe that the VTS radar was operating as well as it should have been. He said that when he first arrived in Valdez during the summer of 1987, the VTC

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[48]The pulse length, which is measured in microseconds (nanoseconds), is the transmission time of a single pulse of radio-frequency energy. The higher the range scale in use, the longer the pulse length. The lower the range scale becomes, the shorter the pulse length.

[49]PRR is the number of pulses transmitted per second. Assuming sufficient power is available, the higher the range scale in use, the lower the PRR. On the other hand, the lower the range scale in use, the higher the PRR.

[50]Gain control is the feature that controls the strength of the video and noise shown on the radar scope. With too little gain, some weak echoes are missed and there is a decrease in the range at which some targets can be detected. With excessive gain, additional echoes might not be seen because the difference between echoes and the background noise signals is reduced, making observation more difficult.

watchstanders were often able to view the top of Naked Island[51] on the radar scope. He stated that during the past 2 years, however, he had observed a marked deterioration in the range performance of the radar. He believed that the age and condition of the microwave video link between the Potato Point remote radar site and the VTC might have been one reason that the VTC lost radar contact with the EXXON VALDEZ before it grounded.

According to testimony received from the VTC watchstanders, the performance of the VTS radar was affected by the wide variety of weather and sea conditions in Prince William Sound. Several traffic watchstanders indicated that weather fronts, accompanied by heavy precipitation and high winds, frequently swept through the VTS area, causing radar interference that interrupted radar surveillance. When this interference occurred, targets being tracked or monitored by radar were frequently lost and the system became temporarily disabled. The 1600-2400 VTC watchstander stated that weather and sea conditions within the radar surveillance area needed to be "ideal," i.e., clear weather, little wind, and calm seas, in order for the VTS radar to be capable of acquiring and tracking vessels transiting the Valdez Arm south of Busby Island. (The VTC, at the Safety Board's request, plotted all outbound tankships during April 1989 and found that 53 of 71 transits, or about 74.6 percent, could be monitored on radar out to 13 miles or more.

The VTC and the communications center were linked to seven remote communication sites located throughout Prince William Sound: Potato Point, Naked Island, Naked Island Tertiary, two at Cordova, Point Peugeot, and Cape Hinchinbrook. (See figure 11.) There was an additional HF-SSB site at Cape Yakataga outside Prince William Sound that was used in the event that the Cape Hinchinbrook remote site became inoperative. According to the VTS Users Manual, VHF-FM Channel 13 (156.65 MHz), the bridge-to-bridge navigation safety frequency, was designated as the radiotelephone frequency for the entire VTS area. The VTC maintained a continuous guard on Channel 13 and used this frequency to transmit and receive vessel movement data and other marine safety information.

On the day of the accident, the remote communication sites at Naked Island[52] and Cape Hinchinbrook were inoperative. According to the Coast Guard, the Naked Island site was inoperative.

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[51] Naked Island is about 29 miles south-southwest of the Potato Point remote radar site.

[52] The Naked Island site was used by VTC watchstanders to establish VHF-FM radiotelephone (primarily VHF-FM Channel 13-16) communications with inbound vessels approaching Cape Hinchinbrook and with vessels transiting that part of Prince William Sound south of Naked Island (particularly those tankships proceeding to and from the Knowles head anchorage area).

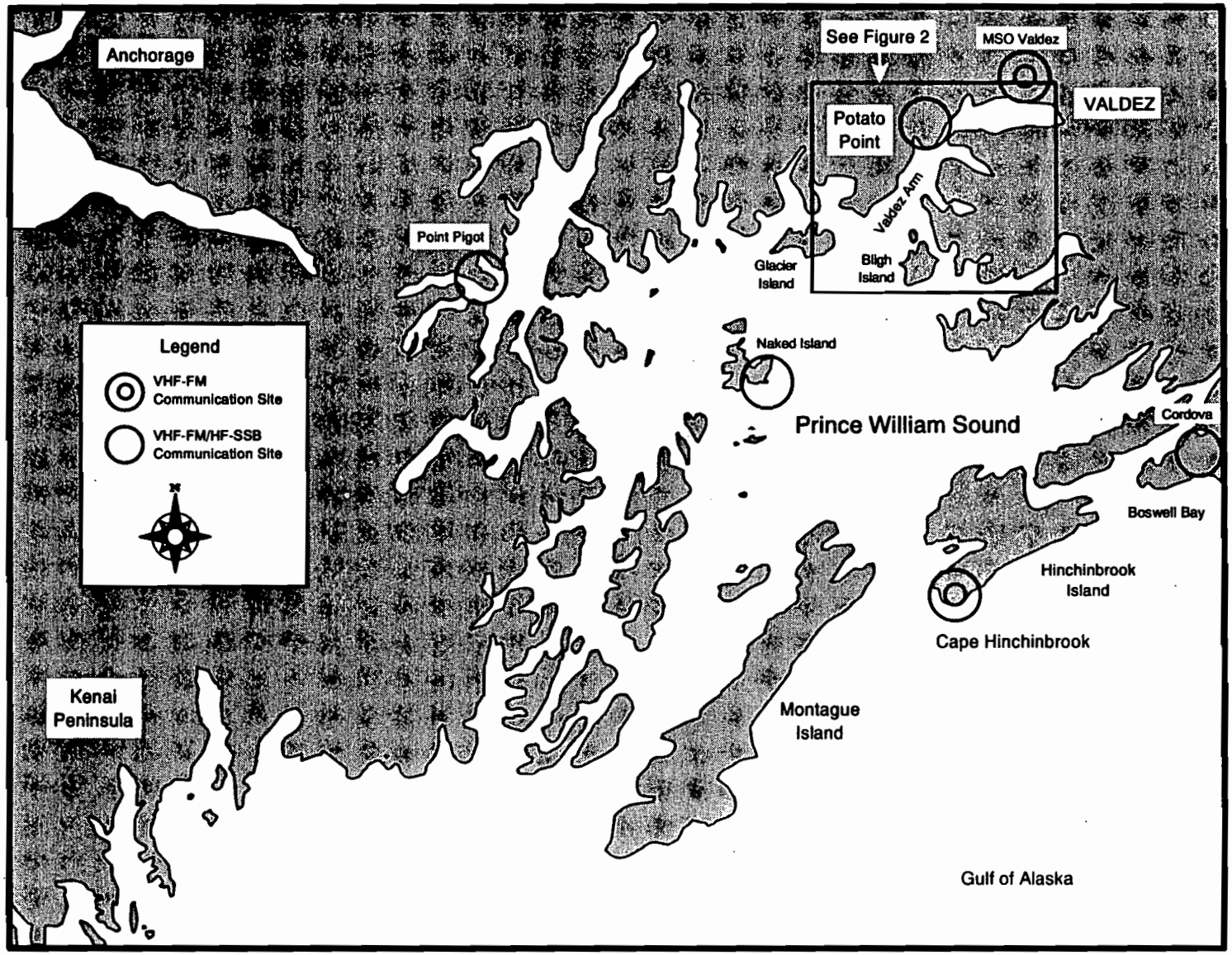

Figure 11.--Communication sites.

According to the 1600-2400 VTC watchstander, because the Naked Island site was inoperative during the evening of March 23, the VTC had difficulty establishing VHF-FM communications between the VTC and vessels south of Naked Island. To maintain communication with those vessels, VHF-FM traffic was rerouted via a remote communication site near Cordova. When the Naked Island site was inoperative, there was no communication link to Cape Hinchinbrook, which meant the loss of the Cape Hinchinbrook communication site. The loss of the Cape Hinchinbrook site forced the VTC to reroute HF-SSB communications between the VTC and vessels en route to Prince William Sound through the Cape Yakataga (HF-SSB) remote communication site.

According to the Coast Guard, during the first and second quarters of FY 1989, the Cape Hinchinbrook remote communication site was inoperative an average of 28.5 percent of the time and during the third quarter, the site was inoperative 6 percent of the time. In addition, during the second and third quarters of (FY 89) the Naked Island remote communication site was inoperative 11 percent of the time.

The CO, Operations Officer, the six VTC watchstanders, and the two Electronics Technicians assigned to MSO Valdez stated that they were generally dissatisfied with the way the VTS communication system performed. According to the Operations Officer, there were four recurring problems that frequently interrupted or interfered with radio communications with vessels transiting Prince William Sound: (1) Many buttons on the two communication consoles (original equipment installed in 1977) in the VTC that were used to switch VHF-FM radiotelephone frequencies often failed to function properly; (2) Radio interference caused by "bleedover"[53] frequently occurred; (3) VTS communications were interrupted owing to excessive radio noise in the VTC; and (4) VTS communications were interrupted by echoes created when VHF-FM radio sites utilizing landline/satellite relays were used.

Several VTC watchstanders complained that VHF-FM communications were frequently interrupted because the noise level within the VTC was excessive. When the VTC was established in 1977, the VTC radio and radar consoles were located in different areas. However, during the ensuing years, the VTC radar and radio watchstanding stations were combined at one site. As a result, a significant percentage of non-VTS radio traffic was overheard by the VTC radar watchstander, who was trying to concentrate on his duties on the other side of the room.

Both the CO and the Operations Officer of MSO Valdez stated that the Commander, Seventeenth Coast Guard District, was aware of the problems they were having operating and maintaining the communication equipment in Prince William Sound. In 1985, the CO submitted a planning proposal to Coast Guard headquarters requesting that the communication system in Prince William Sound be updated. According to the VTS Microwave and Communications Upgrade and Planning Proposal (PP #17-012-85) submitted by the MSO Valdez to the Commander, Seventeenth Coast Guard District, on December 3, 1985, "due to

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[53] Bleedover occurs when one radio channel or frequency is heard on another radio channel.

obsolescence and increasing difficulty in obtaining parts support, system reliability and performance are expected to begin deteriorating at the end of the current life cycle." In addition, the proposal stated that "pushing the communications and microwave network equipment beyond FY 89 without replacement is projected to result in degradation of reliability and on-air time."

In a letter dated December 6, 1988, to the Commander, Maintenance and Logistics Command Pacific (MLCPAC), the CO of MSO Valdez requested information regarding the status of the project (PP #17-012-85) to upgrade the communications system in Valdez. The MSO was subsequently notified[54] that as of February 13, 1989, "There is no project plan, or funds established for your upgrade at MLCPAC or COMDT."[55]

The VTS communication system was maintained by an outside contractor, who was responsible for the maintenance of all electronic communication equipment maintenance for the Coast Guard's Seventeenth District. According to the Specific Operating Requirements, the communication system was required to maintain a 99.9-percent system availability.[56] Testimony and written statements by the CO, Operations Officer, and electronics technicians assigned to MSO Valdez indicated that over the past few years, the communication system in Prince William Sound had been plagued with numerous equipment failures. According to the Operations Officer, the equipment failures occurred for various reasons, including weather, aging equipment, and poor contractor performance.

According to the Operations Officer, the age of many of the components that comprised the communication system made it difficult for MSO Valdez to obtain necessary parts support.[57] He said that in some cases, it had taken several months to obtain necessary spare parts.[58]

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[54]Letter from Commander, Coast Guard MLCPAC, to the CO, Coast Guard MSO Valdez, dated February 13, 1989.

[55]Coast Guard headquarters (Office of Command, Control, and Communications)

[56]System availability is defined as the "on-air" availability of all equipment in the system less scheduled preventative maintenance periods, the time between detection of the failure at the VTC and the Coast Guard's notification of the contractor, and the time allotted for the contractor to respond.

[57]According to the Microwave & Communications Upgrade (PP# 17-012-85), the communication system had a 10-year expected life cycle.

[58]According to the Operations Officer, in order to replace the oscillator for one of the microwave paths, for example, a replacement oscillator had to be custom-made because a ready-made replacement was not available. According to the Operations Officer, this component, which is a vital part of the microwave system was last manufactured about 10 years earlier. The component took about 5 months to replace.

The Operations Officer stated that he was generally dissatisfied with the performance of the contractor. He further stated that service representatives were not always available when part of the system became inoperative and as a result, repairs were not always made in a timely manner. He also complained of sloppy workmanship, such as the prevalence of jumper wires and lose circuit boards in the radio equipment. The senior ET stationed at MSO Valdez stated that the slow response time of the contractors was one of his biggest system maintenance problems.

The former Chief, Command, Control, and Communications Division, for the Coast Guard's Seventeenth District, stated that the communications maintenance contract contained a clause that was designed to penalize the contractor for failure to perform according to the terms of the contract. He stated that during the time he administered the contract for the Coast Guard, the contractor had been penalized under the terms of this clause on several occasions.

The microwave system installed in Prince William Sound performed the following functions:

(1) It provided the necessary microwave paths linking each of the remote communication sites and the VTC;

(2) It provided the microwave paths that enabled the VTC watchstander to control the radar transceivers located at the Valdez Spit and Potato Point; and

(3) It provided the necessary microwave paths that permitted the transmission of returning target echoes from the remote radar sites to the radar consoles installed in the VTC.

In maintaining radar surveillance of vessel maneuvers, the VTC watchstander either monitors or plots each vessel, depending upon the vessel's location. The term "monitoring" means that the VTC watchstander is visually watching the progress of targets through the radar surveillance area. The latest edition of the Prince William Sound VTC Manual (November 1988) does not define what is meant by "monitoring," nor does the manual require that vessels participating in the system, except those participating vessels that are transiting the Narrows, be monitored by the VTC. According to statements made by the CO, Operations Officer, Assistant Operations Officer, and Senior Watchstander, despite the lack of written instructions, all VTC watchstanders were supposed to monitor the movement of all vessels under radar surveillance to the maximum range of the radar.

When the Prince William Sound VTS was established in 1977, the term "plotting" meant that the VTC watchstander was required to obtain the range and bearing of all vessels transiting the part of the system under radar surveillance (between Port Valdez and Bligh Reef) and manually plot the position of the vessel on a chart. The manual plotting of vessels was the only way that the VTC traffic watchstander could determine a vessel's true course, speed, and location, and verify that vessels transiting the VTS radar coverage area adhered to all VTS regulations during the transit.

In 1984, the Raytheon VTS radar was installed in Valdez. The Raytheon radar had a number of labor-saving features, such as automatic tracking[59] of up to 20 targets simultaneously. According to the CO of MSO Valdez, plotting the location of vessels that were participating in the system on charts was discontinued in 1984 when the Raytheon VTS radar was installed. Instead of plotting, vessel positions were recorded on data sheets. The CO stated that the new recording procedures permitted the VTC watchstander to recreate the path of a vessel at a later date, should the need arise. However, this change in procedures was not reflected in the August 6, 1986, edition of the Prince William Sound VTC Manual:

> (Section 4.2.5.) Participating vessels within the area of radar coverage shall be plotted. The reported position of a vessel entering the radar coverage area shall be correlated with the contact observed on radar.
>
> (Section 4.2.6) All participating vessels (including voluntary participants) will be plotted while in the radar coverage area.
>
> Normally the intervals of fixes shall be every three minutes between Tongue Point and Entrance Island [Valdez Narrows] and every six minutes in all other areas.
>
> Each fix will be plotted on the plotting sheets provided at the time the fix is taken.

On August 31, 1987, a memorandum issued by the Senior Watchstander to all VTC watchstanders initiated a change in the recording requirements.[60] According to the memo:

> You no longer need to plot the vessels from the 15-mile mark (point located about .5 NM past Bligh Reef) southwest of Potato Point. Plots are required as follows: commence plot three marks prior to the vessel's entry into the Narrows, then until the vessel passes either Entrance Island (inbound), and Tongue Point (outbound). [In the foregoing, the word "plot" means a written record of vessel bearings and ranges from the Potato Point radar site.]

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[59]Automatic tracking refers to electronic monitoring of a vessel's progress through the radar coverage area. The term "tracking" evolved when the latest generation of radars was developed that was capable of acquiring and processing information from numerous targets. A radar that is tracking a target has information such as the vessel's range and bearing, true course and speed, and target history continuously updated for immediate access by the operator.

[60]The memo was issued by the Watchstander Supervisor pursuant to guidance from the Assistant Operations Officer with the full knowledge and consent of the Operations Officer.

As a result of the memo, the VTC watchstanders were required to record the positions of only those vessels transiting the Valdez Narrows.

According to the Operations Officer, the August 1987 memo was issued because the dramatic increase in fishing vessel and cruise ship traffic during the summer months was placing excessive monitoring and recording burdens on the VTC watchstanders.

According to the Assistant Operations Officer, the August 31, 1987, memo required that VTC watchstanders record target data (i.e., target range, bearing, and time of observation) of all vessels transiting the Narrows. All other vessels under radar surveillance were still supposed to be monitored even though their positions were no longer required to be plotted. He also stated that the memo was not intended to relax the requirement to monitor the movement of all vessels under radar surveillance. When queried about the meaning of the new plotting requirements and the effect(s) that the new policy would have on VTS operations, he stated:

> We no longer, after this date (referring to the memo dated August 31, 1987), we no longer marked the bearing and range of the vessel and recorded it. But the watchstanders were still told to watch the target.

During March 1988, the Raytheon data logger was installed in the VTS. Shortly thereafter, the recording procedures for participating vessels were formally incorporated into the latest edition of the Prince William Sound VTC Manual (November 2, 1988), which states:

> (Section 4.2.6.) Participating vessels shall be plotted with the Raytheon data logger from a position one nautical mile prior to entering the Valdez Narrows and until the vessel has departed the One-Way Zone.
>
> Plotting intervals outside of the Valdez Narrows shall be six minutes. Slow vessels may be plotted at ten minute intervals.
>
> (Section 4.2.6.d.) With the addition of the Raytheon data logger, watchstanders are now available to devote additional time to vessel communications, telephone calls, and other matters.

The VTC Manual provides the VTC watchstander with specific guidance to be followed when monitoring the movement of participating vessels:

> (Section 4.3.3.e.) The VTC may, on request, issue an authorization to deviate from the TSS rules on a "one-time" basis. Except for minor deviations not involving other traffic, the VTC shall refer all such requests to the Commanding Officer as per his standing orders. Deviations shall not be authorized for major vessel traffic except in unusual circumstances, and shall not be authorized strictly for convenience of the vessel (i.e. saving time, fuel economy, etc.) at any time.

> (Section 4.3.3.f.) In an emergency, any vessel may deviate from the VTS rule to the extent necessary to avoid endangering persons, property, or the environment. The master or pilot must report the deviation to the VTC as soon as possible.

The VTS User Manual states:

> A radio equipped vessel may join, cross, or leave a traffic lane only after the VTC has been notified of the point at which the vessel will join, cross, or leave the traffic lane.

The CO of MSO Valdez stated:

> If a participating vessel intends to, and does, cross out of the traffic lanes completely (either east or west) the watchstander should contact the vessel and inquire into the vessel's intentions. If the vessel knows its position, and is maneuvering, no further radio contact is required but a vigilant radar watch of the vessel shall be performed. Nothing in the regulations prohibit a vessel from exiting the traffic lanes, however it must notify the VTS of its intentions.

He further stated:

(1) The EXXON VALDEZ should never have deviated from the TSS where it did because it was not safe to do so;

(2) There is no good reason for a vessel to deviate from the TSS;

(3) A vessel requesting a deviation is requesting something out of the norm;

(4) VTC traffic watchstanders do not have the authority to allow vessels to leave the traffic lanes north of Bligh Reef;

(5) A vessel should call the VTC whenever it crosses a boundary line;

(6) It is the responsibility of the watchstanders to identify those vessels that are deviating from the TSS; and,

(7) When a VTC watchstander discovers that a vessel has departed the TSS, he should contact the vessel, inquire about its intentions, and tell the vessel that it does not belong outside the TSS because there is not enough room there.

According to the CO of MSO Valdez, a request from a tankship to deviate from the TSS (except those tankships proceeding to and from Knowles Head anchorage) must be forwarded to the OOD, who would then forward the request to either the CO or the XO for reply. The OOD on duty during the evening of March 23 stated that he departed the station about 2230[61] and that he was not notified that the EXXON VALDEZ was deviating out of the southbound lane because of ice. He was, however, cognizant of other vessels deviating because of ice earlier in the day.

When the OOD was not available, the VTC watchstander was permitted to contact the CO or the XO directly for permission to allow vessels to deviate from the TSS. When the EXXON VALDEZ began its transit of the Valdez Arm on the day of the accident, neither the CO nor the XO was at the VTC and neither was aware that the master of the EXXON VALDEZ had notified the VTC that he intended to depart from the TSS. The Operations Officer stated that VTC watchstanders were authorized to grant permission to vessels seeking to deviate from one traffic lane to another without notifying the OOD or the CO. He also stated that he considered the deviation from one traffic lane into another a minor deviation.

The Assistant Operations Officer stated that the master of a vessel encountering ice in the traffic lanes had the option of maneuvering around the ice for safety reasons and that the master might depart from the TSS during such a maneuver. He also said that before the accident he was not aware that vessels were deviating from the TSS.

The 1600-2400 VTC watchstander stated that a vessel was permitted to depart from the TSS to provide a lee for the pilot when a vessel was proceeding to and from the Knowles Head anchorage and when small tankships with a State pilot aboard were given permission to exit Prince William Sound via Montague Strait. He also stated that most of the masters aboard outbound tankships were accustomed to deviating from the southbound traffic lane into the northbound traffic lane and that they normally headed toward a stretch of clear water near Bligh Reef buoy that was usually ice-free. The watchstander also stated that he could not recall ever having observed any vessel actually leave the TSS because the VTC generally lost radar contact with outbound tankships in the vicinity of Busby Island.

The 0000-0800 VTC watchstander stated that he was aware that vessels sometimes deviated from the TSS because of the presence of ice in the traffic lanes. He said that such deviations occurred at the discretion of the master. He stated that vessels generally reported to the VTC if they departed their traffic lane and crossed the separation zone boundaries. He went on to say that:

> If a vessel requests permission to leave the lanes entirely or there exists opposing traffic, he would monitor closely on radar if conditions permit.

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[61] When departing the station for any reason, the OOD is required to notify the VTC of his absence and to have a functioning radio and/or pager in his possession.

> A vessel intending to leave their lane with conflicting traffic in the area would be advised by the VTC not to do so until the traffic had cleared.

Two other VTC watchstanders said that on several occasions they were either aware of or had given permission to vessels to deviate from the TSS because of the presence of ice in the traffic lanes. They also stated that because the ice often extended all the way across the lanes toward the vicinity of Bligh Reef buoy, vessels deviating from the TSS were frequently forced to pass close to Bligh Reef buoy.

Personnel changes have led to changes in supervision of the VTC. When the VTS was first established, there were five VTS watch supervisors, consisting of five lieutenants who performed OOD duties for MSO Valdez. As part of these duties, the watch supervisor stood a VTC watch along with two radarmen (RDs). In 1978, a Chief Warrant Officer (CWO4) billet was added to the VTC. One of the lieutenants was then replaced on the watch rotation by the CWO4, and the lieutenant was assigned to non-VTS duties of the MSO Valdez. According to the 0000-to-0800 VTC watchstander involved in this accident, the watch supervisors were required to be qualified as Deck Watch Officers[62] before the billet reduction.

During 1982, MSO Valdez was reorganized and four of the five watch supervisors were made department heads and were tasked with additional MSO duties and responsibilities that had little to do with the day-to-day operation of the VTS. According to the CO, this was an effort to provide these individuals with additional challenges, as well as the opportunity to exercise leadership. He also stated that exclusive use of these officers to stand 12-hour VTC watches was not, in his opinion, an efficient use of their talents.

In a letter to the Commandant dated August 1, 1986, the CO of MSO Valdez proposed that MSO Valdez be downgraded to a Marine Safety Detachment under the authority of MSO Anchorage and that the VTS become a separate command under the control and supervision of the Program Officer on the Seventeenth Coast Guard District staff. The primary motivation for the proposal was to reduce the number of billets assigned to support roles, i.e., public works and personnel services, etc. The proposal also called for the elimination of five VTS officer watchstander billets and their replacement with two lieutenant (junior grade) billets. According to the CO, "As I see it, the present structure of 5 watch officers (4 lieutenants and 1 CWO4) is a waste of officer talent and billets." The proposal was approved by CGD17 and forwarded to Commander, Pacific Area, who endorsed the letter and forwarded it to Commandant (G-CMA) for consideration on January 13, 1989.

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[62] A qualified Deck Watch Officer is an individual who has been certified to stand a bridge navigation watch aboard commissioned vessels of the Coast Guard.

In a memorandum issued by the Operations Officer dated August 7, 1987, the MSO/VTS OOD watches were discontinued and replaced by a Command Duty Officer (CDO) duty section. This new section consisted of the Marine Safety Department head, the Operations Officer, the Assistant Operations Officer, the Public Works Department head, and the Personnel Services head (later changed to Administration Department). The CDO, unlike the MSO/VTS OOD, was no longer required to be in the VTC during routine vessel transits of the Valdez Narrows. CDOs were, however, required to be in the VTC whenever any conflicts in the one-way zone or other serious traffic problems existed. There was no specific guidance specifying what type of conflict or serious problem traffic must exist before his presence was required.

On February 23, 1988, the Coast Guard announced plans to reduce VTS staffing at MSO Valdez by seven billets. MSO Valdez later counterproposed the elimination of five VTS billets and two MSO billets. The Personnel Allowance Amendment dated March 3, 1988, indicates that five VTS billets, including three lieutenants, a third class boatswain mate and a third class RD were eliminated.

The loss of five VTS billets forced the CO to reorganize MSO Valdez. The Operations Officer was assigned a number of duties and responsibilities unrelated to the VTS, including Maritime Defense Zone (MDZ) contingency planner, Classified Materials Custodian (COMSEC), Unit Training Officer, and Claims Investigating Officer. The lieutenant, who previously acted as head of the Communications Division,[63] no longer participated in day-to-day VTS activities. The Assistant Operations Officer, who had been in charge of day-to-day supervision of the VTC traffic watchstanders, stated that because of his additional duties, he was able to devote about 5 hours a week to the VTS program. As a result, the Senior Watchstander, by default, assumed responsibility for supervision of the day-to-day operation of the VTS. When he did so, he became responsible for monitoring the performance of the five VTC watchstanders (three civilians with previous Coast Guard military experience and two enlisted Coast Guard personnel) and five enlisted radio watchstanders assigned to the communication center. The Senior Watchstander worked days and also stood VTC watches when watchstanders called in sick, took annual leave, or were otherwise unavailable.

In a memorandum dated May 16, 1988, the CO stated that because of a reduction in personnel at the unit, the CDO and OOD duty sections would be merged. The resulting watch was called the OOD. On weekdays, OODs stood watch between 0900-2230. On weekends, they stood watches between 0900-2400. They were required to carry a beeper/radio and were required to check in with the VTC before leaving the station building. The OOD acted to a large extent in a security capacity. According to the VTC Manual, one of the OOD's responsibilities was to ensure that the performance of the watch in the VTC was in accordance with all applicable instructions. Thus, the security

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[63] As head of the VTS Division, his responsibilities included supervising the VTC traffic watchstanders to ensure that they followed all Coast Guard Rules and regulations and local VTS policies on a day-to-day basis.

duties of the OOD were expanded to include some supervision of VTC operations. In addition, the VTC Manual stated that OODs were to be informed when hazardous circumstances existed or were anticipated anywhere in the VTC area. According to the VTC Manual, the OOD was to:

> monitor the performance of the radar/VTC watchstander and the communications watchstander. When necessary, he shall personally take charge of vessel communications.
>
> check all display, communications, and other equipment for proper operation. If not operating properly, insure that the Commanding Officer has been notified.

On the day of the accident, only one of the OODs was qualified as a VTC traffic watchstander.

Pilotage Information.--The Trans-Alaska Pipeline Authorization Act,[64] which enabled the pipeline to be built, specified that any domestically produced crude oil transported by the pipeline was for domestic consumption and that the North Slope crude oil "should be equitably shared, directly or indirectly, by all regions of the country." This meant that the crude oil would be transported to U.S. refineries. A provision of the Jones Act pertaining to the transportation of cargo (cabotage) from one port in the United States or its possessions to another port in the United States or its possessions requires that such cargo must be transported by U.S. flag vessels. The significant exception to the cabotage requirements of the Jones Act permits cargo between the U.S. Virgin Islands and other U.S. ports to be carried by foreign flag vessels.

Federal law (46 USC 8502) also requires that coastwise seagoing vessels (domestic vessels) be under the direction and control of a Federally licensed pilot while transiting U.S. pilotage waters, which include waters inside the 3-mile territorial seas, such as coastal waters, bays, inlets, rivers, harbors, and ports of the United States, its territories and possessions. Therefore, domestic tankships calling at Port Valdez are required to be under the direction and control of a Federally licensed pilot while transiting Prince William Sound. A Federally licensed pilot may be an officer on the vessel who has acquired a Federal pilot's endorsement on his license from the Coast Guard for the particular waterway. To obtain a Federal pilot's license for Prince William Sound, a licensed deck officer must complete 20 roundtrips over the waterway and pass an examination administered by the Coast Guard.

Prior to the commencement of crude oil shipments from Port Valdez,[65] several U.S. oil companies cooperated to provide a tankship for pilotage training of their masters and prospective masters. These mariners rode the

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[64] Public Law 93-153.

[65] The first shipment of North Slope crude oil left Port Valdez on August 1, 1977, on board the U.S. Tankship ARCO JUNEAU.

vessel for a number of trips over the route that they would follow from the entrance to Prince William Sound at Cape Hinchinbrook to the vicinity of the Alyeska Terminal in Port Valdez so that they could become familiar with the waterway and acquire the requisite number of transits to qualify for a Federal pilotage endorsement on their licenses. The initial plan of the U.S. oil companies was that their masters, once they obtained the required Federal pilotage, would pilot their own vessels through Prince William Sound and into Port Valdez to the vicinity of the Alyeska Terminal. Upon arriving off the piers of the terminal, each vessel would be met by tugs and be boarded by a docking master, who would then conduct the docking, or berthing, of the vessel. The undocking of each vessel was also to be conducted by a docking master.

About this same time, State-licensed pilots of the Southwest Alaska Pilots Association also were seeking a means to participate in piloting the tank vessels that would be calling at Port Valdez. As a result of lobbying efforts, the State pilots succeeded in obtaining passage of an Alaska State law[66] requiring tankships of 50,000 or more deadweight tons, when navigating State waters, either to:

1. Employ a pilot licensed by the State; or

2. A Federally licensed pilot whose duty station had been on that tank vessel throughout that particular voyage.

The law also required that control of the vessel during all docking operations be conducted by either the State or the Federal pilot referred to in the law, thereby excluding the use of docking masters. To facilitate the commencement of oil shipments from Port Valdez, the U.S. oil and tank vessel companies chose to accept State-licensed pilots for vessel movements between Cape Hinchinbrook and the Alyeska Terminal and for docking and undocking their vessels at the terminal. The State-licenced pilots also possessed Federal licenses for Prince William Sound and Port Valdez and thus met the Coast Guard requirements for Federal pilotage on U.S. vessels.

The Southwest Alaska Pilots Association established a state pilot station at Cape Hinchinbrook in 1977 using a converted fishing vessel, the BLUE MOON, and commenced providing pilotage for all tank vessels engaged in carrying Alaska North Slope crude oil. High winds and heavy sea conditions, particularly in the winter, frequently made it difficult to keep the BLUE MOON on station and dangerous to embark and disembark pilots. On January 7, 1980, the BLUE MOON foundered during heavy weather, leaving the pilots with no means to board vessels at Cape Hinchinbrook. The State pilot station was then moved to the vicinity of Rocky Point in Valdez Arm. The State of Alaska Board of Marine Pilots subsequently decided not to reestablish the pilot station at Cape Hinchinbrook, and the Board eliminated the State requirement for pilotage between Cape Hinchinbrook and the pilot station at Rocky Point.

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[66] State of Alaska Statutes Sec. 08.62.185.

The requirements for Federal pilotage remained in effect, but there was no means for a pilot to board a transiting tankship following the sinking of the BLUE MOON. The lack of a pilot station at Cape Hinchinbrook had little effect on most U.S. tankships calling at Port Valdez because most U.S. masters held the necessary Federal pilotage endorsement. However, foreign flag tankships, which had started carrying Alaska crude oil from Port Valdez to an American refinery in St. Croix, U.S. Virgin Islands, and a few U.S. tankships whose officers did not hold Federal pilotage were directly affected because they depended on the pilot station at Cape Hinchinbrook for pilotage to navigate Prince William Sound.

To accommodate foreign flag tank vessels and those U.S vessels whose licensed deck officers did not have Federal pilotage endorsements for Prince William Sound, the Coast Guard COTP for Port Valdez established a set of requirements that were intended to enhance navigation safety for such vessels while navigating Prince William Sound and to help compensate for the lack of a pilot on board. The requirements were promulgated as OTP Order 1-80 on February 25, 1980. (See appendix I.) The order required compliance with the following:

1. Status of all machinery, personnel, charts, publications and navigation equipment required by 33 CFR 164 will be reported.

2. Based on satisfactory condition, entry of the vessel into Prince William Sound will be permitted, provided transit to or from the pilot station can be completed during daylight hours and during a period of predictably good visibility.

3. A licensed officer, in addition to the licensed officer on watch, will be employed as a navigator to continuously plot the position of the vessel during the transit of Hinchinbrook Entrance and Prince William Sound. This position will be reported on request to Valdez VTC.

4. The Valdez Port Pilot will board or depart the vessel at the entrance to Valdez Arm off Bligh Reef in lieu of the established pilot station at Busby Island.

5. Transit to the anchorage area off Knowles Head during other than emergency conditions will be evaluated on a case basis, taking into account weather, vessel traffic, and operating conditions.

6. An English-speaking officer will be on watch during the entire Prince William Sound Transit period.

The COTP or the duty officer, based on the vessel's reported condition, time of day, and reported visibility, determined whether the vessel would be permitted to transit Prince William Sound.

The requirement in COTP Order 1-80 that vessels without Federal pilots (nonpilotage vessels) transit Prince William Sound only during daylight resulted in vessel delays, numerous complaints to the Coast Guard from vessel operators, and requests for relaxation of the daytime requirement. A review of Coast Guard files revealed that the need for Federal pilotage in Prince William Sound was being evaluated as early as the implementation of COTP Order 1-80, which stated that proposed rulemaking to revise or rescind the pilotage requirement already was under consideration. Other internal memoranda indicated that cancellation of COTP Order 1-80 as an alternative was considered by the Coast Guard soon after its implementation. Other COTP orders augmented COTP Order 1-80 from time to time, but it was this order that was ultimately rescinded by the COTP.

In 1986, the COTP cancelled COTP Order 1-80, except for the provision that the requirements of the checkoff list were to be incorporated into VTS procedures; hence, the requirements for an English-speaking officer on the bridge, an additional officer on the bridge for navigation, frequent fixing of the vessel's position, and obtaining vessel information from each nonpilotage vessel would continue in effect. The CO's decision was explained in a memorandum dated September 3, 1986, directed to all OODs and VTC watchstanders. The requirement for daylight transits by nonpilotage vessels was eliminated. The primary factor for determining whether a nonpilotage vessel would be granted permission to transit Prince William Sound would be a requirement that visibility be 2 miles or greater. If visibility was less than 2 miles, nonpilotage vessels normally would not be allowed to transit Prince William Sound. However, consideration would be given to a vessel's need to enter Prince William Sound for safety reasons.

Although COTP Order 1-80 and other Coast Guard correspondence mentioned the possibility of rulemaking as a means of eliminating the requirement for Federal pilotage in Prince William Sound, this was not a feasible solution at the time because the Coast Guard lacked legal authority to change the designation of pilotage waters to nonpilotage status. Public Law 98-557, sponsored by the Alaska Congressional delegation, amended the Federal Pilotage law at 46 U.S.C. 8502 by adding that the "Secretary [of Transportation] shall designate by regulation the areas of the approaches to and waters of Prince William Sound, Alaska, on which a vessel subject to this section is not required to be under the direction and control of a [Federal] pilot."

Following passage of Public Law 98-557, the first proposed regulatory change to reduce the requirement for Federal pilotage in Prince William Sound was published by the Coast Guard in the Federal Register on June 24, 1985. This rulemaking effort would have eliminated the requirement for Federal pilotage in Prince William Sound between the entrance at Cape Hinchinbrook and Rocky Point in Valdez Arm. After a review of comments on the proposed change, the Coast Guard, on June 6, 1988, published a supplemental notice of proposed rulemaking, which, like the June 24, 1985, proposed rules, addressed a number of pilotage issues in addition to reduced pilotage requirements in Prince William Sound. The section of the 1988 supplemental notice regarding pilotage in Prince William Sound was worded

differently from the 1985 proposed rules as a result of written comments received by the Coast Guard; however, it was still very similar in substance to the 1985 proposal. The pertinent part of the 1988 supplemental notice of proposed rulemaking is quoted below:

> (1) Vessels are excluded from pilotage requirements when entering or departing Prince William Sound, Alaska, via Hinchinbrook Entrance and
>
> (a) Proceeding directly to and from the established Valdez/Whittier pilot station at Rocky Point (Latitude 60°57.1'N, Longitude 146°46.0'W), or
>
> (b) Proceeding to ...Cordova ..., [or]
>
> (c) Proceeding directly to or from a designated anchorage described in 33 CFR 110.[67]

The Coast Guard received no significant adverse comment on that part of the 1988 supplemental notice pertaining to Prince William Sound pilotage. However, considerable comment was received on other pilotage issues contained in the notice, and the need for the Coast Guard to address those comments delayed implementation of the entire package of pilotage regulations. Following the grounding of the EXXON VALDEZ, the Coast Guard withdrew the proposed pilotage changes for Prince William Sound for further review.

On April 12, 1989, the Alaska Board of Marine Pilots relocated the pilot station for Port Valdez from Rocky Point to a location of latitude 60° 49' N, longitude 147° 01' W so that pilots would embark and disembark south of Bligh Reef. The pilot station at this location ensures that there will be a pilot on board throughout the length of Valdez Arm.

Alternative Tankship Designs.--On June 1, 1989, the chief of the U.S. Coast Guard's Office of Marine Safety, Security, and Environmental Protection requested the assistance of the National Academy of Science to investigate methods of minimizing accidental pollution from tankships. The task was assigned to the Marine Board's Committee on Tank Vessel Design. The "Statement of Task" as outlined by the Coast Guard was as follows:

> The committee will review the safety, economic, and environmental implications of alternative oceangoing tank vessel designs and make recommendations. It will update what is known about tank vessel accidents and the effectiveness of alternative tank vessel designs in preventing accidental oil pollution; assess technical concerns about alternative tank vessel designs; identify

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[67]This includes Knowles Head Anchorage, which is described at 33 CFR 110.233.

needed research; and elucidate the safety, environmental, and economic costs and benefits of alternative tank vessel designs. The committee will focus its assessment on tanker vessels 10,000 deadweight tons (DWT) and larger.

The committee will use a series of meetings to collect and analyze data; identify and assess alternative tank vessel designs and their implications; formulate recommendations; and ensure access to the widest possible range of perspectives on the issues. In its final report, the committee will identify how alternative tank vessel designs might affect the overall consequences of tank vessel accidents.

The Coast Guard will use the technical information, analysis and recommendations of the Academy in its deliberations concerning whether to establish new or alternative tank vessel design requirements as one measure to improve maritime safety and marine environmental protection. The results of the study will also be of interest to the U.S. Congress, the domestic and international marine transportation industry, the International Maritime Organization, environmental protection organizations, and States and communities along tank vessel routes.

This study will be completed within 15 months of its initiation. Funds for this project are being provided by the U.S. Coast Guard.

The Safety Board was informed by the Marine Board that they were reviewing two generic groupings of alternative tankship designs: (1) prevention of penetration of the cargo oil containment barrier and (2) prevention or restriction of oil outflow after penetration. Some of the alternative oceangoing tank vessel designs under review were:

1 Double bottom

2. Double sides

3. Double hull (double bottom and sides)

4. Use of high tensile steel in the hull

5. Relocation of protectively located ballast tanks

6. Cargo tank internal membranes

7. Interior/exterior honeycomb bumpers

8. Collapsible bow (crashworthiness)

9. Subdividing the cargo tanks horizontally, vertically, or both ways

10. Rapid pumping of cargo from a damaged tank to an empty (ballast) tank

11. Elevating the cargo/ballast piping above the tank bottom for protection of the piping systems

12. Creating a vacuum in the cargo tank, including the rapid, automatic closure of deck openings and valves

13. Octagonal-shaped tanks

14. Damage control (patches)

15. Pressure loading, i.e., cargo loading levels limited to height that equalizes the internal pressure (head + I. G. pressure) in the tank with the exterior hydrostatic pressure at the planned draft of the vessel.

Pressure loading was one option that could be adopted without any change to a vessel. The Safety Board calculated the approximate amount of cargo the EXXON VALDEZ would have been able to carry if it had been pressure loaded for a planned draft of 56 feet (draft restrictions owing to water depth at the port of Long Beach).

For the purpose of these calculations the tankship was assumed to be hard aground on an even keel in a static condition without adverse environmental influences and with the inert gas system activated. Ullages used were those recorded prior to vessel departure from Valdez and after the tankship had grounded on Bligh Reef. Because of draft restrictions, cargo was loaded to bring the vessel to a draft of about 56 feet, and cargo tanks were filled, on average, to about 84 percent capacity.

At the time the EXXON VALDEZ departed from the terminal at Valdez, Alaska, the average internal pressure at the bottom of the cargo oil tanks was calculated to be about 28 psi and the external hydrostatic pressure was about 24 psi with a draft of about 56 feet. Based on the assumptions and calculations performed by the Safety Board, the EXXON VALDEZ would have spilled about 170,000 barrels had it been loaded to 84 percent of capacity. However, ullage readings indicated that the amount actually spilled by about 0900 was about 225,000 barrels. (See tables 1 and 2 on page 27.) The difference in the calculated versus actual oil outflow could be owing to several factors such as vessel ahead motion, vessel listing, loss of cargo containment because of extensive damage, tides, and currents.

If the cargo tanks were loaded to about 98 percent capacity (1,484,829 barrels), with a corresponding draft of 63.5 feet, the internal tank pressure would have been about 34 psi and the external hydrostatic pressure would have been approximately 28 psi. In this condition of loading, the EXXON VALDEZ would have spilled about 329,000 barrels owing to the increased internal tank pressure.

By loading the tankship using the pressure loading method, the EXXON VALDEZ cargo tanks could have been filled to about 70 percent capacity (about 1,060,000 barrels). Then the internal and external pressure would have been equalized at about 24 psi and theoretically, no oil would have been spilled. The EXXON VALDEZ would have carried about 230,000 barrels less cargo if pressure loading had been the method used.

Tank Arrangement Requirements Applicable to the EXXON VALDEZ.--The 1973 International Convention for the Prevention of Pollution from Ships, commonly referred to as MARPOL '73, established regulations that govern the design and arrangement of cargo tanks aboard tank vessels. These regulations require that cargo tanks be sized and arranged to limit the accidental outflow of oil (including crude oil, fuel oil, sludge, and other petroleum products) to 30,000 cubic meters (1,059,440 cubic feet/188,693 barrels) or 400 times the cube root of the vessel's deadweight,[68] whichever is greater, assuming the number does not exceed 40,000 cubic meters (1,412,590 cubic feet/251,571 barrels). In addition, MARPOL '73 regulations limit the volumetric capacity of cargo tanks. A wing cargo tank is limited to 75 percent of the hypothetical oil outflow, and a center cargo tank is limited to a capacity of 50,000 cubic meters (1,765,730 cubic feet/314,464 barrels).

In 1978, a protocol to MARPOL '73 introduced the concept of locating segregated ballast tanks (SBTs) in a manner that would provide a means of protection against accidental oil outflow in case of collision or grounding. The segregated ballast arrangement consists of protectively locating ballast tanks along the cargo tank length to provide side and bottom protection. In addition, the SBTs are required to have sufficient capacity to allow the ship to have enough trim and draft to operate in the ballast condition. This requirement virtually eliminates the need to use cargo tanks as ballast tanks, thereby reducing the amount of operational pollution discharges. However, the international maritime community rejected the U.S. proposal to require that segregated ballast be carried in double bottoms having a depth of at least one-fifteenth the breadth of the ship (B/15) or 2 meters, whichever was less, to protect against groundings.

Mathematical formulas were developed to help ship designers locate the ballast tanks and meet the objectives of damage protection and reduction of dirty ballast discharges. The formulas governing the protective location of ballast tanks were primarily based on an area-ratio coefficient, which is a ratio of the protected shell area to the total side and bottom shell area within the cargo tank length. The regulations provide guidelines for

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[68] Deadweight refers to a vessel's carrying capacity, including cargo stores, and provisions, in tons.

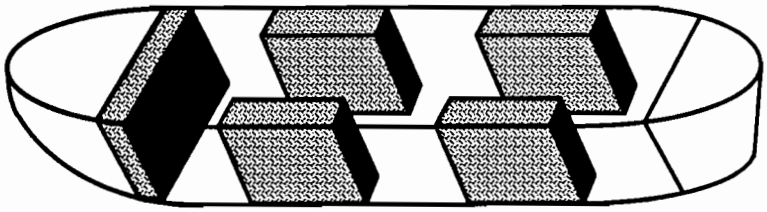
determining the size and location of the SBTs, but they do not specify a ballast tank configuration.

The vessel owner is permitted to meet the regulations by implementing the tank configuration that will result in the lowest cost and least loss of deadweight. For most vessel owners, a staggered wing tank configuration (see figure 12) constitutes the most operationally efficient and cost-effective option. For tank vessels over 20,000 deadweight tons,[69] a typical staggered wing tank arrangement would consist of four sets of wing tanks, two sets carrying segregated ballast and two sets carrying cargo. This arrangement, however, only provides partial protection against oil outflow owing to collisions because only four wing tanks are ballast tanks, and only minimal protection from grounding is provided because none of the cargo tanks are protected. This method was used in the design and construction of the EXXON VALDEZ.

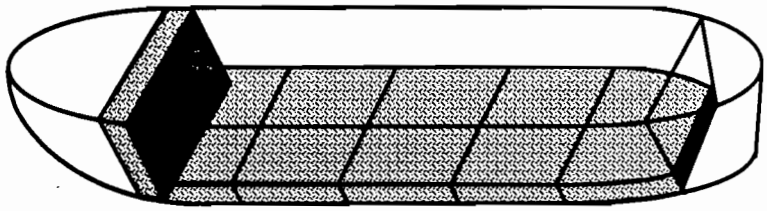
Oil Spill Response.--This section considers only the first 24 hours of the oil spill response. The preparation for and the initial response to the oil spill was governed by three Federal plans, one State of Alaska plan, and one plan produced by the Alyeska Pipeline Service Company, that had been approved by the State of Alaska. Subsequent response to the spill was conducted by Exxon Shipping Company pursuant to Exxon's spill response plan, but this was more than 24 hours after the spill and is therefore not covered in this report. Two of the Federal plans, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the Alaska Regional Oil and Hazardous Substances Pollution Contingency Plan (RCP), provide for implementation by a team that is similar to a board of directors for a company. Members of each team include representatives from various Federal government agencies and in the case of the RCP, a representative from the State of Alaska. The NCP board of directors was referred to as the National Response Team (NRT) and the RCP board was referred to as the Regional Response Team (RRT). The third Federal plan was the COTP Prince William Sound Pollution Action Plan, which was the local Coast Guard plan for investigating a pollution incident, identifying the responsible person or company, monitoring oil spill cleanup activities, granting permission in some cases for the use of certain cleanup methods, and taking over responsibility for the cleanup if necessary.

The State of Alaska Oil and Hazardous Substances Pollution Contingency Plan provided guidelines for a coordinated response to spills. State regulations require terminals in Alaska that handle oil and hazardous substances to produce spill cleanup plans and to provide resources to clean up spills. Pursuant to State regulations, the Alyeska Pipeline Service Company (Alyeska) had developed a spill plan to clean up spills occurring at the Alyeska marine terminal in Valdez, spills from tankships carrying North Slope crude oil in Port Valdez, and spills in Prince William Sound. The Alyeska plan governed the activities initiated to contain and clean up the

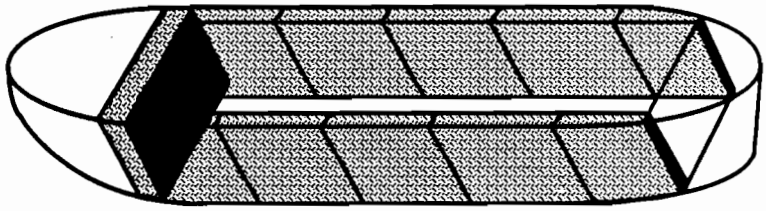
[69] The size of tankships that would be required to have SBTs and to meet other requirements for cargo tank size was determined by international agreement to be those crude carriers over 20,000 deadweight tons.



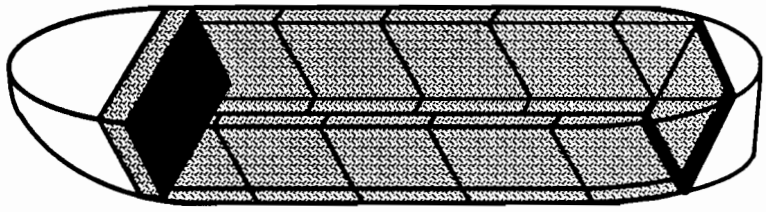
a. Staggered wing tanks



b. Double bottom



c. Double sides



d. Double hull

Figure 12.--Tankship design alternatives.

oil spilled by the EXXON VALDEZ, using equipment and manpower provided by Alyeska. Alyeska's cleanup equipment was the first to arrive on scene.

About 0027 on March 24, 1989, the master of the EXXON VALDEZ reported to the Coast Guard VTC at Valdez that his vessel was aground on Bligh Reef and leaking oil. The vessel's log book shows that the EXXON VALDEZ grounded at 0004 on March 24. The height of the tide was about +9.8 feet above mean lower low water (MLLW), which is the chart datum of soundings.

About 0030, the COTP for Prince William Sound at Valdez, Alaska, closed the port to all traffic. About the same time, the VTC watchstander requested that the tug STALWART be dispatched from the Alyeska Valdez Marine Terminal (Terminal) to assist the EXXON VALDEZ. He then notified the Alyeska marine operations supervisor on duty at the Terminal of the accident and oil spill. The marine supervisor on duty notified his superiors, commenced the Alyeska mobilization call-out, and ordered that the pollution response barge and cleanup equipment be prepared for deployment. In response to a Safety Board query, the Valdez Terminal Marine Manager stated, "There is no list of equipment 'normally loaded' on Alyeska's response barge because every spill is unique in size, location and viscosity and, by definition, every spill will require different equipment."

At 0030, about 26 people were working at the Terminal. They included 10 marine technicians and 2 power vapor technicians, who were available to prepare spill response equipment. The remaining personnel were handling Terminal functions and vessels. By 0330, 57 people were working at the Terminal, 38 of whom were manning the emergency center and handling oil response activities. By 0500, 83 persons were at the Terminal, of whom 63 were involved in the spill response. By 0600, approximately 140 people were working at the Terminal, and 113 were involved in spill response.

About 0040, the COTP, who was the Federal on scene coordinator (OSC), and the MSO's XO arrived at the MSO. About 0050, the COTP called the Alyeska marine operations supervisor on duty and told the supervisor that he wanted to talk to the marine superintendent. The COTP also advised the marine operations supervisor "to start thinking about getting dispersants up here, we may want to use them." About the same time, the OSC notified the person in charge of the Alaska Department of Environmental Conservation (ADEC) Prince William Sound District Office about the grounding and the oil spill, and the XO notified the Coast Guard alternate cochairman of the RRT at the Seventeenth Coast Guard District Office, Juneau, Alaska. The Coast Guard cochairman of the RRT and the District Commander also were notified. The person in charge of the ADEC District Office initiated the ADEC communications plan. The commissioner of ADEC testified that "within about 2 hours, we had staff either preparing to move or actually moving toward Valdez."

At 0115 and 0130, respectively, the Alyeska emergency response centers opened in Valdez and Anchorage. At 0125, the president of Alyeska in Anchorage notified the president of the Exxon Pipeline Company, in Houston, who then notified the president of the Exxon Shipping Company, who was also in Houston. Alyeska in Valdez commenced mobilizing men and equipment from

the local area, as well as from other parts of the State and from pipeline employees.

At 0148, MSO Valdez contacted the Coast Guard Air Station at Kodiak, Alaska, for a helicopter overflight of the grounded vessel at first light. High tide, which was predicted to occur at 0206 at +12.8 feet above MLLW, failed to refloat the EXXON VALDEZ and oil continued to spill from the vessel. The next low tide was predicted to occur at 0821 at -0.3 feet below MLLW. About 0227, the tug STALWART arrived at the EXXON VALDEZ and stood by. At that same time the pilot boat CHIRIKOF reported that there was an oil slick about one-half mile south of the EXXON VALDEZ.

About 0230, the XO and the SIO from the MSO, together with the person in charge of the ADEC District Office, departed Valdez on the pilot boat SILVER BULLET for the grounded vessel.

At 0238, the Alyeska marine manager at Valdez and the COTP discussed the need to use dispersants on the spill. The COTP advised the Alyeska to prepare to use dispersants.

At 0249, the OSC requested assistance from the Coast Guard Pacific Area (PACAREA) Pollution Strike Team at San Francisco. Members of the team were expected to arrive in Cordova, Alaska, at 1530. The XO and the SIO from MSO Valdez and the ADEC District Office chief arrived on board the EXXON VALDEZ at 0335 to assess the situation and to begin the accident investigation. They learned from the master of the EXXON VALDEZ that about 138,000 barrels of oil had already been lost from the EXXON VALDEZ's starboard wing tanks Nos. 1, 3, and 5 and the No 5 center tank. They reported this to the OSC.

Between 0414 to 0445, the OSC made lightering of the EXXON VALDEZ a "high" priority because of concern about the stability of the vessel. Alyeska had to provide fenders and hoses for lightering. The OSC and Exxon officials decided to use the tank vessel EXXON BATON ROUGE, then en route to Valdez, for lightering the EXXON VALDEZ. That vessel's estimated time of arrival on scene was 1100.

By 0435, Exxon had activated the Exxon-wide response team, their third and highest level of response. They were mobilizing, sending, or contracting for available oil spill cleanup equipment to be sent to Alaska. Oil spill response equipment was ordered from stockpiles in San Francisco, California, and in Southampton, England. Oil containment booms or sea barriers were ordered from the USSR, Norway, Denmark, France, Canada, and the United Kingdom. Contracts were let for dispersant aircraft, and dispersant stockpiles were being located and transported to Anchorage. The Exxon Company plane with the president of the Exxon Shipping Company and other company employees departed Houston at 0836 for Valdez.

By about 0600, all members of the RRT had been notified by the Seventeenth Coast Guard District and given preliminary information about the spill. A telephone conference meeting of the RRT was scheduled for later that morning at 1000.

At 0727, a Security Air Company helicopter contracted by Alyeska was airborne for an overflight of the accident area with a Coast Guard investigator on board. The oil slick by that time was 1,000 feet wide and 4 to 5 miles long.

At 0830, ADEC convened a meeting of its response staff members in Juneau, and the Governor joined via telephone conference call from Fairbanks. About 0930, the commissioner of ADEC departed Juneau for Cordova. Shortly after his arrival in Cordova, a Coast Guard helicopter took the commissioner for an overflight of the accident area.

About 0830, the Regional Response Center (RRC) in Juneau received, via facsimile, an application from Alyeska to use dispersants on the oil spill. This application was relayed to the other members of the RRT.

At 1010, the tug SEA FLYER departed the Terminal with lightering equipment for the EXXON VALDEZ. At 1137, the Alyeska barge departed the Terminal under tow of the tug PATHFINDER. The barge had to be moved to a loading area on the Terminal at 0200, where 25 tons of pollution response equipment was loaded on board. Equipment stowed on the barge had been removed to permit cleaning after an oil spill response in January 1989 and for repairs to the barge following damage sustained during a wind storm in early February. The repairs had not commenced before the barge was reloaded with spill response equipment for this incident. The barge had one or two connex boxes (8'x8'x20' shipping container) with containment boom on board before the additional equipment was loaded. The 200,000-barrel spill scenario described in the Alyeska contingency plan for Prince William Sound allowed a 5-hour response time for the tug and contingency barge to arrive on scene, about 30 miles from the Valdez Terminal, near the same location as the grounded EXXON VALDEZ.

About 1130, an RRT telephone conference was held with the OSC to update the team and to discuss use of disperant chemicals (dispersants) and in-situ (wherever the oil is located) burning of the oil. The spill was approximately 3 miles wide and 5 miles long. A decision on dispersant use in Zone 2 was not made at that time. (See figure 13.) The OSC had pre-approved authority to use dispersants in Zone 1. The RRT concurred in the use of in-situ burning, which could not commence until the State of Alaska issued a burn permit. About 1200, Alyeska submitted a handwritten request to the Coast Guard in Valdez for permission to conduct in-situ burning.

The estimate of cargo lost was increased to 200,000 barrels by the OSC at 1310 and to 250,000 barrels at 1459.

At 1430, the Alyeska barge arrived 2.5 miles north of Bligh Reef and proceeded southwest of the EXXON VALDEZ to deploy its equipment. It arrived 1/2 mile south of Bligh Reef at 1454. At 1510, the OSC authorized a dispersant test on the leading edge of the oil slick in Zone 1. During most of the time on the first day, the oil remained in Zone 2 and was drifting toward Zone 1. Exxon arranged for three aircraft and two Air Deliverable Dispersant System (ADDS) packs to be delivered to Alaska for use on fixed

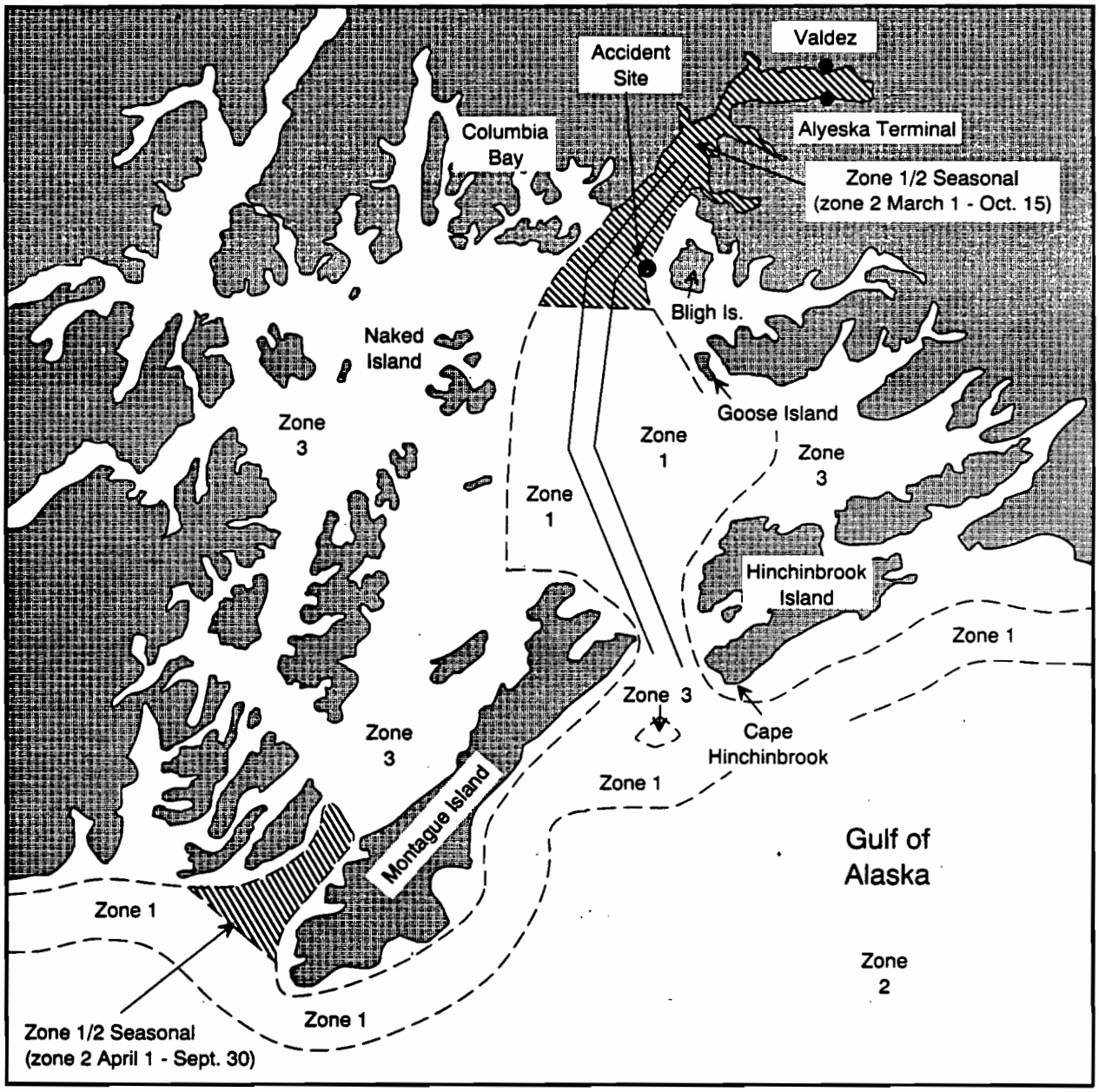


Figure 13.--Oil dispersant use zones.

wing aircraft, but they did not arrive during the first 24 hours after the spill.

About 1500, the RRC in Juneau received, via facsimile, an application for in-situ burning of oil from Alyeska. This application was relayed to the other members of the RRT. A State of Alaska burn permit dated March 24, 1989, was telecopied to Exxon on March 25, 1989.

About 1700, the Governor of Alaska and the commissioner of the ADEC boarded the EXXON VALDEZ. They observed the dispersant test from the vessel and departed at 1907.

At 1737, the president of the Exxon Shipping Company arrived in Valdez. He met with the OSC and, about 1930, with the Governor.

At 1800, Exxon conducted, with the OSC observing from a helicopter, the oil dispersant test application. The dispersant test was conducted on the leading edge of the spilled oil about 4 miles from the EXXON VALDEZ . The dispersant was delivered by a helicopter with a spray bucket that had a capacity of 300 gallons. As reported by the OSC in Pollution Report No. 3, the dispersant test was conducted "with less than satisfactory results. Effects minimal due to lack of wave action. Further use of dispersants deemed inappropriate at this time."

At 1820, 11 Coast Guard PACAREA Strike Team members arrived at Cordova.

By the evening of the first day of the spill, ADEC had established its command post in Valdez. The post was fully operational for its role of oversight, assessment, and monitoring of cleanup activities. The commissioner of ADEC testified at the public hearing that "about 18 hours into the spill, it became clear that Alyeska was not responding under the conditions of the contingency plan and that neither Alyeska nor Exxon appeared to be able to carry out the requirements of the plan." The commissioner did not specify what requirement he was referring to.

At 2010, the EXXON BATON ROUGE was alongside the EXXON VALDEZ but was not secured until 2154. Between 2215 and 2338, two transfer hoses between the vessels were connected in preparation for lightering operations that were planned to commence about 0630 on March 25.

At 2030, divers contracted by Exxon arrived on the EXXON VALDEZ for underwater survey work.

The CO, MSO Valdez, who was the Federal OSC, was asked at the public hearing if there was "any reason as OSC to take over cleanup activities [to give more specific direction, to purchase and order more equipment, and to hire contractors] in the first 24 hours?" He replied: "No. There wouldn't have been anything that I could have done. There were no other resources readily available to put in place than those that were already there [Alyeska equipment] or en route. So there was no benefit to be derived from me taking it over." The OSC also testified that: "If basically I took over the spill [cleanup from Alyeska], we [the Coast Guard] would have to basically tell

Alyeska to do the same thing they were already doing, just, now you're being paid to do it by the Federal government." When asked if taking over the spill cleanup response would enhance the situation, the OSC replied: "Well it wouldn't have. That's the bottom line. It wouldn't have in this situation because there is nothing--actually, it probably would have been a substantial delay in getting the Federal mechanism up to speed to take over the response."

The regulations describing the NCP are found at Title 40 CFR Part 300 and were developed to "effectuate the response powers and responsibilities created by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the authorities established by section 311 of the Clean Water Act (CWA), as amended." The plan describes procedures and standards for conducting response activities for discharges or substantial threats of discharges of oil and hazardous substances. The Environmental Protection Agency (EPA) is the agency responsible for amending the NCP; however, before amendments are published, EPA must seek comments from the NRT members.

Subpart A of the NCP contains the introduction, authority, and definitions used in the plan. National planning and coordination of the NCP was accomplished through the NRT. Subpart B lists the Federal agencies on the team and the responsibilities delegated to those agencies. There were 14 Federal departments or agencies that were members of the NRT: EPA, the Coast Guard, DOT, Department of Defense (DOD), Department of the Interior (DOI), Department of Commerce (DOC), Department of Agriculture, Department of State, Department of Justice, DHHS, Department of Labor, Department of Energy, Nuclear Regulatory Commission (NRC), and the Federal Emergency Management Agency (FEMA).

Subpart C describes the organization of the response activities. It sets forth the activities and responsibilities of the NRT, RRT, OSC, and special teams. Also addressed in this subpart are multiregion responses, worker health and safety, public information, and OSC reports. Paragraph 300.31 states in part: "Three fundamental kinds of activities are performed pursuant to the Plan: Planning and coordination, operations at the scene of a discharge and/or release, and communications." When the NRT is activated for a pollution response action, either the EPA or the Coast Guard provides the chairman, depending on the location of the spill, inland or coastal, respectively, or as agreed on by the two agencies. The NRT will try to arrive at a consensus on all matters brought before it, but if a problem cannot be resolved, each agency representative has one vote in the proceedings. The NRT also monitors incoming reports from the RRTs, develops procedures to ensure that response groups coordinate their activities in handling discharges, monitors response-related research, and monitors response training among agencies.

Subpart D of the plan requires Federal regional contingency plans for each standard Federal region, Alaska, and the Caribbean, as well as local contingency plans for areas in which the Coast Guard provides the predesignated OSC. Where the EPA is the predesignated OSC, it is encouraged, but not required, to maintain local plans for its zones of responsibility.

The OSC is either the Federal official predesignated by the Coast Guard or EPA to coordinate and direct Federal responses under Subpart E and removals of spilled pollutants under Subpart F of the NCP or the DOD official designated to coordinate and direct removal actions from releases of hazardous substances, pollutants, or contaminants from DOD facilities and vessels.

Subpart E describes the "Operational Response Phases for Oil Removal:" Phase I:--Discovery and notification, Phase II:--Preliminary assessment and initiation of action, Phase III:--Containment, countermeasures, cleanup, and disposal, and Phase IV:--Documentation and cost recovery. After the OSC has been advised or has discovered an oil spill, he shall classify the size of the spill, determine and make contact with the responsible party, determine if the responsible party is taking proper removal action, contact the appropriate State and local officials, and either initiate phase III or monitor the responsible party for phase III actions, or if necessary, take over the cleanup. If the responsible polluter is unknown, or he or his representative is not taking timely or adequate actions to clean up the oil, the OSC shall determine whether authority for a Federal response exists. If so, the OSC will assume cleanup response activities.

Subpart F describes hazardous substances discharge/spill response and Subpart G describes the actions to be followed when natural resources are lost or damaged as a result of an oil or hazardous substance discharge.

Authorization for the use of dispersants and other chemicals to remove or control oil discharges is provided for in Subpart H of the NCP. The OSC, with the concurrence of the EPA and the State(s) representative(s) to the RRT may authorize the use of dispersants, surface collecting agents, and biological additives on the oil discharge, provided that products are on the NCP Product Schedule. Burning agents may be used on a case-by-case basis under the same concurrences as described. Sinking agents are not authorized for use on oil discharges.

The **Alaska Regional Oil and Hazardous Substances Pollution Contingency Plan**, which was referred to as the Federal RCP, was developed for the Alaska region in accordance with the NCP. The RCP, with its annexes and appendixes, was to be used by the OSC in conjunction with and not independent of the NCP. It was a plan developed for the coordinated and integrated response to pollution incidents by agencies of the Federal and the State governments The plan provided for an RRT cochaired by the Coast Guard and EPA. The RRT consisted of representatives from the same Federal departments or agencies that were on the NRT and a representative from the ADEC.

The RRT was an advisory body to the OSC that enabled Federal, State of Alaska, and local government agencies to participate in the response to major pollution incidents. The OSC presented information to and received advice from the RRT. The OSC for Prince William Sound (Coast Guard COTP Valdez) testified at the public hearing that "specific members of the RRT, with respect to dispersants, are required as per the national contingency plan to approve the use of dispersants. So it's--the members of the RRT [who] approve certain items. The RRT as a whole is an advisory body."

Each Coast Guard COTP in Alaska, under the authority of the NCP and the Alaska RCP, coordinates Federal response activities on scene as either the predesignated OSC or as the first Federal official on scene, in the absence of the predesignated OSC.

The OSC, as delineated in the RCP, shall:

1. collect pertinent facts about the discharge and its potential impact on the environment, human health, and safety;

2. promptly advise the appropriate State of Alaska agency about the spill;

3. address worker health and safety at the response scene;

4. notify, as promptly as possible, the affected land managing agency and trustees of natural resources;[70]

5. direct response operations as described in Subparts E and F of the NCP;

6. consult regularly with the RRT when it has been activated;

7. evaluate incoming information and advise FEMA of potential major disaster situations and the DHHS when a public health emergency exists; and

8. consult with DOI and DOC National Oceanic and Atmospheric Administration (NOAA) if a discharge may adversely affect any endangered or threatened species or result in the destruction or adverse modification of the habitat of such species.

The appropriate RRT cochairman will activate the RRT whenever one of the following situations occurs:

1. a major or potentially major discharge or release of more than 100,000 gallons of oil (activation in these situations is automatic);

2. any pollution emergency when the OSC or any member of the RRT makes a request to the RRT cochairman; and,

3. at any time when deemed necessary by either cochairman.

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[70]The head of the Federal agency authorized to protect or manage certain lands and/or other natural resources.

The cochairmen of the RRT on March 10, 1989, and ADEC's Chief, Oil and Hazardous Spill Response Section on March 20, 1989, approved an amendment to the Memorandum of Agreement between the Coast Guard, EPA, and ADEC regarding Oil Dispersant Use Guidelines for Alaska that specifically addressed the use of dispersants in Prince William Sound and incorporated this amendment into the RCP for Alaska. The Sound was divided into three zones (see figure 13):

a. Zone 1 - the OSC is pre-authorized to use dispersants.

b. Zone 2 - conditional; before the OSC can use dispersants, the RRT must concur with their use.

c. Zone 3 - dispersant use is not recommended; before the OSC can use dispersants, the RRT must concur with their use.

During the first 24 hours of the spill from the EXXON VALDEZ, the spill was located within zone 2; part of the spill then spread into zone 1.

Burning oil "in-situ" to reduce the effects of oil in the water and to clean up spilled oil is an option available to the OSC, but the State of Alaska must issue a burn permit after the RRT recommends the use of this method of cleanup.

The COTP Prince William Sound at Valdez is the predesignated Federal OSC for Prince William Sound and the **COTP Prince William Sound Pollution Action Plan** is the local contingency plan developed in accordance with the requirements of the NCP and the RCP. The plan may also be used in conjunction with the Alyeska Pipeline Service Company's Oil Spill Contingency Plans for Prince William Sound and Port Valdez. The COTP plan provides "COTP Prince William Sound personnel specific action plans with which to work in the event of oil or hazardous substance spill within the COTP Prince William Sound area of responsibility." It does not duplicate information in the NCP or RCP. The COTP plan describes the geographical area of responsibility and the duties of MSO Valdez and other Coast Guard personnel.

The State of Alaska developed an **Oil and Hazardous Substances Pollution Contingency Plan** to provide State "guidelines for a coordinated response of Federal, State, and local government agencies to spills of oil and hazardous substances within Alaska." It is Alaska's policy:

1. to protect the State's natural and human resources from the damage that may be caused by the discharge of oil;

2. that to the maximum extent possible, the prompt containment and cleanup of discharges is the responsibility of the spiller;

3. to ensure that those engaged in oil storage, transfer, transportation, exploration and production are capable of responding to an oil discharge; and

4. that third parties suffering damage for oil discharges will be compensated promptly by those responsible for the spill.

The ADEC has four statutory responsibilities for oil spills:

1. provide for containment and cleanup of oil discharges of unknown origin;

2. require the maximum practical use of private contractors in cleanup activities;

3. ensure that the cleanup action is initiated in a timely and adequate manner; and

4. identify the source and cause of the spill and the party responsible for cleanup.

When the Federal RRT is activated, the ADEC representative is required to be prepared to render aid on spill response activities, to act as a clearinghouse for input from other local or State agencies, and to act as an adviser to the Federal OSC. The ADEC representative may advise the Federal OSC on the following subjects: State and local resources available for information and help; priority areas for cleanup or protection; preferred methods of containment, abatement, and cleanup; potential staging areas; potential disposal areas; human and wildlife resources threatened; adequacy of cleanup; and activation of State-funded response.

According to the State plan, the decision to use dispersants will be made on a case-by-case basis after extensive consideration has been given to containment of the oil by mechanical means. The State plan provides for a State on-scene coordinator. If the State is in charge of the cleanup (unlikely in any major spill), the State OSC may use dispersants if it appears that they are the only means to diminish the threat and damage from the spilled oil. However, the State OSC must consult with Federal and State agencies before dispersants are used.

Alyeska had an **Oil Spill Contingency Plan** dated January 1987. Alyeska and the Trans-Alaska Pipeline System (TAPS) is owned by seven common-carrier pipeline companies: Amerada Hess Corporation, ARCO Pipe Line Company, Exxon Pipeline Company, Mobil Alaska Pipeline Company, Phillips Petroleum Company, BP Pipe Line Company, and Union Alaska Pipeline Company. Each company has an undivided interest in the pipeline, which it operates as if it were a discrete or separate pipeline. Each pipeline carrier publishes Federal or State tariffs with the Federal Energy Regulatory Commission and the Alaska Public Utilities Commission, respectively. Alyeska is the operator of TAPS. Alyeska is not a common carrier, does not have a published tariff, and does

not collect tariff revenues for the carriers. Shippers are those persons who have North Slope oil that needs to be transported through TAPS.

Before an oil terminal facility is permitted to operate in Alaska, it must have an oil discharge contingency plan approved by ADEC. Also, before oil is transferred to or from a tank vessel in the State of Alaska, the vessel must have an oil discharge contingency plan that has been approved by ADEC. The ADEC is the only State agency empowered to approve a terminal's oil discharge contingency plan, and State law requires that the plan must be reviewed at least every 3 years by the ADEC. Alyeska had prepared oil spill contingency plans required by Alaska State law for the pipeline (12 individual volumes for the 12 pipeline sections) and the Valdez Terminal Plan for the storage and terminal facilities at Port Valdez (1 volume). Alyeska had also prepared a General Plan (one volume) and a Prince William Sound Plan (1 volume).

The following excerpts from the General Plan are pertinent to this accident.

Alyeska will direct cleanup operations of spills resulting from:

> Trans-Alaska Pipeline operations, including spills within the right-of-way or related facilities under the ownership or control of Alyeska or the owners.
>
> Marine Terminal at Valdez operations involving tankers carrying or destined to carry crude oil transported through the Trans-Alaska Pipeline System occurring at the Valdez Terminal [or] in Port Valdez, Valdez Arm or Prince William Sound.

Introductory information in the Prince William Sound Plan states:

> This contingency plan covers the entire Prince William Sound from Middle Rock in Valdez Narrows to the southern limit of Hinchinbrook Entrance off Cape Hinchinbrook. This contingency plan has been developed specifically for rapid and effective response to possible oil spills due to marine vessels in trade with Alyeska's Valdez Terminal.

The Alyeska plans for the Prince William Sound area cover organization, alert procedures, response actions, exclusion site descriptions, two oil spill scenarios, response times, cleanup procedures, lightering of tank vessels, climatology information, oceanography information, wildlife/fish resources, sensitive areas to be protected, a listing of booms and other equipment used in cleanup, a list of cleanup cooperatives, oil spill supervisory personnel assignments, personnel qualification sheets, and training of personnel in oil spill response. There is nothing in the Alyeska plans that provides for a tank vessel's owner or operator to assume cleanup responsibility from Alyeska. The president of Exxon testified that Exxon had submitted oil spill contingency plans for its vessels to the ADEC

on two occasions; however, the plans were returned and Exxon was advised by the ADEC that it did not have to provide any contingency plans because its vessels were covered by the Alyeska plans. The State of Alaska stated in a letter dated December 12, 1989, that "the ESC response plan did not meet the State's requirement for a contingency plan, and it was never approved by the State as [a] free standing contingency plan." The president of Exxon also testified that:

> I think we have an understanding with them [Alyeska] that they're the initial responder, but I don't think we have any formal agreements as such. We've traded letters. Very recent letter, maybe six months ago, they [Alyeska] asked us to clarify under which circumstances would we exercise our oil spill response team to take control, and I think we told them that in spills roughly over 250 barrels or any spills that they felt were out of their control we would certainly exercise our response team.

When the manager of the engineering department of Alyeska was asked whether Alyeska had a policy on how to transfer spill response responsibility to an owner company, he testified:

> No, I don't believe we have a policy. We have an understanding with several owner companies. As I mentioned before, Alyeska is prepared to engage in initial response in ongoing cleanup in the event of any spill in Port Valdez and Prince William Sound. We have an understanding with ARCO Pipeline Company and Exxon Pipeline Company that they will probably come up and take over a major spill in which they are the spiller.

In May 1988, ARCO Marine, Inc., and Alyeska conducted a 2-day Administrative Oil Spill Drill at the Valdez Civic Center. Alyeska's letter inviting participants to attend stated: "The purpose of the drill is to exercise the resources of ARCO Marine, Inc., in taking over management of an oil spill from an ARCO vessel in Prince William Sound." When the Federal OSC was asked if anyone from Alyeska had informed him explicitly in the first 24 hours that Alyeska was turning over its response responsibilities under the contingency plan to Exxon, he replied:

> I don't recall. Although, ...in my mind was the ARCO drill that ...we had done last May,...where that scenario was played out, and I think probably, if it wasn't expressed vocally, it was at least in my mind...that [the] same,...chain of effects [events] may take place in this spill.

When the Commissioner of ADEC was asked whether Exxon's Contingency Plan, which Exxon implemented, was consistent with State regulations, he testified that "there is only one State-approved contingency plan for oil spill response and that is Alyeska's." All tank vessel companies are required to have a contingency plan by State of Alaska statutes and

regulations 18 AAC 75.305 and .345, which state that the plans must be submitted by the owner or charterer of the tank vessel. The transmittal letters that accompanied the Alyeska Pipeline Service Company Contingency Plans stated that Alyeska submitted the plan as an "agent" of the owner companies. Likewise, the Alyeska Pipeline Service Company Contingency Plan general provisions, pages 1-1 and 1-3, state that Alyeska is acting as "agent" for the owner companies. The State believes "that the word agent in this context means that Alyeska submitted the plan on behalf of all the owner companies."

The Alyeska Oil Spill Contingency Plans were developed in 1976, republished in 1978 and 1980, and revised in 1987. In 1987, a supplement to the Valdez Terminal plan and a 200,000-barrel oil spill scenario for the Prince William Sound Plan were required by ADEC as a condition for approving the 1987 Alyeska Oil Spill Contingency Plan. The supplement provided information on the application of the contingency plan using personnel as they are organized at the Valdez Terminal. It also contains information on the minimum oil spill response competence required for Valdez Terminal technicians, and it provides information on current training hours for Valdez Terminal personnel.

There are two oil spill incident scenarios, a 4,000-barrel spill and a 200,000-barrel spill, included in the 1987 Prince William Sound volume of Alyeska's contingency plan that can be summarized as follows:

1. Spill of 4,000 Barrels: An outbound tanker near Entrance Point experiences a steering casualty and goes aground at Potato Point. One wing tank is damaged and loses 2,000 barrels of oil the first hour and 500 barrels per hour for the next 4 hours. The spilled oil is concentrated in an area about 6,000 yards on each side of Potato Point--into Valdez Arm and into Port Valdez. The scenario assumes that "the sea state and weather conditions are in and remain in a state conducive to oil containment and cleanup. Sea state is less than 5 feet, currents are less than 1.6 knots, waves are less than 2 feet, and visibility is equal to or greater than 2 miles." It also assumes that "the simulated weather is sunny to overcast with some light rain, winds are from the southwest at 8 knots, high tide is approximately 6 hours after the incident," and the incident occurs on June 22, 1986. Three hours after the incident, skimming equipment is on scene and operating. The cleanup should take about 2 months.

   If the spill had occurred in an area where dispersants could be used and the OSC approved the use of them, Alyeska could have had an airplane on scene prepared to spray dispersants in as little as 9 hours, with an average response time of about 17 hours.

2. Spill of 200,000 Barrels: Alyeska believes "it is highly unlikely a spill of this magnitude would occur. The spill incident occurs through some failure of the tanker crude tanks and does not discuss other disaster possibilities such as collision or fire." The incident would involve either an immediate spill of 200,000 barrels or a spill of 10,000 barrels per hour for 20 hours about 30 miles from the terminal. Assumptions under this scenario are: the incident occurs at 6 a.m. on June 22 and "the sea state and weather conditions are in and remain in a state conducive to oil containment and cleanup. For example, winds less than 15 knots, sea state less than 5 feet, currents less than 1.6 knots, waves less than 2 feet, visibility equal to or greater than 2 miles." The wind is from the east at 5 knots.

A table provided with the scenario indicates that a tug towing a contingency barge from the Alyeska Terminal, with response equipment aboard, could be on scene in 5 hours. Dispersant use was included as a spill control measure. According to the plan, "There would, of course, be a long-term cleanup of the spill on the various beaches of Prince William Sound....Burning also has to be looked at as a very good alternative to the cleanup in Prince William Sound on the various inlets and bays in which oil may accumulate."

The Manager of Alyeska's Engineering Department testified: "There are no response times specifically required. The response times mentioned in all the scenarios are estimated times." When asked whether Alyeska had a fire boom[71] available in Valdez at midnight on March 24, he replied: "I don't know. If they weren't there, they were on the way... They were not on the way before the accident...We obtained them from two sources, on the North Slope, [and] one in Seattle."

The 200,000-barrel spill scenario also included the statement: "The closest empty or light loaded tanker will be directed to the spill site with an estimated maximum arrival time of 12 hours." Response equipment listed for initial response included two tanker lightering systems. The Prince William Sound Contingency Plan also described guidelines for lightering a distressed tanker. The manager of Alyeska's engineering department testified: "The lightering of a vessel in distress is an integral part of the plan."

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[71] A fire boom is a inflatable oil containment collar that will not be destroyed by fire.

The Alyeska General Plan stated that "the use of dispersants at the Marine Terminal in Valdez and in the waters traveled by tankers using the terminal provide an additional spill control measure. The use of dispersants is not considered a 'cleanup' technique. However, they do provide Alyeska," the OSC, and the RRT "with an important trade-off option. When considering the advantages and disadvantages of physical removal techniques, burning, natural degradation, and shoreline cleanup, it becomes apparent that chemical dispersants are an additional response option that could be used alone or in conjunction with these techniques." As a State of Alaska, an Alyeska, and a Coast Guard representative testified, dispersants are not very effective in low wind and calm sea conditions. The RCP provides some guidelines for the use of dispersants but does not contain any guidelines for in-situ burning. The Alaska RCP and the Alyeska plans do not contain any information concerning what type of oil (and whether it is mixed with water or the degree of debris present) and under what weather conditions (wind velocity, water temperature, and sea state) dispersants are effective, when in-situ burning is effective, or what is needed to conduct a burn.

Alaska State oil regulations 18 ACC 75.375 require that the ADEC be informed within 3 days whenever any "significant equipment specified in a contingency plan becomes nonoperational,...and provide a schedule for its substitution, repair, or return to service." The Alyeska marine manager at Valdez stated in a letter dated December 22, 1989, that "The barge was not nonoperational and was deployed in the spill response without any delay attributable to its condition." The Manager of Alyeska's Engineering Department testified: "The barge was ready for response....No, the barge was not loaded." He also testified: "The spill plan does not require Alyeska to have the barge loaded....It was our [Alyeska's] normal practice to have the spill barge loaded with six connex containers, five of which contained containment boom, the sixth contained various absorbent booms and absorbent pads and other supplies, and normally the Vikoma sea skimmer was mounted on the barge with its power pack."

Global Positioning System.--GPS is a highly accurate, real-time, satellite-based navigation system developed by DOD. The complete GPS satellite constellation will consist of 18 active satellites and 3 spares in 6 orbits, with each orbit spaced so that at least 4 satellites are in view at the same time anywhere on Earth. Each satellite rotates around the Earth at an altitude of nearly 11,000 miles about two times per day, continuously transmitting atomic frequency standard time, orbital information and other parameters. A GPS receiver receives a satellite signal, interprets a digital sequence on the signal, measures the elapsed time since the signal was transmitted with reference to its own internal clock, and converts the signal to the distance to the satellite. Three satellites are required for a marine fix. GPS signals provide surface navigation fixes, accurate to less than 100 meters, 95 percent of the time.

A land-based receiver can be used in conjunction with the GPS satellites to provide greater accuracy and continuous coverage of an area. One such station, referred to as a differential GPS station, could provide very accurate navigation throughout Prince William Sound.

The vessel's position, provided by GPS or Loran, can be projected as a dot on an electronic chart, which is a video display of a navigation chart. The process is similar to showing a navigation chart on a television screen. This system obviates the need for plotting and enables the vessel's position and the proximity of dangers to navigation to be ascertained by simply watching the electronic chart. Furthermore, a vessel's coordinates can be transmitted by radio and projected on an electronic chart ashore, thereby enabling a VTC to monitor continuously the movements of the vessel very accurately.

New Investigative Techniques: Voice Analysis

One responsibility of the Safety Board, as defined by the Transportation Safety Act of 1974, is to "assess and reassess techniques and methods of accident investigation" (88 Stat. 2168, 49 U.S.C. 1903). Such an assessment was completed during the current investigation, using speech analysis of recorded radio conversations made by the master of the Exxon Valdez. It was anticipated that speech information might provide a secondary source of evidence to supplement toxicological and eyewitness information concerning the master's physical condition at or near the time of the accident.

Several recent scientific papers have reported measurable changes in speech associated with alcohol consumption. In its work, the Safety Board solicited assistance from the two research organizations that are the most active in developing the scientific literature. It should be noted, however, that even informal speech examination has long been recognized by the law enforcement community as a source of information on drug use. The DOT recently developed a Drug Evaluation and Classification Program that trains officers to recognize patterns of speech that may show alcohol/drug impairment. These patterns include "thick, slurred speech," "difficulty in speech," "repetitive speech," "low, raspy speech," and "slow, mumbled, and incoherent" speech.[72] Such characteristics are also recognized by the general public. For example, the ship's agent, who met the master on the day of the accident and later reviewed tape-recorded communications of the master, stated to Safety Board investigators that his speech on the tape was slower than when she spoke to him by radio shortly after the vessel departed Valdez. It was this observation and similar observations by investigators that led the Safety Board to assess speech analysis as an investigative technique.

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[72] Briefing Paper: Drug Evaluation and Classification Program. U.S. DOT, National Highway Traffic Safety Administration, October 1989.

Description of the Available Recordings[73]

All the recorded statements selected for analysis were excerpted from radio transmissions from the bridge of the EXXON VALDEZ. The master and three officers of the EXXON VALDEZ were authorized to make radio transmissions from the bridge, and several distinct voices could be readily recognized in the EXXON VALDEZ transmissions recorded by the Coast Guard.

Forty-two statements by the master were identified. (See appendix J.) The master made these statements during the five periods noted below; each has implications for issues of alcohol consumption:

(1) Thirty-three hours before the accident. These statements were recorded about 1500 on March 22 as the EXXON VALDEZ was inbound to Valdez.

(2) One hour (about 45 minutes) before the accident. These statements were recorded from 2324.50 to 2330.54 on March 23 during the outbound passage.

(3) Immediately after the accident. These statements were recorded from 0026.41 to 0038.47 on March 24 and include the initial report of the accident.

(4) One hour after the accident. These statements were recorded from 0107.29 to 0131.36.

(5) Nine hours after the accident. These statements were recorded from 0912.00 to 0938.19 on the morning following the accident while the master discussed salvage of the cargo.

A composite recording of all statements made by the master was used in evaluations by Safety Board staff members and by expert consultants at two outside research organizations, the Addiction Research Foundation, Toronto, Canada, and the Speech Research Laboratory, Indiana University, Bloomington, Indiana. Their reports are included in appendix J.

Evidence of Effects Produced by Alcohol

Alcohol is associated in the scientific literature with four effects on speech: (a) slowed speech, (b) speech errors, (c) misarticulation of

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[73]Additional technical description of the study is available in the reports: "Speech Examination Study" and "Speech Examination Study--Addendum" included in the NTSB public docket on the accident.

difficult sounds, and (d) changes in vocal quality. These four effects were evaluated in the master's speech and are summarized as follows:

(a) Slowed Speech: Several scientific experiments indicate that the speaking rate slows in response to alcohol.[74] [75] [76] [77] [78] The graph in figure 14 summarizes speaking rate evidence from two experiments with relatively large numbers of subjects and data points. Sixteen male volunteers who had a history of alcoholism participated in the first experiment (see footnote 74). The subjects read an identical prose passage aloud on three separate occasions: once while they were sober, once after drinking a medium level of alcohol (estimated BAC = 0.10 percent), and once after drinking a high level of alcohol (estimated BAC = 0.25 percent). Sixteen male college students who had no history of heavy alcohol use took part in the second experiment (see footnote 75). These subjects also read an identical prose passage while under the effect of three levels of alcohol consumption. Figure 14 summarizes the degree of speech slowing found for each group in response to different levels of alcohol.

Measurements of speaking rate were made on all 36 extended statements by the master. The measurements were completed at the Safety Board's audio laboratory by means of computer digitization and accessing of speech segments. Table 6 is a mathematical table that summarizes the speaking rate measures obtained.

Figure 15, based on the data in table 6, is a graph that summarizes the master's average speaking rate during each of the five time periods. An analysis-of-variance test confirmed the statistical significance of the differences observed during the five time periods (probability of occurring by chance less than 1 in 1,000). Contrast tests confirmed that the master's speech about 45 minutes before the accident was significantly slower than his

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[74] Sobell, L. C., and Sobell, M. B., "Effects of alcohol on the speech of alcoholics," Journal of Speech and Hearing Research, 15, 1972, pp. 861-868.

[75] Sobell, L. C., Sobell, M. B., and Coleman, R. F., "Alcohol-induced dysfluency in nonalcoholics," Folia Phoniat., 34, 1982, pp. 316-323.

[76] Pisoni, D. B., and Martin, C. S., "Effects of alcohol on the acoustic-phonetic properties of speech: Perceptual and acoustic analyses". Alcoholism: Clinical and Experimental Research, 13, 1989, pp. 577-587.

[77] Pisoni, D. B., Yuchtman, M., and Hathaway, S. N., "Effects of alcohol on the acoustic-phonetic properties of speech," Alcohol, Accidents, and Injuries, Society of Automotive Engineers, Pittsburgh, Pennsylvania Special Paper P-173, 1986, pp. 131-150.

[78] Lester, L., and Skousen, R. "The phonology of drunkenness," ed. A. Bruck, R. Fox, and M. LaGaly, Papers for the Parasession on Natural Phonology, Chicago Linguistic Society, 1974, pp. 233-239.

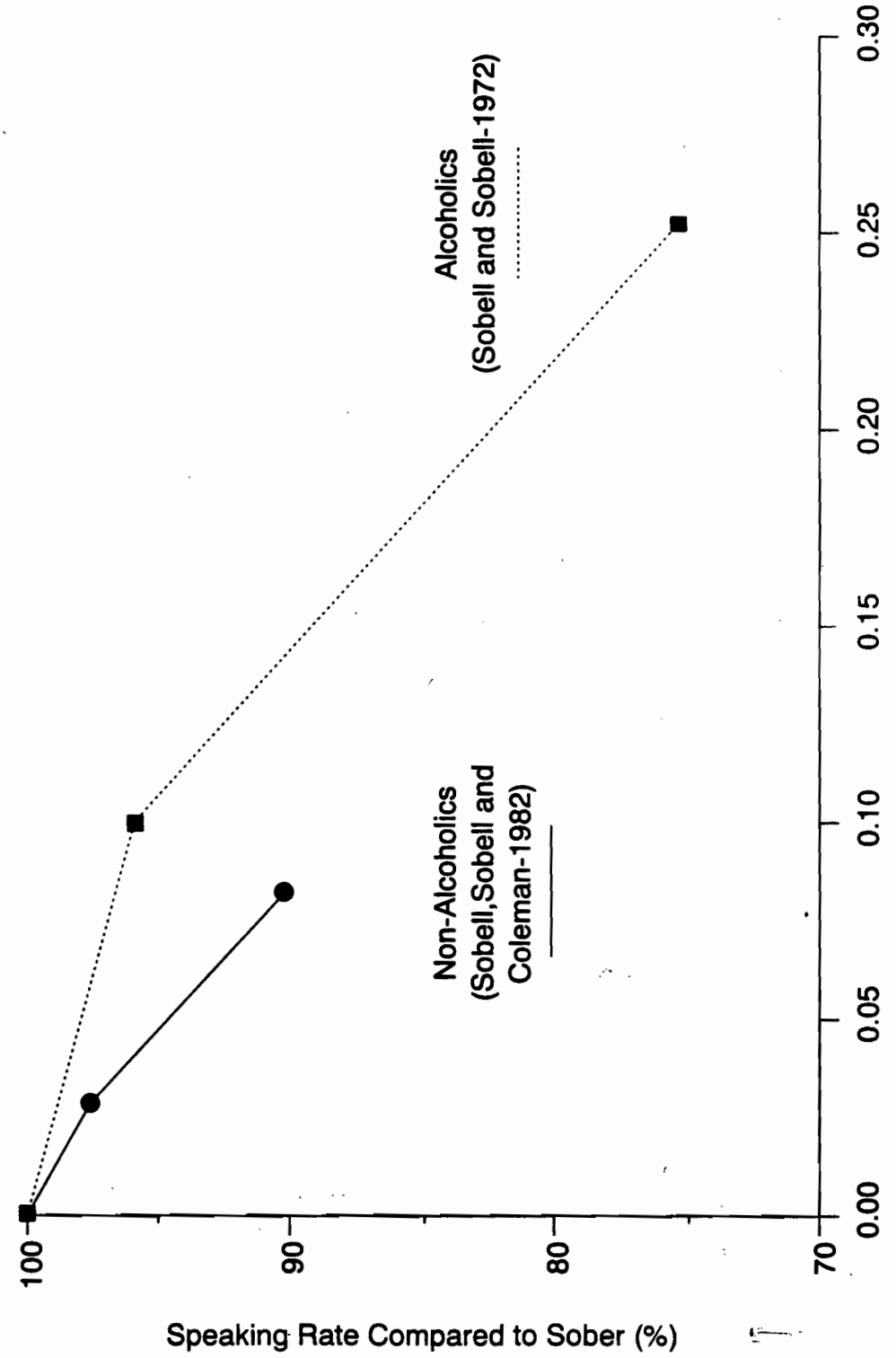

Figure 14.--Speaking rate changes with blood alcohol level.

Table 6.--Speaking Rate

Statement Number	Number of Syllables Analyzed	Measured Duration (seconds)	Speaking Rate (syllables per second)	Hours with respect to accident
1.	12	2.18	5.5	-33
2.	88	19.28	4.6	-33
3.	11	3.79	2.9	-1
4.	42	16.20	2.6	-1
5.	50	16.16	3.1	-1
6.	48	15.24	3.1	-1
7.	16	4.18	3.8	-1
8.	17	4.35	3.9	-1
9.	78	24.20	3.2	-1
10.	11	3.50	3.1	-1
11.	66	35.43	1.9	0
13.	16	3.83	4.2	0
14.	7	1.67	4.2	0
15.	25	10.36	2.4	0
16.	7	2.56	2.7	0
17.	18	9.54	1.9	0
18.	7	1.94	3.6	+1
19.	58	19.54	3.0	+1
20.	68	17.49	3.9	+1
21.	65	20.34	3.2	+1
23.	15	5.83	2.6	+1
24.	16	4.11	3.9	+1
25.	33	9.06	3.6	+1
26.	15	3.37	4.5	+1
27.	94	22.10	4.3	+9
28.	50	14.05	3.6	+9
29.	39	7.61	5.1	+9
30.	28	6.08	4.6	+9
33.	9	1.86	4.8	+9
34.	21	4.97	4.2	+9
35.	38	10.91	3.5	+9
36.	52	11.73	4.4	+9
37.	48	12.56	3.8	+9
40.	13	2.88	4.5	+9
41.	13	2.81	4.6	+9
42.	7	1.33	5.3	+9

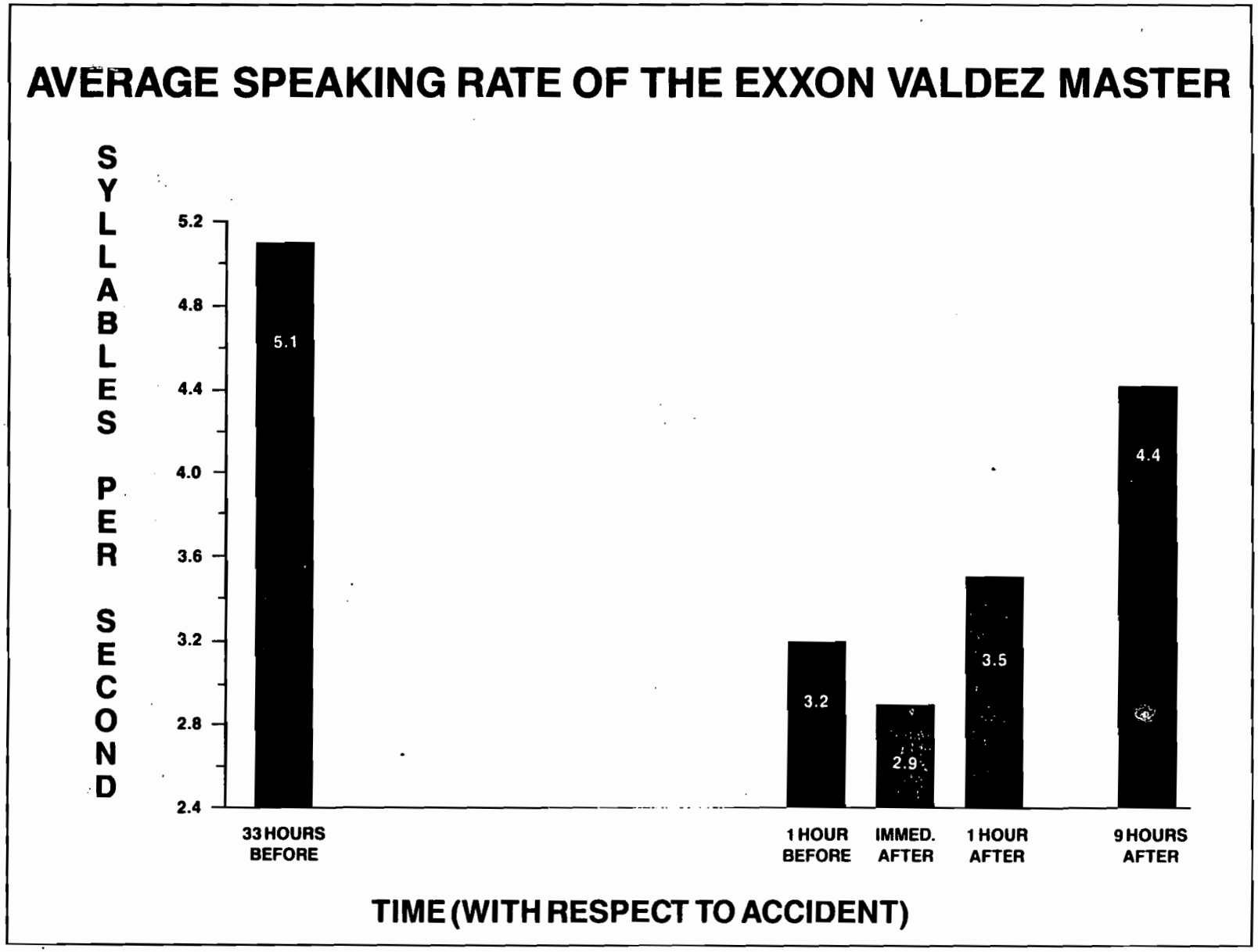

Figure 15.--Graph summarizing speaking rate.

speech 9 hours after the accident and that it was significantly slower than his speech 33 hours before the accident.

Researchers at the Indiana University Speech Research Laboratory completed measurements of speaking rates for the phrase "EXXON VALDEZ" spoken by the master during each time period. This phrase should be well rehearsed and provide a measure of the master's speaking rate with a minimum of thinking or hesitation difficulties. The results were as follows: at -33 hours, the master required 706 msec to say the phrase; at -1 hour, 934 msec; immediately after the accident, 1087 msec; at +1 hour, 980 msec; at +9 hours, 883 msec.

The largest change shown in figure 14 is for alcoholics who have consumed a large amount of alcohol; their rate of speech is only about 75 percent as fast as it is when they are sober. By comparison, the master of the EXXON VALDEZ showed a similar change between his speech at 33 hours before the accident and about 1 hour before the accident. For the phrase "EXXON VALDEZ," his speaking rate was 76 percent as fast; for overall speech, his rate was 64 percent as fast. The slowing of speech by the master is consistent with alcohol impairment demonstrated by test subjects after drinking a high level of alcohol.

For purposes of comparison, speaking rate measurements were completed on 45 statements by speakers other than the master. The average observed speaking rates were as follows: chief mate, 4.4 syllables per second; second mate, 5.8; pilot, 5.7; VTC watchstander who conversed with the master 1 hour before the accident, 6.5. During the period about 1 hour before and immediately after the accident, the master spoke more slowly than any other speaker tested.

(b) Speech Errors: Speech errors occur as a normal part of speech, but scientific literature indicates that errors tend to increase with alcohol consumption. Many speech errors have been demonstrated when a speaker under the influence of alcohol simply reads aloud a prepared text. These include omitting words in the text, misreading words, interjecting extraneous statements, and reading words incorrectly but correcting oneself aloud before completing the text. (See footnote 74).

Speech errors are more difficult to recognize in conversational speech because there is no prepared text against which to confirm the speaker's intention. However, about 1 hour before the accident, four obvious speech errors of the sort associated with the influence of alcohol appeared in the master's speech:

Statement 3.	"EXXON BA ah VALDEZ"
Statement 4.	"We've ah departed the pilot or disembarked the pilot. Excuse me."
Statement 5.	"by our radar, I we'll probably"

Statement 9. "ice out of Columbia Gla...Bay"

(c) Misarticulation of Difficult Sounds: Scientific literature indicates that people under the influence of alcohol tend to mispronounce certain sounds. This effect probably forms the basis for what is described as "slurring of speech."

Based on laboratory evidence, researchers at the Indiana University Speech Research Laboratory (see footnotes 76 and 77) have described sounds that are especially subject to misarticulation owing to alcohol. They indicate that the speech sounds most affected tend to be those that require fine control and timing of the vocal muscles.

For the current analysis, members of the Indiana University Laboratory examined the master's speech for similar evidence of misarticulation. The examination involved detailed phonetic transcription and power spectra displays of individual sounds. Examples of misarticulation observed included the following:

> misarticulation of "r" and "l," demonstrated by the master in words such as "northerly," "little," "drizzle," and "visibility";
>
> changing the sound "[iz]" to the sound "[is]", demonstrated by the master in his pronunciation of the final sound in "VALDEZ" in certain statements;
>
> changing the sound "[s]" to the sound "[sh]", demonstrated by the master in his articulation of "EXXON" in the time periods close to the accident. This effect may be especially characteristic of alcohol impairment.

(d) Vocal Quality Changes.--Researchers from the Addiction Research Foundation indicated that they observed marked changes in vocal quality within the master's speech during the five time periods. They characterized speech from 33 hours before the accident as "rapid, fluent, without hesitation, and with few word interjections (i.e., 'ah')." They characterized speech immediately before and after the accident as markedly different, with a considerable number of word interjections, broken words, incomplete phrases, and corrected errors, as well as increased speaking time and hesitations. The researchers indicated that the samples "sound so impaired" that "crew members who could also be considered untrained raters would probably have noticed changes in the person's speech." With regard to content, the master described the accident site inaccurately as "north of Goose Island off Bligh Reef" (instead of on Bligh Reef, more than 8 miles from Goose Island).

The researchers indicated that the master's vocal quality appeared to change again 9 hours after the accident, when "the speaker sounds more fluent (more rapid speech, more responsive) and makes fewer word interjections."

Explanations Other Than Alcohol

Scientific literature indicates that factors such as fatigue, psychological stress, drugs, and medical problems can affect speech.[79] [80] [81] Information related to these factors was examined for alternate explanations of the changes in the master's speech.

(a) Fatigue: Information on the master's work/rest schedule was reviewed to evaluate the possibility that fatigue rather than alcohol caused the changes in his speech.

The master's sleep schedule was not determined during the investigation. The master, unlike the mates, was not involved in any watchstanding duties on the night before the accident. Evidence suggests continuous activity by the master from about 1030 on March 23, when he went ashore to meet the ship's agent, until the time of the grounding. During the outbound passage, the master retired to his quarters for an extended period of about 1 1/2 hours. According to the available evidence, including statements from Coast Guard personnel who boarded the vessel, the master remained awake and active all night from the time of the grounding until 1050 on March 24 when he provided toxicology specimens.

For purposes of speech analysis, speech samples obtained 9 hours after the accident were examined as exemplars of effects from normal fatigue. As noted above, these samples provided less evidence of speech impairment than did samples obtained before and after the accident.

(b) Psychological stress: Psychological stress has been shown to affect speech, and the master was probably subjected to tremendous psychological stress as a result of the accident.

For purposes of speech analysis, speech samples obtained 1 hour and 33 hours before the accident were examined as examples of effects not subject to psychological stress from the accident. As noted above, there was evidence of speech impairment 1 hour before the accident.

(c) Drug effects: Toxicology tests for all major drugs of abuse were completed on the specimens provided by the master. The blood tested negative for all drugs except alcohol.

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[79] Darby, J. K., ed., Speech Evaluation in Psychiatry, Grune and Stratton, New York, New York, 1981.

[80] Brenner, M., and Shipp, T. "Voice stress analysis," Mental State Estimation, ed. J.R. Comstock, NASA Conference Publication 2504, National Aeronautics and Space Administration, 1988.

[81] Ruiz, R., Legros, C., and Guell, A., "Voice analysis to predict the psychological or physical state of a speaker,". Aviation, Space, and Environmental Medicine, March 1990, pp. 266-271.

(d) Medical problems: Medical problems likely to produce speech impairment would be neurological problems such as those related to stroke, trauma, drug use, and mental states. Such problems would normally be associated with symptoms in the master's medical history.

According to the insurance carrier employed by Exxon shipping, the master did not submit medical claims in the year prior to the accident. The master was treated for alcohol problems in 1985. He was arrested on motor vehicle offenses involving alcohol in 1985 and 1988.

For purposes of speech analysis, alcohol abuse was treated as the only medical problem in the master's history because it was the only medical problem for which there was any evidence.

Expert Evaluation of the Speech Evidence

In their report to the Safety Board, researchers at the Addiction Research Foundation indicated that "a constellation of factors suggests that the individual probably had consumed an amount of ethanol sufficient to affect his speech" and that "various selections on the tape definitely sound impaired. The speech characteristics are consistent with those we have observed in highly intoxicated individuals whom we have evaluated in our laboratory."

In their report to the Safety Board, researchers at the Indiana University Speech Research Laboratory indicated that "acoustic-phonetic changes" observed in the master's speech "revealed a number of changes in speech behavior which correlate well with the findings of previous research on the effects of alcohol on speech production."

ANALYSIS

The Accident

There was a considerable amount of ice in Valdez Arm when the EXXON VALDEZ entered the outbound traffic lanes on the evening of March 23, 1989. Ice floes spread across both the inbound and outbound traffic lanes of the TSS. However, as is widely known, even when ice clogs the traffic lanes in Valdez Arm, the area between the southeast edge of the TSS and Bligh Reef buoy usually remains passable. For this reason, it was fairly common practice for vessels to leave the TSS in the vicinity of Bligh Reef when there was a considerable amount of ice in the traffic lanes.

Two other loaded tankships, the BROOKLYN and the ARCO JUNEAU, had departed from Valdez ahead of the EXXON VALDEZ, and both vessels had traveled outside the TSS in the vicinity of Bligh Reef to avoid ice. The master of the EXXON VALDEZ was confronted with the same two alternatives that confronted the masters of the BROOKLYN and ARCO JUNEAU: (1) slowing down and navigating the tankship through the ice field or (2) navigating around the ice, which would entail passing within about a half mile of Bligh Reef. The master of the EXXON VALDEZ had to contend with the additional complication of

navigating in darkness, which could increase the risk of collision with ice if he tried to proceed through the field. Passing near Bligh Reef, while posing a potential hazard to the vessel if there were either a propulsion or steering malfunction or a navigation error, was probably preferable to navigating through a heavy ice field in darkness. The vessel's engine had operated satisfactorily since departing from San Francisco, California; all navigation equipment, including the steering system, was operating satisfactorily; and there were abundant landmarks for fixing the vessel's position at all times. The master held a Federal pilot license for Prince William Sound. To qualify for the license, he had had to pass an examination on local knowledge that included geography and conditions affecting navigation in Valdez Arm, and he had had to complete a number of transits through the area. Moreover, the master had navigated through Valdez Arm on numerous voyages in the past 10 years and was therefore well qualified by experience to navigate his vessel over the intended track. Thus, all essential requirements for effecting a safe transit past Bligh Reef appear to have been present. Therefore, the Safety Board concludes that the decision by the master of the EXXON VALDEZ to depart from the TSS was a reasonable course of action under the circumstances.

To maneuver the vessel safely through the area between Bligh Reef and the TSS under the conditions that were present at the time required diligence on the part of the vessel's navigation watch. The watch had to frequently fix the vessel's position in order to be constantly aware of the vessel's proximity to Bligh Reef and carefully watch for ice along the vessel's trackline around the ice field. Although the area between Bligh Reef and the TSS was usually ice free, ice was sometimes present. Encountering ice in the relatively confined area between the ice field and Bligh Reef might require skillful shiphandling and expeditious use of rudder and engine speeds to effect avoiding action. At the same time, skillful piloting was required to ensure that any action taken to avoid ice would not result in either grounding the vessel on Bligh Reef on one side or colliding with the ice field on the other.

The maneuver by the master of the EXXON VALDEZ, however, entailed somewhat greater risks than the maneuvers of the BROOKLYN and ARCO JUNEAU when they approached Bligh Reef and departed from the TSS. The location of the ice when the BROOKLYN and the ARCO JUNEAU were transiting Valdez Arm allowed them to depart from the traffic lanes adjacent to Bligh Reef. Thus, those two vessels, which were making their transits during daylight, had much shorter distances to travel outside the TSS and much less exposure to the danger of grounding on Bligh Reef. However, in the case of the EXXON VALDEZ, the ice was much farther to the northeast, so the vessel departed from the TSS about 4 1/2 miles from Bligh Reef buoy. Not only did the EXXON VALDEZ have a longer distance to travel outside the TSS before clearing the ice field, the master's decision to come left to a course of 180^{o} placed the EXXON VALDEZ on a course toward shoal water to the east of Bligh Reef, requiring that the vessel's course be changed back to the right as soon as practicable.

Considerable uncertainty remains regarding the master's intentions for maneuvering the vessel back toward the TSS. The third mate testified that

the master had directed him to start turning back toward the traffic lanes when the vessel was abeam of Busby Island Light; however, according to the Coast Guard investigator, both the master and third mate identified a position on the chart about 0.7 of a mile farther south along the vessel's track as the location for starting the turn. By initiating the turn when Busby Island Light was abeam, even though the vessel's maneuvering characteristics would have caused it to travel about one half mile before it started to turn appreciably, the vessel could have been brought to a course approximately parallel to the traffic lanes, causing it to pass a few tenths of a mile west of the northern part of Bligh Reef and a short distance west of Bligh Reef Buoy. Following such a course, the vessel would have passed close to the northern part of Bligh Reef, but it would also have headed toward the 0.9-mile-wide clear water near Bligh Reef Buoy that the third mate had observed on radar. From a position abeam Busby Island Light, the vessel would have had to travel about 3.5 miles, requiring about 18 minutes to pass completely by Bligh Reef. However, the third mate stated that he had determined by radar at the start of the turn that the vessel might have had to pass through the edge of the ice field. Thus, a turn made when Busby Island Light was abeam still might have required careful maneuvering to avoid the ice while the vessel was passing close to Bligh Reef.

Starting the course change at a point 0.7 of a mile farther south would have placed the vessel closer to the northeastern part of Bligh Reef. Had the vessel made a course change from this position toward Bligh Reef buoy, it would have passed very close to the northwest part of the reef. Hence, a greater course change to the right would have been needed to avoid the reef. This change to avoid the reef would have been followed by a course change back to the left, generally parallel to the outbound lane, to head the vessel toward the clear water near Bligh Reef buoy. Careful navigation would have been required to execute this maneuver; it would have involved frequent position fixing to ensure that the vessel was passing well clear of the northern part of Bligh Reef and to determine when it would have been safe to bring the vessel left to head for the clear water and what course to use to head the vessel toward the expected clear water between Bligh Reef and the TSS. Any delay in initiating the right turn would have put the vessel in danger of striking the northern part of the reef and would have required a more radical turn to the right to avoid the reef.

A course change to the right initiated when the vessel was 0.7 of a mile or more south of Busby Island Light would have allowed the vessel to avoid Bligh Reef but could have caused it to head toward the ice field. Although the third mate did not indicate that he felt any particular concern about maneuvering the vessel, a heading toward the ice could have been confusing and possibly alarming to an officer with limited conning experience in confined or congested waterways and the third mate may therefore have delayed changing course. He would have had to determine how far west the vessel had to travel to clear the reef and whether the ice field would interfere with the westward movement. Thus, he would have had to maneuver the vessel to avoid ice and to navigate the vessel close to a charted hazard. The Safety Board concludes that it was feasible to start turning toward the traffic lanes either when Busby Island Light was abeam or at a point 0.7 of a mile farther south, as long as the navigation watch was capable of simultaneously

monitoring the vessel's position relative to Bligh Reef, watching out for ice, and conning the vessel.

The frequent fixing of the vessel's position could have taken a substantial amount of the third mate's time and would have limited his ability to concentrate on other important functions, such as watching for ice and conning the vessel. Conning also requires careful supervision of the helmsman. Under normal conditions, when a master or a pilot is conning the vessel, the watch officer assists by carefully observing the actions of the helmsman in response to orders from the master or pilot. This enables the officer conning the vessel to concentrate on observing and directing the vessel's movements. In this instance, the helmsman had limited steering experience and required additional supervision. The master was aware of the helmsman's limitations and should have considered them before leaving the bridge.

In the situation confronting the master of the EXXON VALDEZ, a navigation watch in which the master served as the conning officer and the watch officer fixed the vessel's position about every 5 to 6 minutes would apparently have been adequate to maneuver the vessel safely around the ice and past Bligh Reef. The master, with his considerable experience, may have possessed an accurate mental picture of the area that would have enabled him to visualize the vessel's movements near the reef by simply observing landmarks and the radar, aided by only an occasional fix to confirm the vessel's location; but the master should have realized that the third mate's experience was considerably less than his own. In this case, there were demanding conning, lookout, and navigation functions that required the presence of an experienced conning officer assisted by a competent navigation watch officer. The masters of the tankships BROOKLYN and ARCO JUNEAU were on the bridge supervising the navigation, and the watch officers were taking frequent fixes of their vessels' position. The Safety Board concludes that the waterway that the EXXON VALDEZ was navigating, which was bordered by heavy ice on one side and a dangerous reef on the other, demanded the master's presence on the bridge.

There are great demands on a master's time, among them the pressing requirements of administrative duties, such as compiling records and reports and sending messages by radio to shoreside company management. Occasionally, such reports should be submitted as soon as possible. However, no matter how urgent such administrative duties may seem, they must not prevent the master from attending to those things that are important to the safety of the vessel. The master's primary responsibility is to ensure the safety of his vessel, its cargo, and its crew. When his vessel is proceeding in confined or congested waters, the master must place the safe navigation of his vessel above all other considerations. He must identify the parts of the transit that present the greatest danger, the possible consequences of an error in navigation, what constitutes an adequate navigation watch, and, above all, when he should be on the bridge supervising the navigation watch.

In this case, the master knew that his vessel would be passing close to Bligh Reef and that grounding on this reef could result in grave danger to his vessel, crew, and cargo. Hence, it was critically important that the

vessel be navigated with great care and with adequate manning of the navigation watch until it was safely past the reef. Once the vessel had passed Bligh Reef, the master could expect that most of the ice floe would be astern of the vessel and that the vessel would be in relatively open water, where a minor error in navigation or shiphandling would be unlikely to cause grave consequences. The master was familiar with the area, and he could easily have determined that the vessel would be past the reef in about 20 minutes. Also, he was familiar with the watch officer, whom he regarded as a competent third mate, and knew that the third mate had had only about a year of experience as a deck officer. He was also aware of the number of extra hours that his officers had worked to load the vessel and should have recognized that the third mate might be very tired and, by virtue of his limited conning experience and possible fatigue, might not be competent to navigate the vessel between the ice and the reef by himself. The Safety Board concludes that these are very compelling factors that the master should have considered before deciding to leave the bridge.

Moreover, there were clear directives that required the master to be on the bridge in this particular situation. The Exxon Bridge Organization Manual directed that under conditions, such as those existing in Prince William Sound on March 23, the master or the chief mate was to be on the bridge with the watch officer. As usual, the chief mate had been up during most of the deballasting and loading of the vessel and needed rest. Thus, the master was the officer obligated by the Bridge Organization Manual to be on the bridge. Furthermore, the vessel was navigating in pilotage waters, and Federal regulations required that a Federal pilot be in charge of the vessel's navigation. Although rescinding the regulation had been proposed, the regulation was still in effect. Because the master was the only officer on board who possessed the required Federal pilotage endorsement, he was required by Federal law and regulations to be on the bridge. Finally, under the conditions confronting the EXXON VALDEZ, it was normal practice for the master to be on the bridge. The Safety Board concludes that the situation was complex and dangerous and hence warranted the master's presence on the bridge in active supervision of the vessel's navigation.

The third mate claimed that the following events relating to the grounding took place or were observed:

(1) The vessel was on course 180° on automatic pilot (gyro) as it approached Busby Island Light.

(2) He shifted steering from automatic pilot (gyro) to hand steering before the vessel came abeam of Busby Island Light.

(3) Busby Island Light was abeam to port at 2355.

(4) The vessel was 0.9 mile from Busby Island Light when abeam.

(5) He ordered 10° right rudder to start the turn to return to the TSS less than a minute after Busby Island Light was abeam.

(6) He telephoned the master that he had started the turn back toward the traffic lanes and that the ship would pass through the edge of the ice field.

(7) He desired a gradual turn and had ordered 10^{0} of right rudder and had not ordered any course to steer.

(8) About 1.5 minutes after ordering the right 10^{0} rudder, he recognized that the vessel had not turned, so he ordered right 20^{0} rudder.

(9) He observed the white sector of Busby Island Light from the port bridge wing after ordering the rudder to right 20^{0}.

(10) About 2 minutes after ordering right 20^{0} rudder, he ordered hard right rudder.

(11) He recognized that the vessel was in danger and telephoned the master to say that they were in "serious trouble."

(12) He felt the vessel touch ground, possibly forward on the starboard side.

(13) About 40 to 50 seconds after the first contact with the bottom, the vessel jolted about six times and stopped, between 0004 and 0006.

(14) The vessel continued to swing right after the grounding, so he shifted rudder to hard left.

(15) At the grounding, he noted that the vessel's heading was 285^{0}.

The course recorder trace confirmed that the vessel was on a course of 180^{0} at the time it passed Busby Island Light. Testimony by three persons confirmed that the vessel was on autopilot before it passed Busby Island Light. The course recorder trace showed a very straight line during most of the time that the vessel was on a course 180^{0}. No change could be detected in the course recorder trace that could be definitely linked to a change from hand steering to autopilot and then back to hand steering. The steering wheel on the SRP-2000 steering console could be turned while the vessel was on autopilot without producing any effect on the steering and no alarm would sound. Thus, the helmsman, on receiving the order for right 10^{0} rudder, could have turned the wheel to 10^{0}, as indicated by the mechanical indicator on the front of the steering console, which was the usual practice, and then could have waited for the rudder angle indicator to show when the rudder reached right 10^{0} without actual rudder movement occurring. However, a competent helmsman would soon recognize that something was wrong if the rudder did not respond.

Both the mate on watch and the helmsman customarily observe the rudder angle indicator to ensure that the rudder moves in the correct direction, right or left as ordered, and that the rudder reaches and stops at the ordered angle. The helmsman could only recall that although he turned the wheel, the vessel did not turn for some time. Similarly, the third mate could not recall looking at the rudder angle indicator to ensure that his order was carried out. Some time after giving the order for right 10° rudder, the third mate, while looking at the radar, recognized that the vessel was still on course 180°. The third mate stated that he did not recall looking at the rudder angle indicator at this time, but he claimed that he gave an order for right 20° rudder and that he did see the rudder angle go to the right 20° and stop there. After ordering the right 10° or right 20° rudder, the third mate became concerned because the vessel had not changed course, and he stepped out to the port bridge wing to see if the vessel was still in the white sector of Busby Island Light. Because the vessel's trackline would cross into the red sector if the course were not changed to the right, ascertaining that the vessel was still in the white sector would provide some indication about how far the vessel had traveled past Busby Island Light. The purpose of the red sector was to warn mariners of the location of Bligh Reef; as long as the vessel remained in the white sector, it would not ground on the reef.

Since the CAORF track simulation showed that the course change from 180° to 247° occurred well inside the red sector, the third mate probably made his observation of the white sector substantially before he allegedly ordered the right 20°. Seeing the white sector may have been reassuring and may have led the third mate to continue to try to change the vessel's course using only 10° of right rudder. However, the computer simulation found no evidence that the turn had been initiated by any rudder greater than 10°, which was probably used for less than 1 minute. Thereafter, the simulator indicates that the turn to about 247° was made by an average of 4° to 5° of right rudder. If there had been a delay owing to inadvertently having the vessel in autopilot, the third mate and the helmsman would have failed for about 6 minutes (2355 to 0001.5) to detect that the order for right 10° rudder had not been executed. This is a considerable length of time for a watch officer and a helmsman not to notice something as fundamental as a failure to obtain the ordered rudder angle or for the watch officer to fail to notice that the vessel was not swinging right as expected. Only 10 to 20 seconds should have been required to start the vessel swinging with 10° of rudder, and the third mate should have been waiting and watching for the turn to begin.

The third mate stated that his practice was either to shift steering modes himself or to stand at the steering console and supervise the shift if it was done by the helmsman. In this case, both the third mate and the helmsman were trying to push the helm steering button at the same time. This could indicate there was some urgency to make the shift, possibly owing to a belated realization that the vessel was still in autopilot or to the third mate's belief that he had waited long enough for the helmsman to act and would have to make the shift himself.

If the delay in changing course from about 2355 to about 0001.5 was caused by inadvertently leaving the vessel in automatic pilot, the length of the delay or its significance apparently was not recognized by the third mate, who would have realized that the vessel was much closer to the reef and that there was an urgent need to turn the vessel more quickly to avoid the reef. Since the turn was a gradual one, the third mate apparently believed there was either no lost time or no need to compensate for any lost time caused by any error such as mistakenly leaving the vessel in automatic pilot.

The third mate stated that he did not believe that his attention was distracted from his duties by fatigue. However, a fatigued person might not realize that there were longer lapses of time between events or that his duties, such as navigating, were requiring more than the normal time to execute. The plotting of the vessel's position abeam of Busby Island Light may have been accomplished in about a minute or less, as estimated by the third mate. However, the lookout almost certainly located the third mate at the chart table and reported a flashing red light broad (45^{o}) on the starboard bow only about a minute before the course change was executed at 0001.5. According to the lookout, after making her initial report, she walked directly back to the starboard bridge wing, recounted the flashing rate of the red light, and returned to the wheelhouse where she located the third mate at the port radar. Her actions probably required no more than a minute. She stated that after making her second report, she returned to the starboard bridge wing and observed that the vessel was beginning to turn right slowly. Also, a line of bearing 45^{o} on the vessel's starboard bow to Bligh Reef buoy passes very near the location identified by the CAORF simulator study as the one where the vessel started turning. Thus, the third mate was apparently at the chart table 4 to 6 minutes after the vessel had passed abeam of Busby Island Light, a much longer time than would have been required to plot the vessel's position. He may have made a subsequent trip to the chart table to look at the chart one more time, or he may have remained at the chart table for a much longer period than he realized.

However, if the third mate had intended to begin the turn when the vessel was 0.7 of a mile past Bligh Reef, the vessel would have begun the turn about 4 minutes after it passed Busby Island Light. According to the Coast Guard Investigating Officer, both the third mate and master, in separate interviews, identified a 38-fathom curve (about 235^{o}, 1.2 miles from Busby Island Light) at a position about 0.7 mile past Bligh Reef as the position where the turn was supposed to begin. The third mate testified that he was supposed to initiate the turn when Busby Island Light was abeam, but he did not do so. Moreover, according to the computer simulation study, the vessel did not begin to turn until it was about 1.4 miles south of the position abeam of Busby Island Light. Therefore, if the third mate had been heading for the position 0.7 of a mile south of Busby Island Light (near the 38-fathom sounding), he would have overshot that position by more than half a mile. Such a mistake could be attributed to lack of diligence because of fatigue or concern about passing close to the ice field. Consequently, the third mate may have vacillated before starting the turn, or he may have made a deliberate decision to begin the turn farther south. The possibility cannot be ruled out that he mistakenly selected a location at another

38-fathom sounding farther south (225°, 1.5 miles from Busby Island Light) to begin the turn and somehow passed the point without initiating the turn.

Regardless of what caused the critical delay in starting the turn until well beyond Busby Island Light, very little of the testimony provided by the third mate helps to resolve the matter. The Safety Board concludes, however, that his delay was most likely owing to inexperience in shiphandling and piloting, fatigue, or both.

Although the third mate testified that he ordered the rudder increased from right 10° to right 20° rudder about 1 1/2 minutes after ordering the right 10° and then ordered the rudder increased to hard right about 2 minutes later, this sequence of rudder orders could not be substantiated using the course recorder trace. The course recorder trace contained no indication of right 10° rudder except for less than a minute at the start of the turn. Nor was there any indication of right 20° rudder or hard right rudder from initiation of the turn at time 0001.5 until 0007. During this time, the vessel's heading changed 67°, from 180° to 247°. According to the computer simulation, the average rudder used during the turn was about 4° to 5° of right rudder. At 247°, the vessel heading became nearly steady, and then the vessel resumed a slow right swing until 0009, when the right swing suddenly increased briefly as the vessel heading changed from about 280° to about 290°. The sudden swing from 280° to about 290° probably was caused by the grounding of the vessel.

The slow turn from 180° to 247° involving, on average, the use of 4° or 5° of rudder, as determined by the computer simulation, could have been made in the gyro mode by inserting the course of 247° into the SRP-2000 console and then pressing the accept button. If the rudder limit had been set at 7° or 10°, which the second mate stated was the customary setting, then the rudder would have moved to 7° or 10° and then been reduced by the autopilot as the vessel's swing approached the set turning rate, possibly 10° per minute. Then, as the vessel approached the desired course, the autopilot would have applied counter rudder of 7° to 10° to gradually steady the vessel on 247°.

Also, the third mate may have ordered right 10° rudder, and the helmsman could have responded by placing the rudder at 10° and shortly afterward inadvertently moving the steering wheel to 4° or 5°. A small turn of the wheel of about 20° could produce a 5° change in the rudder angle. In such a situation, the third mate would had to have failed to detect such an error by the helmsman for a period of about 6 minutes. The third mate testified that initially he wanted to make a gradual right turn. Thus, it is possible that the third mate was satisfied with the vessel's rate of turn and did not note that the rudder was less than 10° until he became aware that the vessel was heading toward the reef. About the time the vessel's heading was becoming nearly steady, at 247°, it probably was near the shallow water over the reef. Thus, the vessel's rate of swing could have been reduced as the bow became affected by bottom suction when the vessel entered the shallow water over Bligh Reef. If the third mate had ordered right 20° or hard right rudder at this time, it probably would have had little effect on the rate of turn because the bottom suction effect, owing to the limited depth of the

water under the vessel, would have greatly reduced the effectiveness of the rudder.

The helmsman stated that he was changing the vessel's course to either 235° or 245°. He is unlikley to have assumed or imagined that he was supposed to steer either of these courses. Either course change, executed at the proper time, would have brought the ship safely past Bligh Reef. Therefore, the third mate quite likely issued an order to the helmsman to change course to either 235° or 245°. Moreover, the course recorder trace showed that the vessel's rate of turn gradually slowed from 240° to 247°, suggesting that the vessel was being steadied on a course of about 247° or probably 245°, allowing for a 2° oversteer. Thus, the course recorder trace tends to substantiate the helmsman's statement during his interview that he was coming to a course of either 235° or 245° and had applied counter rudder to steady the vessel on course.

By allowing the vessel to be turned slowly with an average of 4° to 5° of rudder through nearly 67° of heading change during a period of approximately 6 minutes, the third mate demonstrated that he did not know the location of Bligh Reef in relation to his vessel. If he had had more experience or possibly more training in navigation, he probably would have known how important it was to plot the vessel's position on the chart and then to plot his next course, making allowance for the advance and transfer that the vessel would make during the turn. Instead, the third mate relied too much on the radar, possibly because he was mistakenly more concerned about the danger of colliding with the ice than the danger of being grounded on Bligh Reef. This accident demonstrates that an inexperienced officer, who was probably fatigued, simply became confused.

Performance of the Master

The master's decision to leave the bridge while the vessel proceeded across the length of Port Valdez was not unreasonable since the waterway was about 2 miles wide and there was no large vessel traffic; however, the master should have returned to the bridge in ample time to observe the vessel transit Valdez Narrows. The actions attributed to him on the night of the grounding were, therefore, inconsistent with his qualifications as a master mariner and an experienced career tankship officer. Although no evidence indicated that leaving all navigation responsibilities to the State pilot endangered the vessel, the master's actions reflected a lack of concern for ensuring high standards of crew response under the pilot's direction. Also, he showed a disregard for Exxon regulations that clearly required his presence on the bridge. His departure from the bridge when the pilot was aboard may not have been appropriate; at the very least, it was not the disciplined vessel command oversight expected of a master, particularly when the vessel transited Valdez Narrows.

The Safety Board investigation did not identify any well-founded reason for the master's decision to leave the bridge. According to the third mate, the master departed to send messages before the ship left the Sound. However, the vessel had more than 2 hours of transit ahead before reaching Cape Hinchinbrook. In order for the master to have completed the maneuver

himself or to have monitored the third mate's conduct of the transit, he would have had to remain on the bridge only about 20 minutes longer. Thus, there would have been ample time to send messages after the vessel transited Valdez Arm. His departure again shows that his judgment was unsound since he relegated vessel safety to a secondary priority at a critical time.

When the master left the navigation watch to the supervision of the third mate, he exposed the EXXON VALDEZ to considerable risk. Several uncertainties associated with the maneuver around the ice floe made his departure from the bridge particularly ill advised. When he left, the course of 180° headed the vessel directly toward shoal water. The master should have realized that both careful timing and judgment were required to extricate the vessel from its location outside the traffic lanes between the reef and the ice floe. He should also have known that frequent fixing of the vessel's position was necessary. He should have been concerned that the third mate might be tired and that the helmsman might require greater than normal supervision. Thus, he was giving his responsibility for the vessel's safety to crewmembers whose capabilities were diminished at the very time that navigation was becoming complex and demanding and also at the very time that a failure to navigate correctly and precisely could result in very grave consequences. Also, putting the vessel on automatic pilot in confined waters and not telling the third mate that he had done so was extremely inconsistent with normally accepted practice.

Although the master had recently had marital problems and had been described by the radio electronics officer as depressed, nothing indicated that his personal problems were sufficient to have altered his ability to execute command responsibilities with his usual competency. He was also reportedly in good health.

The master did not inform the Safety Board of the reasons for his actions. As a result, the rationale and priorities that entered into his decisions remain undetermined at the time of this report.[82]

Impairment of the Master.--One explanation for the master's decision to allow the third mate to supervise the navigation watch under such critical circumstances is that the master was impaired by alcohol. There was evidence that he had been drinking with the radio electronics officer and chief engineer for several hours during the day in Valdez. They returned to the vessel without incident, and no witnesses, including security guards at the terminal and their cab driver for the return trip to the terminal, described anyone's behavior as impaired.

The master probably consumed additional alcohol after he boarded the vessel. Additional drinking could explain why, according to witnesses, his condition appeared normal when he returned from Valdez about 2030 but that his speech was unusual by about 2325. The master had a history of alcohol abuse that included alcohol-related traffic violations, and he had undergone

[82]The master was acquitted of criminal charges by an Alaska State Court on March 22, 1990.

a rehabilitation treatment program. It would not be uncommon for a person for whom a treatment program had been unsuccessful to continue drinking alone after consuming several social drinks with companions. Also, one witness stated that the master on at least one occasion had consumed alcohol on board the vessel. His absence from the bridge for about 1 1/2 hours while the State pilot was aboard gave him an opportunity to resume drinking.

Toxicological analysis of blood and urine samples taken from the master about 1050 on the morning of the grounding showed that his BAC was 0.06 percent (urine 0.09 percent). His expected BAC at the time of the grounding can be calculated from the blood value measured at 1050, assuming that (1) he did not drink between the grounding and the sample collection, (2) he was in the elimination phase of alcohol metabolism (approximately 1 hour after the last drink) during the period of back calculation, and (3) he metabolizes alcohol at an accepted average rate (for a light alcohol user it is about 0.015 percent per hour and for a heavy user it may be as high as 0.018 percent per hour).[83] Based on these assumptions, on an elimination rate of 0.015 percent per hour (a conservative value for the master), and on a 10-hour period for the back calculation, his BAC at the time of the grounding would have been about 0.2 percent. If the master did not ingest alcohol after returning to the vessel, his BAC at the time of boarding the vessel (2030), using the same assumptions, would have been about 0.27 percent. A BAC of 0.2 percent is close to the master's BAC value of 0.19 percent during his most recent DWI, when he was stopped for speeding but not for driving erratically. It is unlikely that the master could have had a BAC of 0.27 percent when he returned to the vessel and not have been observed as intoxicated; therefore, he probably consumed additional alcohol after he returned to the vessel. He most likely had an opportunity when he left the bridge after the vessel got under way while the pilot was piloting the vessel out of port. He had another opportunity after he left the bridge about 2352, leaving the third mate in charge of the navigation.

The Safety Board concludes that the master was impaired by alcohol when he returned to the bridge to prepare for disembarking the pilot. Although his decision to navigate around the ice floe was reasonable, his execution of the maneuver demonstrated impaired judgement, as was evidenced by placing the vessel on automatic pilot and then leaving the third mate to continue the maneuver. In addition to the toxicological findings, the master's speech at 2325 was uncharacteristically slower and less fluent than it had been about 2130, when the ship's agent spoke with him on the VHF/FM radio. Slower and less fluent speech has been identified as an indication of alcohol impairment.

The generic behavioral impairments described in the toxicological reference literature for the estimated BAC level (0.2) for the master at the time of the accident are also consistent with his unusual actions after the

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[83] "Relationship of level of blood alcohol concentrations and types of performance decrements," in Drug and Alcohol Abuse: The Bases for Employee Assistance Programs in the Nuclear Utility Industry. NUREA/CR-3196 PNL-4679, Office of Nuclear Regulatory Research, NRC, 1983, p. 51.

pilot disembarked. He exposed the vessel to needless risk when he left the navigation and conning tasks to an officer who, the master should have known, was tired from the day's loading activities. The master apparently failed to recognize or consider the third mate's fatigued condition that had been apparent to one other crewmember earlier after a brief encounter in a companionway. Both risk taking and inability to judge another person's level of performance are factors of impairment at BAC levels greater than 0.08.[84]

The Safety Board's interpretation of the toxicological analysis presumes that the master did not ingest alcohol after the accident. The investigation established that he was told that the onboard computer results showed that the grounded vessel was not meeting required stability standards and that stresses on the vessel's hull were exceeding established limits. He took the precaution of having all crewmembers awakened and notified of the casualty. He explained to the chief mate that he did not want to use the general alarm because it might cause panic. Furthermore, he could anticipate that his vessel soon would be boarded by Coast Guard and other official personnel whom he would have to meet and work with.

The master's attempts to maneuver the vessel from its grounded position until about 0145 also demonstrate that he was trying to improve the situation. However, the Safety Board concludes that it was not wise of him to continue using the main engine to free the vessel because there was no way to assess the seriousness of the damage. However, the Safety Board could not determine whether there were any detrimental consequences from these actions after the grounding.

New Investigative Techniques

Speech Analysis.--The Safety Board examined speech analysis as a new investigative technique and found it provided information useful to the investigation in an area in which scientific information has not been previously available.

No single aspect of speech provides conclusive evidence by itself, but a collection of difficulties was found in the master's speech that constitute a trend. The master displayed slow speech, speech errors, misarticulation characteristic of alcohol impairment, and degraded speech quality in the time period around the accident. Two sets of researchers--from the Addiction Research Foundation and the Indiana University Speech Research Laboratory--concluded independently that the speech changes shown by the master were consistent with those produced by alcohol impairment. The evidence suggests that speech changes of the sort produced by substantial alcohol consumption occurred just before the accident, and this conclusion is consistent with the extrapolated blood alcohol estimation determined from toxicological results.

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[84] "Relationship of level of blood alcohol concentrations and types of performance decrements," p. 51.

This information based on speech analysis may contradict information provided by eyewitnesses, who reported unanimously that the master did not appear impaired on the evening of the accident, although several witnesses stated that the master smelled of alcohol. Two considerations seem relevant to the possible contradiction. First, eyewitnesses might have difficulty recognizing impairment because of the master's ability at masking it. The master had a history of alcohol abuse, including possible use of alcohol aboard the vessel, and had probably developed a considerable tolerance for alcohol. Individuals with such a history are commonly adept at masking the effects of alcohol on their performance of routine and familiar tasks.

A second consideration concerns eyewitness credibility and the possibility that some witnesses were unwilling to acknowledge officially an alcohol situation with which they may have been well acquainted. The many possible motivations for such reluctance include protecting the master, protecting themselves from legal exposure, and protecting their employment. Issues of eyewitness credibility have surfaced in previous Safety Board investigations concerning the issue of alcohol impairment.[85] Eyewitness credibility issues also surfaced in the current investigation in several areas, most notably in the contradictory statements from the radio electronics officer and the third mate concerning a previous incident in which the master allegedly drank alcohol aboard the vessel with several other crewmembers.

The recordings suggest that the master was impaired to such a degree that he was unable to mask speech difficulties before the accident, and it seems likely that everyone on the bridge would have been aware of this situation.

During the outbound voyage, the master made a series of questionable decisions -- he left the bridge during the passage through Valdez Narrows, he ordered the autopilot engaged when departing the traffic lanes, he failed to tell the third mate that the autopilot was engaged, and he left the third mate as the sole officer on the bridge as the vessel approached a critical course change to maneuver around the ice. While there might be justification for individual aspects of the master's actions, taken together, the actions provide a picture of impaired judgment that is consistent with the toxicological and speech evidence.

The Safety Board concludes that the master of the EXXON VALDEZ was impaired by alcohol at the time the vessel grounded on Bligh Reef and that impairment of his judgment owing to alcohol consumption caused him to leave the bridge at a critical time.

By conducting an examination of the National Driver Register (NDR) and driving records, the Safety Board was able to determine that the master

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[85] Railroad Accident Report -- Head-on Collision of Southern Pacific Transportation Company Freight Trains, Yuma, Arizona, June 15, 1987, (NTSB/RAR-88-02).

of the EXXON VALDEZ had an alcohol abuse problem. A similar periodic, routine review of the NDR could be made to ascertain if any licensed merchant marine officers are involved in drug or alcohol abuse that is affecting their driving record. Furthermore, each time a person applies for a license or license renewal, in addition to checking the NDR, a review of the applicant's driving record could be made to determine if there are any offenses related to drug or alcohol abuse. Accordingly, the Safety Board believes that the Coast Guard should have access to the NDR and other driving records and make use of such information to prevent persons with a drug or alcohol problem from holding a merchant marine license.

Exxon Management Oversight of the Master.--The Exxon alcohol policy directive in effect during 1985 when the master underwent treatment instructs supervisors to refer to the medical department employees whose job performance is unsatisfactory owing to the perceived use of alcohol. In this case, the master's supervisor was apparently unaware that the master had an alcohol dependency problem prior to his hospitalization. Upon learning of his dependency problem, his supervisor, according to Exxon procedures, was supposed to have referred his case to the medical department. The personnel documents provided by Exxon showed that a followup treatment program was recommended by the attending physician at the hospital. While it is documented that the master was given a 90-day leave of absence, no documents were provided to establish that this recommended outpatient treatment program was followed or that his progress was monitored by management. Nor does the Exxon medical department appear to have contacted the hospital where he received in-patient treatment. The lack of records suggest that no guidance, advice, or information was provided by Exxon management or the Exxon medical department to the master's supervisor. Furthermore, no one in the Exxon management structure seems to have consulted an expert on alcoholism about the following issues: the kind of support the master would need when he resumed his work, the kind of supervision and monitoring he would need, the chances that he would resume drinking, the signs that might indicate that he had resumed drinking, and the kind of assignments he could perform without risking his sobriety. The president of Exxon Shipping Company testified that the master "thought he was the most scrutinized employee in the company." If this scrutiny did take place, written records either do not exist regarding his supervision and evaluations during this period or the records have not been provided, except one that was constructed from memory after the grounding. Furthermore, the solitary nature of a master's job is not conducive to monitoring; thus, visits to his vessel during short port calls are not likely to have been very effective in determining whether the master was abstaining from alcohol. Some personnel performance records (evaluations) were unsigned; thus, their authenticity could not be established. It must be surmised from the absence of information that the EXXON management and the medical department were unprepared or unwilling to deal with an alcoholic master and made little effort to become informed or knowledgeable regarding the problems of an alcoholic and the rate of recidivism even under the most ideal conditions. As is well known, a carefully constructed support system that includes frequent, continuous interaction with the support system is necessary to prevent an alcoholic from returning to alcohol abuse. In contrast, it is reasonable to assume that if Exxon had a technical problem, such as an

autopilot failure, with one of its vessels, either the problem would be assigned to an expert within the Exxon company structure or an outside consultant would be hired to solve the problem. Considering the investment Exxon had made in the master, the potential cost of a marine accident in terms of human loss or environmental damage as a result of having an alcohol-impaired master, and the lack of oversight documentation, it can be concluded that the Exxon corporate management demonstrated inadequate knowledge of and concern about the seriousness of having an alcohol-impaired master. The Safety Board concludes that Exxon should have removed the master from seagoing employment until there was ample proof that he had his alcohol problem under control.

Based on testimony taken from crewmembers of the EXXON VALDEZ, they were clearly aware of the Exxon policy on alcohol and drug use, at least after the grounding, and knew that they were subject to termination for possession and use of alcohol while on the job. Testimony from various crewmembers regarding the presence and use of alcohol aboard the EXXON VALDEZ and, specifically, use by the master was contradictory. The radio electronics officer stated that he drank with the master and with the third mate on one occasion on the vessel. However, others stated they had no knowledge of alcohol possession or use onboard the vessel. Even though the Exxon policy was clear and simple regarding the possession and use of alcohol and drugs on company property, enforcement of the policy appears not to have been effective on the EXXON VALDEZ. The master's use of alcohol was apparently well known except, perhaps, to Exxon management. According to testimony from the president of the Exxon Shipping Company, no mechanism was available that a crewmember on Exxon vessels could use to report a master's failure to abide by and enforce Exxon Shipping Company policy.

The master's DWI conviction in 1988 and his use of alcohol in March 1989 confirm the inadequacy of the 28-day program and the out-patient treatment that he received. Furthermore, the grounding represents a failure on the part of Exxon policy and management to identify and supervise the master appropriately for his protection, for the safety of crewmembers who worked under him, and for the safety of the vessel.

Third Mate's Qualifications and Workload.--Although the third mate was a relatively new officer, he was an experienced seaman who had served many years as an AB. The third mate was properly licensed and experienced for his position on the EXXON VALDEZ, and he could be expected to conduct routine navigation tasks properly during a normal at-sea watch.

The third mate testified that two officers normally served on the navigation watch of Exxon vessels when maneuvering in confined or congested waters. One officer usually conned the vessel, and the other conducted the navigation. Without the assistance of a fellow deck officer on the night of the grounding, the third mate's workload included both tasks. This workload might have been manageable for an alert, experienced officer even though it became progressively intensive as the EXXON VALDEZ approached the location for the turn back to the traffic lanes. Notwithstanding the intensity of the workload, the third mate's failure to plot positions of the EXXON VALDEZ on the navigation chart was a crucial compromise between the requirements of

conning and navigating the vessel. He reduced his work by relying extensively on radar so that he could monitor the waterway and navigate at the same time. However, the perimeters of the submerged reef were not displayed by radar. If he had practiced conventional navigation techniques of plotting frequent fixes on the chart, he could have methodically incorporated the perimeters and location of the reef into his judgment for a trackline around the ice.

Impairment of the Third Mate.--The third mate had probably had very little sleep the night before the grounding and had worked a stressful, physically demanding day. Since deballasting and cargo handling activities were ongoing while the EXXON VALDEZ was at the Alyeska terminal, the third mate was unlikely to have obtained a full off-watch period of rest when he went to bed at some time after 0100 on March 23. Also, he may have been called as early as 0520 to relieve the second mate. According to the second mate, he and the third mate were covering the chief mate's watch essentially on a 6-hours-on and 6-hours-off basis. An unlicensed crewmember recalled seeing the third mate on deck during the first half of the afternoon 1200-to-1600 watch, and the third mate stated that he did work in the afternoon conducting a salinity test and that later he relieved the chief mate during supper. The third mate testified that he had had a nap in the afternoon, but the time that he would have been resting would have been between being on deck during the 1200-to-1600 watch and relieving the chief mate for supper.

The Safety Board concludes that the third mate could have had as little as 4 hours sleep before beginning the workday on March 23 and only a 1- to 2-hour nap in the afternoon. Thus, at the time of the grounding, he could have had as little as 5 or 6 hours of sleep in the previous 24 hours. Regardless, he had had a physically demanding and stressful day, and he was working beyond his normal watch period.

Impaired task performance could normally be anticipated as a result of these conditions of partial sleep loss,[86] particularly since the preceding work day had consisted of demanding activities. However, the third mate's navigation tasks for starting the turn involved navigating the EXXON VALDEZ in a high-risk situation. If he made the turn too early, the vessel would encounter the glacial ice at maneuvering speed, possibly resulting in hull damage. If he waited too long to execute the turn, the vessel would ground on Bligh Reef. Thus, the significance of the course change and the anticipation of taking action should have increased the third mate's resistance to debilitation from fatigue, at least for the limited period of time involved.[87] Nonetheless, the insidious nature of fatigue is such that

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[86] Holley, D.C. et al., " Effects of Circadian Rhythm Phase Alteration on Physiological and Psychological Variables: Implications to Pilot Performance," NASA Technical Memorandum 81277, March 1981, p. 13.

[87] Johnson, L.C. and Naitoh, P., "The Operational Consequences of Sleep Deprivation and Sleep Deficit," AGARD-AG-193, June 1974, p. 33.

sleep could have overcome him at any time that he momentarily relaxed his vigilance.

The inconsistency of these implications for fatigue can be reconciled by considering the difficulty of one element of the third mate's mental tasks at this time. He had to visualize from recall the perimeters of the reef from prior viewing of the chart while he was using the radar to navigate. Since there probably was some depletion of his stamina and mental resources, he could have been functioning near his personal limit as the EXXON VALDEZ neared the point at which he had to make a decision to start the turn. The mental requirements for all his tasks, including making time and distance judgments, may have exceeded his immediate reserves. He simply may not have been able to incorporate simultaneously all the necessary information for the decision, and his location for the course change was limited to the display of information on radar. After the decision for the turn was made and the EXXON VALDEZ was committed to a slow turn toward the traffic lanes, there was a period of about 6 minutes during which the third mate could consider the situation, possibly enabling him to obtain a grasp of the relative location of the reef. With the realization of the error, he then gave the order for hard right rudder that the helmsman recalled as being uncharacteristically high in verbal pitch and notified the master on the telephone of the serious trouble.

Both performance deterioration relating to attention at times of maximum capacity[88] and memory impairment from sleep loss[89] have been documented in human factors literature. The third mate's lack of rest, workload, and probable impairment underscore the importance of deck officers' compliance with the off-duty requirements in U.S.C. 8104 (a). The opportunity for rest does not guarantee that deck officers sleep at these times. But aggressive company support, combined with an information program about the consequences of fatigue, would inevitably improve compliance by conscientious officers. Exxon Shipping Company had no procedure to ensure compliance with the statute, nor did the Coast Guard have a procedure for ascertaining whether this law was being followed or for awarding any penalty for noncompliance. Since many other tankships calling at Port Valdez carried three mates, disregard for this law is probably widespread.

Giving the chief mate responsibility for the loading and discharging of the cargo and/or ballast and having him on duty during all critical stages of these operations is widely practiced. The result is many hours of work for the chief mate and, in most cases, the assumption of his in-port watches by the other two mates. Thus, on three-mate vessels, the other two mates are essentially or in fact standing 6 hours on watch and 6 hours off, a schedule that seldom enables any officer to acquire adequate rest until the vessel returns to sea and can resume a three-watch system. Consequently, the first

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[88] Wickens, C.D., Engineering Psychology and Human Performance, Merrill Publishing Company, Columbus, Ohio, 1984, pp. 292-293.

[89] Webb, W.B., Biological Rhythms, Sleep, and Performance, John Wiley and Sons, New York, New York, 1982, pp. 117-118.

part of the voyage, the transit through the port and other confined or congested waters, is likely to be conducted by navigation watch officers who are in varying stages of fatigue. This problem is recognized by some masters, who assume the navigation watch until one of their watch officers has obtained sufficient rest to assume the watch, but this is not the practice on all three-mate vessels. The Safety Board believes that vessel operators should be held accountable for ensuring that a rested officer, in addition to the master, is available to stand the navigation watch when the vessel departs for sea. This could be achieved by the costly, but simple, procedure of keeping the vessel in port long enough after loading the cargo to enable an officer to acquire the needed rest. Also, a fourth deck officer could be assigned to the vessel, as was the practice in the past on many tankships, including those of the Exxon Shipping Company, or a qualified tankship officer could be temporarily assigned to assume the chief mate's watch in port. Furthermore, having an overworked, fatigued chief mate in charge of cargo transfer operations could result in a catastrophic accidental release of the cargo while the vessel is in port. The Safety Board also believes that the Coast Guard should monitor working conditions on tankships, both domestic and foreign, in U.S. ports to ensure that enough officers are available in port to load the vessel so that at least one rested deck officer is available, besides the master, to take the vessel to sea.

Performance of the Able Seamen.--The navigation watch also included two ABs, one of whom acted as the lookout and the other as helmsman. The lookout was a recent graduate from a maritime academy and had worked for the Exxon Shipping Company since 1987. She had obtained a third mate's license upon graduation but had only worked as an officer for 1 month. The remainder of her company employment was as a maintenance seaman or AB. On the night of the grounding, she had relieved her counterpart about 2350. Since the lookout was not fully informed about the diversion of the EXXON VALDEZ around the ice floe and this was not a lookout's concern, she could not be expected to assist the third mate beyond simply reporting objects sighted, and she did so, for example, when she reported the red light on Bligh Reef buoy. The Safety Board believes that the lookout fulfilled her responsibilities on the watch when she reported the bearing and characteristic of the light accurately and in a timely manner.

The helmsman had had many years of service with the Exxon Shipping Company and had earned his AB rating several years earlier. Most of his seagoing experience was gained as an ordinary seaman or in other unrated positions. He had not been upgraded to AB previously by Exxon because he had not displayed sufficient watchstanding and steering skills. However, there was no evidence that on the night of the grounding the helmsman misapplied a helm order or implemented any helm order that was not given.

Drug and Alcohol Testing of the EXXON VALDEZ Crew

Specimen collection from the master and the crew of the EXXON VALDEZ for drug and alcohol testing was delayed about 10 hours after the grounding occurred. Some of this delay could be attributed to the serious nature of the grounding and the need to assess the extent of the damage and the stability of the vessel. The greater part of the long delay, however, was

stability of the vessel. The greater part of the long delay, however, was owing to the failure of the Coast Guard to have a collection procedure in place to enforce the alcohol and drug regulation. Such a plan should have included procedures to be followed and provisions for ready availability of the necessary equipment for specimen collection in the event of a marine casualty. Two Coast Guard officers boarded the vessel at approximately 0335, about 3 hours after the grounding, and shortly thereafter noted the strong smell of "stale" alcohol on the master's breath. Although the vessel had equipment on board for taking toxicological specimens, Coast Guard officials did not have this information until at least 7 hours after the grounding.

After determining that the master should be tested for alcohol, the investigating officer and XO both appear to have been uncertain who had the authority to do toxicological testing and how it should be accomplished. Nonetheless, the investigating officer recognized that testing was required and at his urging the CO of the MSO made arrangements first to send a State trooper and eventually a Coast Guard medical technician to collect toxicological samples. The Coast Guard officers from the MSO apparently thought that the State police had responsibility for collecting the toxicology samples. However, 33 CFR Section 95.035 states that only a law enforcement officer or a marine employer may direct an individual operating a vessel to undergo a chemical test. Title 44 CFR Section 4.03-55 defines a "law enforcement officer" as a Coast Guard commissioned, warrant, or petty officer or any other law enforcement officer authorized to obtain a chemical test under Federal, State, or local law. Thus, the Coast Guard officers had the authority and eventually did obtain specimens for toxicological testing. Nonetheless, the Coast Guard officials were not current in their understanding of the relevant regulation regarding drug and alcohol testing. According to the regulation, the State authority also was authorized to collect specimens.

The Safety Board, therefore, believes that the Coast Guard should develop procedures to facilitate the timely collection of toxicology specimens following every marine accident.

Drug and Alcohol Testing of DOT Employees in Safety-Sensitive Positions

According to the DOT's "Drug-Free Departmental Workplace Drug Testing Guide," the Coast Guard's vessel traffic watchstanders were in safety-sensitive positions. The guide explained both the procedures to be followed by DOT agencies in making the decision to test an employee and the procedures to follow in collecting and analyzing specimens. The determination to test Federal employees on duty at the time of an accident was to have been made within 8 hours, and specimen collection was to have taken place within 32 hours of an accident. The decision to test the VTC employee on duty at the time of the grounding was not made until after the employee had gone off duty and said he consumed alcohol during his off-duty time at home. Furthermore, the collection of a urine specimen by a Coast Guard employee was not in accordance with the implementation policy of the DOT employee drug testing program because the program specifies that the collection of urine shall be done by a private contractor. Therefore, DOT determined that since the urine sample was not collected according to

established procedures, a second urine specimen was required. A second urine specimen was subsequently collected about 90 hours after the qualifying marine accident by a DOT contractor who was flown in from Atlanta, Georgia. The second specimen was tested according to the DHHS guidelines, which do not include testing for alcohol despite the fact that alcohol is the drug most often abused. What's more, 90 hours far exceeds any reasonable time period for collection of useful specimens.

The sequence of events and delays in obtaining toxicological specimens clearly indicate that the Coast Guard and DOT personnel were unprepared to implement the drug and alcohol testing program for marine employees in the private sector and for DOT (Federal) employees in safety-sensitive positions. The original set of specimens were processed for a broader spectrum of drugs than the five drugs listed in the DHHS guidelines because of confusion about the limitations of the DOT rules. The additional testing conducted by the Safety Board revealed the presence of low-level concentrations of other drugs. The 0000-to-0800 VTS watchstander stated that he had eaten bread with poppy seeds, and the concentration of morphine found was consistent with the recent ingestion of bread with poppy seeds. The level of THC-COOH (metabolite of marijuana) was so low that no conclusions could be drawn regarding the use of this drug by the 1600-to-2400 VTC watchstander.

To further complicate the situation, a new Coast Guard/DOT postaccident drug testing regulation was supposed to have been implemented by a marine company the size of Exxon Shipping by June 21, 1989. The new regulation provided for the collection of urine and blood specimens from marine employees or for breath analysis of marine employees during postaccident investigations. This new regulation for marine industry employees required measurements for alcohol, although the regulation did not specify what drugs were to be identified in the blood specimen. Alcohol determination by breath analysis was permitted. However, the urine specimens could be tested for only the five drugs specified in the DHHS guidelines.

The Safety Board is concerned about the prevalence of substance abuse, including both drugs and alcohol, and its effect on transportation safety. Substantial differences exist among the postaccident/incident sampling and testing requirements for the various transportation modes regulated by DOT. Substantial differences also exist between the drug testing policies for DOT employees in safety-sensitive positions and for private sector employees. Furthermore, the testing requirements of many pertinent regulations are not sufficient to permit the Safety Board or the DOT agencies to identify the extent to which drug and alcohol abuse contributes to transportation accidents.

The Safety Board has several concerns regarding the incorporation of the DHHS guidelines into postaccident/incident testing regulations. First, the guidelines specify the collection of urine only. Second, the guidelines specify the analysis for only five specific drugs or drug classes. These five drugs do not include alcohol, the substance most frequently abused. Also excluded are prescription medications, which might in some instances be a causal factor in an accident. Third, if tests are required, the presence of drugs or alcohol cannot be related to a level of performance impairment

without the analysis of a blood sample, and such a test is not required. Fourth, the drug level in the urine may be below the measurement threshold cutoffs specified in the DHHS guidelines owing to the high thresholds in these guidelines and to delays in collection of urine following an accident. Even though drugs may have been present at a level sufficient to cause performance impairment when an accident occurred, the level could fall sharply by the time of sampling; the presence of a drug and its contribution to an accident would thus go undetected. Finally, the DHHS guidelines were never designed or intended to be used for forensic purposes, that is, to determine the causal relationship of drugs (or alcohol) to a transportation accident, yet the guidelines are being used to serve that purpose by their incorporation into postaccident/incident testing regulations.

The toxicology testing programs vary among modal agencies in the DOT. For example, the Federal Railroad Administration (FRA) requires the collection of both blood and urine as soon as practicable after an accident involving railroad employees. The investigations of railroad accidents have shown the benefits of the FRA regulations. The definition of substances used and abused includes illicit drugs, prescription medications, and alcohol, all of which can cause sufficient performance impairment to lead to a serious or catastrophic accident. The Safety Board advocates the adoption of common postaccident/incident toxicology testing rules that are similar to those used by the FRA.

The Safety Board is particularly concerned that DOT regulations for postaccident testing of employees do not include alcohol testing. In addition to the regulatory differences concerning whether alcohol testing is to be included in postaccident toxicology examinations and in what body fluid, a number of the modal agencies-- The Federal Aviation Administration (FAA), Federal Highway Administration (FHWA), FRA, and the Coast Guard--within DOT have set a threshold limit for blood alcohol (0.04 percent and above is prohibited) within their regulations. Other agencies, such as the Urban Mass Transit Authority (UMTA) and the Research and Special Programs Administration (RSPA) have not defined a blood alcohol limit.

In addition to the FAA and FHWA, the FRA and the Coast Guard had previously adopted regulations that prohibit operators of commercial vehicles and vessels from having a BAC of 0.04 percent and above. Other agencies, such as the RSPA and the UMTA, have no policy at all. Defining "under the influence" as having a BAC of 0.04 percent or greater may give the impression among transportation workers and the public that drinking is allowable, provided the BAC tests below 0.04 percent. The Safety Board does not believe this is the message the DOT wants to send. It should be absolutely clear that the blood of workers in commercial transportation should show no evidence of alcohol at all because research has demonstrated that even very low blood alcohol levels can produce impairment.

The recent drug and alcohol regulations of the various DOT administrations treat the disclosure of test results for Federal employees and employees in the private sector differently. According to Public Law 101-71 (101 Stat. 471, July 11, 1987), disclosure of toxicological results obtained on Federal employees pursuant to Executive Order 12564

(September 15, 1989) can be released only (1) to the employee's medical review official, (2) to the administrator of any employee assistance program in which the employee is receiving counseling, (3) to any supervisory or management official within the employee's agency having authority to take adverse action against such employee, or (4) pursuant to the order of a court of competent jurisdiction when required by the U.S. Government to defend against any challenge against any adverse action. Release of test results to anyone else requires written consent from the employee. Thus, during an accident investigation, information on drug abuse by a government employee in a safety-sensitive position will not be made available to Safety Board investigators unless the employee gives written authorization. In contrast, drug and alcohol testing results from individuals in the private sector are released by the modal agency without the employee's written consent.

The primary objectives of postaccident drug and alcohol testing are to determine whether such substances caused or contributed to the cause of an accident. The use of the results of such testing by the Safety Board has led and will continue to lead to the development and implementation of recommendations for procedures to prevent accidents. If DOT employees in safety-sensitive positions are free to withhold the results of postaccident toxicological test results from the Safety Board, crucial factual information pertaining to the accident will be kept secret, and the Safety Board's mandate to determine the facts, circumstances, and probable cause of the accident and to develop safety recommendations will be preempted. The Safety Board believes that DOT should eliminate the differences between the procedures governing the disclosure of toxicological test results about private persons who have a direct responsibility for transportation safety and about DOT employees who occupy safety-sensitive positions when these persons may have contributed to a transportation accident.

Blood and urine specimens collected during the investigation of rail accidents and incidents are under the control of the FRA. The FRA contracts with and pays for a private laboratory to carry out the drug analysis of blood and urine specimens. Similarly, the FAA has an interagency agreement with the Armed Forces Institute of Pathology (AFIP) for testing fatally injured crewmembers in aviation accidents. In selected cases, a surviving pilot or crewmember has been tested under this program. However, postaccident testing under new regulations for the modal agencies, except the FRA, gives responsibility for analysis of urine specimens for drugs to the employer. Furthermore, the reporting of toxicological testing, including postaccident testing, results to the appropriate DOT regulatory agency is done on a 6-month basis. Thus, a DOT agency may not know the results of postaccident testing until months after an accident has occurred.

With the exception of railroad and perhaps marine employees, alcohol- and drug-impaired employees involved in accidents may not be identified under the current modal regulations and DOT's "Drug-Free Departmental Workplace Drug Testing Guide" for DOT employees in safety-sensitive positions. The drug and alcohol regulations for the various transportation modes are inconsistent, confusing, and in some modes of transportation, inappropriate.

Therefore, the Safety Board on December 5, 1989, recommended that the DOT:

> Develop postaccident and postincident testing regulations that are separate from the pre-employment, random, and reasonable suspicion testing regulations in all modal agencies. (Class II, Priority Action) (I-89-4)
>
> Adopt uniform regulations for all drug and alcohol testing, other than postaccident and postincident testing, in all transportation modes, including U.S. Department of Transportation employees who are in safety sensitive positions. (Class II, Priority Action) (I-89-5)
>
> Adopt uniform regulations on postaccident and postincident testing of private sector employees for alcohol and drugs in all transportation modes. Use the Federal Railroad Administration's (FRA) current regulation as a model regulation for all transportation modes except for the permissible blood alcohol level of less than 0.04 percent. Using the FRA regulation as a model for other transportation modes refers only to the collection of blood and urine and the screening and confirmation of positives in blood. As a minimum, the drugs identified in FRA screen should be used in the other modes. Reference to the FRA model does not refer to the administration or implementation of the regulation. The Safety Board recognizes that the implementation of the regulation may be different in the various transportation modes. The regulations for all modes should provide:
>
> - for the collection of blood and urine within 4 hours following a qualifying incident or accident. When collection within 4 hours is not accomplished, blood and urine specimens should be collected as soon as possible and an explanation for such delay shall be submitted in writing to the administrator. (Class II, Priority Action) (I-89-6);
>
> - testing requirements that include alcohol and drugs beyond the five drugs or classes specified in the Department of Health and Human Services (DHHS) guidelines and that are not limited to the cutoff thresholds specified in the DHHS guidelines. Provisions should be

made to test for illicit and licit drugs as information becomes available during an accident investigation. (Class II, Priority Action) (I-89-7)

Adopt uniform regulations in postaccident and postincident testing of U.S. Department of Transportation employees in safety sensitive positions. The regulations should provide:

- for the collection of blood and urine within 4 hours following a qualifying incident or accident. When collection within 4 hours is not accomplished, blood and urine should be collected as soon as possible. An explanation for such delay shall be submitted in writing to the administrator by the local official making the decision to test. (Class II, Priority Action) (I-89-8)

- testing requirements that include alcohol and drugs beyond the five drugs or classes specified in the Department of Health and Human Services (DHHS) guidelines and that are not limited to the cutoff thresholds specified in the DHHS guidelines. Provisions should be made to test for illicit and licit drugs as information becomes available during an accident investigation. (Class II, Priority Action) (I-89-9)

- that toxicological results from Federal employees be made available to investigators of the National Transportation Safety Board. (Class II, Priority Action) (I-89-10)

- procedures by which Federal employees are sent to the nearest hospital or medical facility for obtaining blood and urine specimens for toxicological testing following a qualifying incident or accident. (Class II, Priority Action) (I-89-11)

Issue rules specifying zero (no alcohol) as the blood alcohol concentration for private sector employees in safety sensitive positions in all transportation modes and for Federal employees in safety sensitive positions. (Class II, Priority Action) (I-89-12)

The DOT has not responded to these recommendations and they are still classified as "Open--Await Response." The Safety Board believes that the EXXON VALDEZ accident demonstrates the continuing need for action on these recommendations; accordingly, they are reiterated.

Manning on the EXXON VALDEZ

The EXXON VALDEZ was operated with a reduced crew complement. Evidence indicated that watchkeeping safeguards on the EXXON VALDEZ had been compromised because of the manning level. The number of unlicensed crewmembers in the deck department was not sufficient to provide uninterrupted lookout capability when other routine deck-department duties arose. When one AB was required to serve as helmsman, the remaining ABs on duty had to cover all work and lookout responsibilities unless an AB from another watch was "turned to" on overtime. Moreover, when a lookout was required for long transits through congested waterways, no other qualified persons on duty were available to relieve that crewmember for breaks. As a result, on the EXXON VALDEZ, the lookout position routinely went unattended when the AB was called for other tasks or took a break.

The Exxon Seamen's Union officials testified during depositions that the sea passages for voyages between Alaska and California were not long enough for conducting necessary maintenance or permitting thorough crew rest between the around-the-clock demands of cargo handling in port. When the current minimum crew requirements were established for the EXXON VALDEZ, the vessel had been scheduled for the Valdez-Panamanian trade. But that trade was discontinued after December 1988, and the EXXON VALDEZ then began operating regularly between Valdez and ports in California.

According to company and union officials, crewmembers in addition to those required by the COI were regularly assigned to the EXXON VALDEZ. The minimum crew for the EXXON VALDEZ required by the Coast Guard was 15, including the master, and the company regularly assigned 4 additional unlicensed crewmembers to the vessel. Two of these crewmembers were QMEDs; one performed pumpman's duties and the other performed maintenance. These additional crewmembers, specifically the two QMEDs, showed the company's awareness of manpower needs in addition to those recognized by the Coast Guard. The other two additional seamen regularly assigned to the EXXON VALDEZ were members of the steward's department and prepared meals for the crew. A third unlicensed engine department crewmember was aboard when the vessel was grounded but apparently was riding for only that one trip. The Safety Board believes that the additional crewmembers regularly assigned to the EXXON VALDEZ engineering department were needed to perform essential work and that the number of crewmembers required by the Coast Guard was not adequate.

The mates on the EXXON VALDEZ were usually fatigued after cargo handling operations in Valdez, and the vessel usually put to sea with a fatigued crew. Although the EXXON VALDEZ had cargo handling automation, the equipment did not eliminate the need for deck officers to spend many hours on cargo watches. The Safety Board is concerned that the manning and working conditions producing fatigue on the EXXON VALDEZ are likely to exist on other U.S. tankships that carry three mates and/or have reduced manning.

Compliance with Exxon Shipping Company procedures that require two officers on the bridge during maneuvering may have provided sufficient sharing of the workload to prevent the grounding of the EXXON VALDEZ. However, the Safety Board is reluctant to endorse the routine use of two officers, who may not have had adequate rest, as a means of obtaining a sufficient number of personnel for a navigation watch. The Safety Board contends that manning levels aboard ships should incorporate realistic expectations for human endurance and fallibilities so that the amount of work required for peak periods, such as cargo handling in port and tank cleaning at sea, can be accomplished without debilitating fatigue.

Reduced Crews

Coast Guard Manning Practices.--The investigation reviewed relevant Coast Guard practices and standards for setting reduced-crew minimum manning levels for inspected vessels. The regulatory agency is admittedly under conflicting pressures from ship owners, operators, and labor unions. Long-standing manning practices are being replaced with more economically advantageous ones, and current manning appears to be at or near the limits for individual workloads. Although these circumstances explain some of the criticism of Coast Guard manning decisions and the manning review process, the Coast Guard's limited perspective for justifying reduced crews may be the primary shortcoming. The trend toward reducing crew complements has been based principally on labor-saving shipboard equipment and equipment reliability, which serve to reduce workload at sea primarily in the engineroom. However, in establishing reduced manning levels, the Coast Guard gave practically no thought to the work load in port. This omission is serious because tankship crews are required to perform much more demanding work in port than at sea, and this work leads to fatigued crews taking their ships to sea. Also, having fatigued crewmen in charge of cargo transfer operations increases the risk of a catastrophic accidental release of the cargo in port that could result in fire/explosion, as well as pollution.

The Safety Board believes that the Coast Guard must promptly implement manning safeguards that directly address crew working conditions in port, as well as at sea. If additional authority is needed, the Coast Guard should seek such authority. These safeguards should incorporate verifiable man-hour requirements for cargo handling in port and for all vessel operations, including tank cleaning, at sea. The safeguards should directly address risk factors associated with fatigue, low morale, and other consequences of longer work hours. The safeguards must also address the consequences of the social isolation that results from lower manning levels and longer tours of sea duty. The Safety Board believes that human

capacities and limitations require no less attention in the manning process than the shipboard equipment criterion.

The Safety Board is particularly interested in the outcome of two research efforts sponsored by the Coast Guard that are intended to examine variables in human factors on reduced-crew vessels. One project, which is being conducted by the Marine Board at the National Academy of Sciences, has used input from vessel operators and marine labor unions to obtain information about existing workloads and working conditions. The Safety Board believes it is important that the Coast Guard evaluate different viewpoints in order to assess the current safety of manning and to develop guidelines to ensure that future manning levels are appropriate to the work load. Similarly, the Safety Board recognizes the interest that the Coast Guard and MARAD have shown in the fatigue factor in their companion project for manning vessels with smaller crews.

Although Coast Guard officers stated that the review process for manning decisions used a "worse case" criterion, there is no evidence of this consideration in documentation related to the manning of the EXXON VALDEZ or EXXON LONG BEACH. Nor is there any evidence that the Coast Guard considered the fact that crewmen may be fatigued from in-port work or additional work owing to tank cleaning or to machinery breakdown. The Safety Board believes that the Coast Guard should re-examine minimum manning practices and establish amended standards using the same care given to other safety standards for vessels. For example, calculations to obtain structural standards acceptable to the Coast Guard are normally predicated on the vessel being in adverse loading conditions and, in some cases, the most adverse conditions possible. Even if it can be argued that the vessel will seldom operate in those adverse conditions, standards based on less rigorous loading criteria are generally considered inadequate. The Safety Board urges the Coast Guard to exercise comparable rigor for manning standards and to set minimum manning requirements that provide safe vessel operation for all foreseeable operating circumstances.

The equipment currently installed for deck-department operation may not reduce manpower needs to the extent projected in the reduced manning requests. With the exception of cargo tank sounding automation, remotely controlled cargo tank valves, and newer equipment that required less maintenance than older equipment, no substantial labor-saving devices were on board the EXXON VALDEZ. In fact, crewmembers on Exxon vessels normally verified manually the operation of all automated sounding and cargo tank valve positions. Since reduced manning of vessels means fewer people on board to do about the same amount of work as was previously done by larger crew complements, the Safety Board views future verification of the assumed lower workload for deck-department personnel as important. Thus, the Coast Guard should develop procedures to more accurately gauge the manning requirements for modern tankships that also take into account human performance needs such as adequate rest, relief from isolation owing to smaller crews, and less time in port.

Exxon Shipping Company Practices.--The Safety Board identified several general operating practices of the Exxon Shipping Company pertaining to

reduced crews that prompted concern. First, no evidence indicated that the company had policies or procedures intended to compensate for the risks involved in having smaller crews on its vessels. For example, Exxon had no program to ensure that mates complied with the requirement in U.S.C. 8401(a) that they have 6 hours of off-duty time in 12 hours before taking charge of the navigation watch. Aside from one introductory reduced-crew manning conference, officers received no specific supervisory training in recognizing fatigue in subordinates or in understanding the debilitating effects of fatigue on themselves or on their subordinates.

Finally, Exxon Shipping Company policy was to manipulate overtime records relevant to crew workload for vessels assigned to at least one "ship group coordinator" in order to support periodic unmanned status for enginerooms and thus to permit reducing crew size. Payment of overtime for officers on all Exxon vessels had been discontinued several years earlier, and during the investigation, no company method was identified that was designed to monitor officers' work in excess of 8 hours daily. Aside from concern about the morale problem created by the loss of direct compensation for time worked, the Safety Board is concerned that unrecorded overtime was not reflected in the work load data used by Coast Guard personnel who evaluated reduced-manning requests. Also, this investigation uncovered evidence that deck officers were used to do maintenance and other work previously done by unlicensed crew who had since been eliminated from service on the vessels.

Because of the Exxon Shipping Company memoranda that directed officers to minimize reports of equipment maintenance and overtime, the minimum manning requirements on Exxon Shipping Company vessels may have been based upon incomplete and inaccurate information. Assuming that the recipients of the memoranda complied with the directive, their maintenance and overtime records would not be representative of actual crew work loads. In addition, the Coast Guard had probably agreed to minimum manning reductions using the same deficient information for its evaluations and consequently may have underestimated crew workloads on all reduced-crew Exxon Shipping Company vessels.

Exxon submitted graphs to the Safety Board that showed a favorable comparison between lower manning levels and casualty and personal injury statistics. The Safety Board does not consider these comparisons useful evidence of safe vessel operation. Gross measurements, such as the number of oil spills per vessel or injuries per million man-hours over a 15-year interval, do not provide sufficient information for causal inferences about any safeguards on these vessels. The evaluations did not provide information on safety programs in effect, composition of crew complements, crew overtime, length of crewmember tours, equipment installed on the vessels, or other variables from which the effects of lower manning on safety may be methodically deduced.

The Safety Board is also concerned that Exxon has continued to increase crew work load in its fleet even after the grounding of the EXXON VALDEZ. A recent company directive, issued after the grounding, required manning of periodically unmanned machinery spaces while vessels are in inland

waterways. Since engineering crew complements were reduced on these vessels because the machinery spaces were said to no longer require monitoring, the reestablishment of watchstanding without replacing the deleted engineers and QMEDs places an additional workload on the number of engineers retained. In another directive issued after the grounding, the company restricted off-duty crewmembers to their vessels when cargo handling operations are in progress. The apparent intent of requiring off-duty crewmembers to remain on board was to ensure the availability of enough manpower for cargo-related incidents or other emergencies. These measures may show a necessary concern for engineroom and cargo safety, but they impose additional burdens on crewmembers without compensating for the human factors involved. As a result, the Safety Board is concerned that Exxon's measures may not adequately provide for the safety of personnel, the vessel, or the environment.

Evidence also indicated that the Exxon Shipping Company planned to further reduce the crew size and to lower crew qualifications for most vessels in its operating fleet. The company was planning to eliminate the current position of the radio electronics officer by assigning communication and maintenance duties to the master and engineers, respectively. The company also planned to institute a separate maintenance department of unlicensed seamen having duties across deck, engine, and steward's departments. Implementation of such a department would have weakened the navigation watch by enabling a minimally manned vessel to operate with a complement of only four ABs and two ordinary seaman instead of six ABs. According to the Coast Guard, implementation of the new department was delayed only by the Exxon Seamen's Union. In the interim, the Coast Guard issued a directive requiring that the company retain six certified ABs on each vessel. The maintenance department concept under which ordinary seamen are employed to perform maintenance is reasonable, but its implementation should not lead to a reduction in the number of ABs. Six ABs, two per watch, are needed for an underway navigation watch in order to provide two qualified helmsman so that the helm can be relieved, thereby reducing the possibility of having a fatigued seaman steering.

The Safety Board considers the reduced manning practices of the Exxon Shipping Company generally incautious and without apparent justification from the standpoint of safety. The financial advantage derived from eliminating officers and crew from each vessel does not seem to justify incurring the foreseeable risks of serious accidents.[90] Regarding company manning practices that related to the EXXON VALDEZ, the Safety Board does not believe that the Exxon Shipping Company showed sufficient regard for the known debilitations that occur as a result of crewmember fatigue. Furthermore, the Safety Board could find no reasonable explanation for the following: the absence of company programs to ensure that crewmembers observed hours-of-service regulations; the lack of procedures to ensure that at least one rested deck officer, in addition to the master, was available for watch at departure; the practice of rating a crewmember's performance in part according to willingness to work overtime, thus giving an incentive to work

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[90] The cost of cleanup is expected to exceed $2 billion.

an excessive number of hours; and the indiscriminate increase in work loads and standby time throughout the fleet before and after the grounding of the EXXON VALDEZ.

Fatigue in Transportation Safety

In a letter dated May 12, 1989, to the Secretary of Transportation, the Safety Board expressed its concerns about the far-reaching effects of fatigue, sleepiness, sleep disorders, and circadian factors in transportation system safety. The Board further stated that:

> poor scheduling of work and rest time continues to affect the performance of operating personnel in virtually all modes of transportation. Safety Board experience also indicates that most employees and supervisors in the transportation industry do not receive training on the problems associated with work and rest schedules and the effects such schedules have on safety and performance. Additionally, proper living habits, including attention to exercise, diet, and rest, are important to good health. However, many transportation operating personnel may not adequately appreciate the importance of these habits in relationship to their fitness for duty and their susceptibility to fatigue in the face of their irregular and often unpredictable work/rest patterns. Therefore, the Safety Board believes there is a need to develop and disseminate educational materials that will assist transportation employees in adapting living habits appropriate to their work/rest patterns.
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> Furthermore, it appears that, with minor exceptions, neither management nor the labor segments of the transportation industry properly considers the adverse effects of irregular and unpredictable cycles of work and rest on its vehicle-operating personnel. Although some private research has been conducted on this safety issue, the Safety Board is unaware of any systematic activity by the DOT to address the safety concerns of inadequate work and rest scheduling in any of the transportation modes.
>
> Since 1972, the Safety Board has issued about 39 safety recommendations to transportation modal administrations, operators, and associations concerning fatigue, duty time, and hours of service. Collectively, these recommendations addressed most aspects of the fatigue and fitness-for-duty issues, but they constitute uncoordinated and piecemeal efforts directed to various government and industry segments of the transportation community. The Safety Board is aware of the March 1989 DOT report entitled "Transportation-Related Sleep Research," which was prepared in response to a request by

the U.S. Senate Committee on Appropriations and which describes current departmental activities in this field. This report provides an overview of current diverse activities by various departmental administrations regarding the role of fatigue, sleep disorders, and sleepiness in their respective modes. However, the Board believes a review of the report also indicates a need for more overall planning, direction, and control of these activities to assure that they are administered as a coordinated, effective program that will provide the best possible safety benefits for the entire transportation community.

Based on its experience in accident investigation, the Safety Board believes it is time for an aggressive Federal program to address the problems of fatigue and sleep issues in transportation safety. Such a program should include a coordinated research effort, an extensive educational effort directed toward all segments of the transportation industry, and a systematic review and improvement of regulations governing hours of service across all transportation modes.

Therefore, the National Transportation Safety Board recommends that the DOT:

Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. (Class II, Priority Action) (I-89-1)

Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. (Class II, Priority Action) (I-89-2)

Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues. (Class III, Longer-Term Action) (I-89-3)

These recommendations are currently classified as "Open--Acceptable Action." The Safety Board believes that these safety recommendations are pertinent to the EXXON VALDEZ accident and reiterates them to the Secretary of Transportation.

Response Activities During the First 24 Hours

Coast Guard Response Activities.--At 0027 on March 24, 1989, the Coast Guard VTC at Valdez was advised by the master of the EXXON VALDEZ that his

vessel was aground and leaking oil. About 10 minutes later, the CO and XO of the Coast Guard MSO in Valdez arrived at the VTC and activated the COTP Prince William Sound Pollution Action Plan, and the CO assumed responsibility as the OSC. Soon after arriving, they notified the Alyeska Terminal's marine operations watchstander, the local ADEC representative, and the Seventeenth Coast Guard District Office staff of the accident. The CO also advised the Alyeska Terminal watchstander to send its pollution contingency barge to Bligh Reef. The XO and SIO were sent to the vessel to initiate the casualty and pollution investigations and to determine the extent of the oil spill. The CO of the MSO expected that the spill would be classed as a "major" oil spill (in excess of 100,000 gallons, about 2,380 barrels) because the vessel was a large tanker and had grounded on a rocky reef. At 0249, he asked for assistance from the PACAREA Strike Team. He believed that asking for assistance from the strike team was a prudent action because it has the additional manpower, expertise, and equipment needed to supplement the local response to a major oil spill.

The CO, as Federal OSC for the oil spill, followed proper procedures in initiating Coast Guard actions in response to the report of the spill. Because Alyeska was responsible for cleaning up oil spilled at its Terminal and from ships that carry North Slope crude oil and had successfully cleaned up oil spills from ships carrying such crude oil in the past, the Federal OSC, in accordance with the NCP and RCP, assumed his customary duties: investigating the accident and oil spill, assessing the situation, monitoring the removal actions, and providing guidance and assistance as necessary for the cleanup activities. During the first 24 hours, Alyeska employed company personnel and local workers, ordered additional workers, and was using or had ordered all cleanup equipment available in the area to be delivered to the Terminal or the EXXON VALDEZ. If the OSC had taken over the cleanup during the first 24 hours, he would have had to employ the same people and contract for the same equipment that Alyeska was using at the time. His work load would have expanded considerably because he would not only have been directing the cleanup but also increasing his record keeping and contracting responsibilities. Such an action would not have enhanced the cleanup effort already under way; it would only have changed who was directing and paying for cleanup actions. The Safety Board believes that it was unwarranted for the Federal OSC to assume cleanup responsibility from Alyeska during the first 24-hour period after the spill for the following reasons: all equipment in the area was being used, other equipment was being mobilized or ordered into the area by Alyeska and Exxon, and the only change in cleanup actions would have been who paid directly for the cleanup.

Alyeska's Response Activities.--The contingency barge was not loaded with oil spill response equipment as had been the Terminal's practice in the past and the expectation of the ADEC. However, the Alyeska Contingency Plan, which had been approved by ADEC, did not specify that response equipment had to be kept on board the barge at all times. The barge had been used in response to a pollution incident in early January 1989, and its equipment had been offloaded so that it and the barge could be cleaned. The barge had also been damaged above the waterline during a storm in February 1989, and reloading of the response equipment had been delayed to allow for repairs. Alyeska had not thought it necessary to inform the ADEC that the

barge was not loaded with equipment because the barge could still be loaded and used in an emergency.

When it became apparent that the EXXON VALDEZ could not be moved safely off Bligh Reef in its damaged condition, the Federal OSC assigned a high priority to lightering the EXXON VALDEZ, and Alyeska and Exxon prepared for the lightering of the vessel. Exxon had to request lightering hoses and fittings from tankships at anchor near Bligh Reef and hired a small freighter in the area to collect and deliver the equipment to the EXXON VALDEZ. Lightering of a damaged or stranded tanker was covered in the Alyeska contingency plan, and the plan included a list of some of the equipment needed for the process. Large ship fenders for mooring the EXXON VALDEZ and the lightering vessel together had to be found in Valdez, and other lightering equipment had to be located and gathered from various storage areas at the Terminal, requiring additional time to load the barge. The extra effort and time necessary to locate and collect sufficient lightering equipment demonstrated a lack of preparation on the part of Alyeska and the need to have such equipment readily available.

On the night of the spill, poor weather conditions, darkness, and the gathering of extra cleanup equipment, including lightering equipment, prolonged the loading of the Alyeska contingency barge. Had another contingency barge been preloaded with lightering equipment, locating, collecting, and gathering the equipment would not have been necessary and the cleanup supervisors could have used the additional time to plan other cleanup activities. These actions increased the time needed to load and prepare the barge for towing from the 2.5 hours provided in the plan to 10 hours. It took another 5 hours to tow the barge to the EXXON VALDEZ, which was about 28 miles from the Terminal. The Alyeska contingency plan's 200,000-barrel oil spill scenario, which was predicated on daylight and summer weather conditions, allowed a total of 5 hours for preparation and towing of the barge to a spill site about 30 miles from the Terminal. This timetable can only be met if the barge is already loaded. If the contingency barge had been preloaded with its cleanup equipment and had left the dock as soon as the tug PATHFINDER received orders to proceed to the EXXON VALDEZ, the barge could have been at Bligh Reef within the 5 hours prescribed in the Alyeska contingency plan. The Safety Board believes that the almost 10 additional hours needed to load, prepare, and tow the barge to the site constituted an unwarranted delay that could have been avoided if the barge had been loaded. The 10-hour loss had no material impact on the cleanup because of the size of the spill. However, had the spill been more manageable, the opportunity for quick response would have been lost. Even though the 10-hour delay did not make a difference in this spill, the delay might have been significant under other conditions.

Because every spill is different in size and location, a variety of cleanup equipment is required. Equipment stored on one barge may be adequate for a small spill, while larger spills may require additional equipment that must be loaded on two or more barges. An accident may also necessitate the use of lightering equipment, as was the case in this spill. To save time in gathering and loading response equipment and to allow cleanup supervisors to use their time for other activities, such equipment should be preloaded on

barges and ready for deployment. Thus, Alyeska should be prepared beforehand with barges loaded with different levels of cleanup equipment so that the response to an accident is not delayed by the need to load or unload equipment.

The cost of an additional barge or barges with equipment aboard, compared to the value of the oil on board a tankship and the large volume of oil transported from the Alyeska Terminal in Valdez, should more than justify the need for additional barges loaded with cleanup and response equipment. Moreover, the equipment on the barges should be placed in protective containers, and the loaded barges should be moored under shelters to protect them from the detrimental effects of weather. The Safety Board believes that barges should be loaded with different levels of oil spill cleanup equipment and lightering equipment and that the barges should be ready at all times for immediate deployment to the scene of a spill.

State of Alaska's Activities.--ADEC also established an emergency response center in Valdez that was fully operational by the evening of the day of the spill. It planned to monitor, assess, and oversee the cleanup response from the response center. During the first day of the spill, ADEC was concerned that Alyeska had not deployed cleanup equipment to the scene as provided for in the Alyeska contingency plan. The State wanted to make sure that the Federal OSC would intervene early in the response process and take over the cleanup if the responsible parties did not do what was expected in a timely and effective manner. A letter was drafted by the ADEC for the State representative to the RRT. Although the letter mentioned the State's concerns, it was not conveyed to the RRT during the first day. ADEC was following the requirements of its contingency plan to assess, monitor, and oversee spill cleanup activities.

Contingency Plans.--Not covered in the Alyeska contingency plans was a procedure for the transfer of cleanup responsibility from Alyeska to the shipping company that was responsible for the oil spill because it came from one of that company's vessels. A procedure for transferring cleanup responsibility should be developed by Alyeska and the individual shipping companies loading oil at the Valdez Terminal so that there will be continuity in the cleanup work and so that the transfer can be fully monitored by the Coast Guard and the State of Alaska. Because of the remote location of Valdez and the time it takes for a shipping company's oil spill response personnel to arrive on the scene, Alyeska should continue to be the initial responder to oil spills from vessels carrying oil from the Valdez Terminal in Prince William Sound. The vessel's parent company should have an organization or plan to respond effectively so that it can relieve Alyeska of long-term cleanup responsibility within a reasonably short period of time. After being relieved, Alyeska should remain on the scene to support the responsible company by providing continuity to the cleanup activity, local knowledge, and advice.

ARCO Marine had conducted a simulated oil spill drill in 1988, during which ARCO relieved Alyeska. The Coast Guard, ADEC, and local government officials participated in the drill. ARCO was the only company that had a State-approved plan that included procedures for relieving Alyeska of

cleanup responsibilities. As a result of this drill, the OSC apparently assumed that Alyeska and Exxon would follow similar procedures. Alyeska and Exxon did not have any State-approved procedures for relieving Alyeska of cleanup responsibilities, probably because Alaska had not required any such procedures. Exxon had submitted proposed oil spill cleanup plans on two previous occasions, but the State had returned the plans to Exxon because, according to the State, they were not required. Alyeska stated that it had an understanding with Exxon that Exxon would assume cleanup responsibilities for a major spill, but the understanding was not written into Alyeska procedures. Exxon announced soon after it was advised of the spill that it would assume cleanup responsibility, supporting the contention that such an arrangement had existed with Alyeska. After Exxon received notice of the spill, the president of Exxon Shipping Company activated the Exxon-wide spill response teams, and he and his staff proceeded to Valdez to take over the cleanup responsibilities from Alyeska. They arrived on the afternoon of the accident day, but they did not relieve Alyeska immediately, although Exxon was taking action to assume responsibility for the cleanup. Companies shipping oil from the Alyeska Terminal at Valdez should amend their individual plans to include procedures for assuming cleanup responsibility for major oil spills from Alyeska and have the individual plans approved by the State. It is possible that some companies may not be fully capable of assuming responsibility quickly. Each company's response capability and procedures should be listed in the Alyeska contingency plan. Following State approval of a company's plan, it should be included in the Alyeska contingency plan for Prince William Sound.

Use of Dispersants.--The Alaska RCP addresses the use of oil dispersants in the State. It provides a decision matrix and a description of the biological effects of dispersants in the water but no guidance or information about the conditions under which the application of dispersants is effective. Wind and sea conditions and the length of time that the oil has been on the water when dispersants are applied alter their effectiveness. Such information about dispersant application should be included in the Alaska RCP and other contingency plans so that proper dispersant procedures are readily available. An OSC would then know when to use dispersants and would not waste time using them when they would not be effective. On the afternoon of the spill, a test was conducted using dispersants when the sea was calm. However, calm sea conditions are not conducive to the effective use of dispersants, which must mix with the oil in order to cause it to break into droplets and disperse into the water column. If the OSC had had guidelines in the RCP that described the wind and sea conditions necessary for effective use of dispersants, a test application would have been unnecessary.

The company contracted by Alyeska needed more than 3 hours to prepare a helicopter with a 300-gallon spray bucket to conduct a dispersant test application, which was done about 18 hours after the spill was reported. Air-deliverable dispersant system (ADDS) packs for fixed-wing aircraft were not available in Valdez and had to be ordered from storage sites in Alaska and the continental United States. The Alyeska plan states that aircraft capable of applying dispersants are to be available in 9 to 17 hours. However, the aircraft and ADDS packs were not available for use during the

first 24 hours after the spill occurred. If dispersants are to be used on an oil spill, especially in such a remote area as Valdez, the delivery system must be readily available and stored on or near the Terminal. The Safety Board believes that if dispersants continue to be regarded as an oil spill response option, ADDS packs and other dispersant application equipment should be stored in Valdez and ready for immediate use and that appropriate aircraft or vessels should be available on short notice.

In-Situ Burning.--The Alaska RCP and the Alyeska plans also mention in-situ burning of oil as an approved alternative to mechanical cleanup, but the plans provide no guidance about how to proceed with in-situ burning or about possible results of burning, such as smoke or oil and tar residue. The use of in-situ burning is at the discretion of the OSC, with guidance from the RRT. Thus, the OSC is in the difficult position of being able to authorize certain methods--dispersant use and in-situ burning--but only after consulting and seeking advice from the RRT. The RRT may provide some information and agree to the use of a particular method, but the final decision is the OSC's. At times, the OSC may not be able to contact the RRT, or the RRT may not provide clear guidance. Such problems may result in delays that could render the application of dispersants useless and in-situ burning ineffectual. The OSC could also make an incorrect decision because of the lack of sufficient guidance or information, but incorrect action probably would not be as harmful as no action while awaiting a consensus from the RRT. In any case, the OSC's decisions will probably be second guessed during and after the cleanup because the results may not be acceptable to all parties. The cleanup party may think there was a delay in authorizing a certain procedure; the environmentalists may believe the physical environment was damaged or fish and wildlife were destroyed; fishermen may think their livelihood was threatened; the State may regard the impact on its environment, revenue, or tourism as negative; or the RRT may think its guidance was interpreted incorrectly. OSCs need more than advice from a committee. They need guidance in writing, before a spill occurs, from the NCP and the RCP about the use of dispersant chemicals and in-situ burning so that their decisions can be based on accepted procedures.

During the first 24 hours after the spill, Exxon applied to the RRT to conduct in-situ burning of the spilled oil. The RRT recommended approval if the OSC was satisfied that the burning could be done without degrading other cleanup efforts. In addition, the State had to issue a burn permit. "Approval to open burn" was issued by the ADEC on the same day, March 24, but the permit was not sent to Exxon until the next day. Even though the permit was not received until the next day, neither Alyeska nor Exxon was prepared to burn oil on the first day of the spill because neither one had a fire- or burn-proof boom on hand. The boom had to be shipped in from the North Slope and Seattle. Had the boom been immediately available and a burn permit issued earlier, this method of cleanup could have been used on heavy concentrations of oil before the wind and currents spread the oil so far that effective containment was not possible.

The burn permit stated: "Exxon has the responsibility to ensure smoke from their burning does not impact public health or violate Air Quality Standards. Following the limits of this permit does not relieve Exxon of

this responsibility." Such a restriction is unrealistic. North Slope crude oil, a hydrocarbon, cannot burn with an open flame without producing considerable smoke, and the State cannot expect oil to be burned in a smokeless fashion. Smoke resulting from burning oil may cause the public some temporary discomfort and will probably violate air quality rules, but it may be preferable to extending the area covered by oil and the time that oil is on the water. Mechanical methods of removing oil from water are slower, although preferable to other methods of cleanup because they do not introduce additional assaults on the environment; but they can have a negative effect on the environment because the oil remains on the water for a longer time. Moreover, the current technology for mechanical oil removal cannot be relied on to cope with a spill of this magnitude. In-situ burning would probably have been the best way to deal with the oil spill early in the cleanup process since use of dispersants was not possible because of the calmness of the sea and because the spill was too large to be removed from the water by skimmers or other mechanical means.

Difficult decisions have to be made by the State and the RRT/OSC--whether to burn the oil in the water (with appropriate safeguards to prevent the uncontrolled spread of fire toward the vessel and shore) and accept the resultant smoke (while reducing the amount of oil in the water and the effect on fish, wildlife, and shoreline) or to try to remove it from the water by mechanical methods. Mechanical methods require the use of booms to contain the oil, and in some situations, use oil of containment booms may not be possible either because the booms are not available or because the sea and weather are not calm enough. Major spills require unusual responses and preplanning, and consideration should be given to in-situ burning as one method of cleanup that needs to be developed and included in response plans.

According to the NCP, dispersants and burning agents may be used only "to prevent or substantially reduce a hazard to human life." In the Alaska RCP and Alyeska contingency plans, dispersants and burning of oil can also be used to minimize the effects of spilled oil on wildlife. This apparent conflict between the NCP, the Alaska RCP, and the Alyeska plans should be resolved. The NCP should also provide additional guidance to assist RRTs in developing dispersant use guidelines in their RCPs. Neither the Alyeska contingency plans, nor the Alaska RCP, nor the NCP have any guidelines or information about when dispersant use or in-situ burning are appropriate, under what conditions they are effective, or what equipment is needed for safe employment. The NCP should also include dispersant use and in-situ burning information guidelines in its plan for use by RRTs in developing RCP guidelines for use by OSCs.

Alyeska submitted a 200,000-barrel spill scenario in response to ADEC's requirement to include one in the 1987 revision to the plan. The scenario was approved by ADEC and included in Alyeska's plan. It used June 22 for the date of the incident, stressed dispersant use, and listed good weather and sea conditions. June 22 is about the time of the summer solstice and thus a day with a maximum amount of daylight. A spill would not be likely to occur in Prince William Sound under such optimum conditions. Good weather and sea conditions are needed if booms are to be effective because they need relatively calm conditions to corral and contain the oil so that the skimmers

can remove the oil from the surface of the water. However, dispersants need wave action to mix the chemical with the oil and disperse the droplets of oil into the water column. The commissioner of ADEC testified that "according to what the plan [Alyeska contingency plan] represented, there would have been the capacity if those assumptions held, and they did, to recover 240,000 barrels [of oil] with the equipment that the contingency plan had designated." When asked how long it would that take with the equipment available, he answered, "That would have been completed prior to the first 72 hours, according to the specifications provided." However, the scenario posits a long-term cleanup of the beaches in Prince William Sound. The commissioner also testified that ADEC was "well aware of the equipment that was available. We were well aware of the plan that Alyeska had committed to, and we see this as a failure of performance." The Alyeska contingency plan for the 4,000-barrel oil spill scenario postulates approximately a 2-month cleanup. A 4,000-barrel oil spill is about 1/60th the size of the EXXON VALDEZ spill; thus, the Safety Board does not concur with the commissioner's statement that the EXXON VALDEZ spill could have been cleaned up in 72 hours and that the failure to clean up the spill within this time frame was a "failure of performance."

The lessons learned as a result of this accident should be incorporated into the Alyeska and individual company contingency plans and drill activities. The plans should include recommended response times for cleanup personnel to report to their stations and for equipment delivery to the cleanup scene. To make this contingency planning meaningful, drills should be conducted with each company that loads oil at the Terminal on a periodic schedule, comparisons of its performance with the plan should be made, and the plan revised, as appropriate. Such drills should always involve an estimate of the amount of oil that can be removed from the water with the equipment on hand within specified time frames.

Alyeska had to order equipment from its pipeline pump stations and from the North Slope of Alaska, and Exxon had to order equipment from all over the world to respond to the spill. The amount of equipment available in Valdez and the immediate areas was insufficient to initiate an effective cleanup response during the first day of the response activities. Alyeska had listed available oil spill cleanup equipment in its contingency plans, and ADEC approved these plans. Although oil spill prevention is paramount, sufficient first-response equipment is also needed to quickly and effectively limit the impact of a spill on the environment. Federal regulations 33 CFR 153 require the removal of spilled oil, but the NCP does not provide any equipment requirements or guidelines that a terminal, port authority, State, or other regulatory entity can use to establish the minimum level of equipment necessary for an appropriate response. Such guidelines for minimum equipment requirements should be developed by the Federal Government and published in the NCP. The RRTs could then use these guidelines to determine the amount and type of cleanup equipment that should be immediately available in a particular area so that the initial response can be effective and give the responsible party time to mobilize and deliver additional cleanup equipment.

Prince William Sound Vessel Traffic System

Performance of the VTS Personnel.--The 1600-2400 VTC traffic watchstander stated that during the evening of March 23, he monitored the EXXON VALDEZ on radar as the vessel departed from the Valdez Narrows and proceeded to the Rocky Point Pilot station about 6.5 miles south of Potato Point. He stated that shortly after the pilot disembarked he began to lose radar contact with the vessel and that subsequent attempts to maintain radar contact with it using the 12-mile range scale on the No. 3 (slave) radar were unsuccessful. All efforts to monitor the vessel on radar ceased about 2330. Assuming that the EXXON VALDEZ was traveling at a speed of approximately 12 knots, the VTC lost radar contact with the vessel when it was about 7.7 miles south of the radar site at Potato Point and about 5.5 miles from the grounding site.

The 1600-2400 watchstander said that when he monitored vessels in Valdez Arm, he normally set the No. 3 radar (slave) on the 6-mile range scale, in offset, which provided an area of about 10.2 miles on the radar scope. He did not state, however, what range scale he usually used for the No. 1 (master) radar. The watchstander said he believed the radar did not detect the EXXON VALDEZ because it was not working properly. However, he apparently did not believe anything was significantly wrong with the radar because no report of malfunction was passed along to his relief, who arrived moments after the vessel was lost from the radar, or to the electronics technician on duty.

The 0000-0800 VTC traffic watchstander stated that when he arrived at the VTC about 2330, he observed that the No. 1 (master) radar was set on the 3-mile range scale and that the slave radar was set on the 6-mile range scale in offset. He also said that he neither observed the EXXON VALDEZ on radar at that time nor changed the range of the radar in an attempt to do so. The relieving watchstander stated that although he generally monitored vessels transiting Valdez Arm on radar, he did not attempt to do so prior to the accident because he had been told by the offgoing watchstander that the EXXON VALDEZ was no longer visible on radar.

With the No. 1 (master) radar set on the 3-mile range scale, the radar transceiver at Potato Point radiated transmissions that have the shortest pulse length and highest pulse repetition rate, a transmission mode designed for accurate tracking of vessels at close range. Although this setting was optimum for tracking vessels transiting Valdez Narrows, it was not the correct range setting for tracking vessels much farther than the 7.7 miles that the EXXON VALDEZ was tracked prior to the grounding. Two other range settings, a 6- to 12-mile and a 24-mile scale, were available on the radar. Use of these range scales on the No. 1 (master) radar would have allowed the Potato Point radar transceiver to transmit correspondingly longer pulses of radar energy, increasing the range of the radar and enabling the EXXON VALDEZ to be tracked to a greater distance.

There were no severe weather or sea conditions at the time to reduce the radar detection range. The radar was operating satisfactorily, as evidenced by the fact that the 0000-0800 VTC watchstander was able to detect the

grounded vessel immediately by using the 12-mile scale, a radar range setting that produced the medium-length radar pulse. The vessel was observed to be broadside to the radar on a heading of about 260°, demonstrating that a substantial radar return was being received. The Safety Board believes that the EXXON VALDEZ could have been tracked by the radar past Busby Island Light (about 10.5 miles from the radar) and probably all the way to the grounding site if the 1600-to-2400 VTC watchstander had selected a higher range scale on the master radar. By failing to use a higher range scale, the watchstander virtually ensured that radar tracking of the EXXON VALDEZ would end well before the vessel reached Bligh Reef. The Safety Board concludes that the Coast Guard had the ability to monitor the transit of the EXXON VALDEZ to the grounding site by radar.

Radar Monitoring and Plotting Policy.--Personnel associated with the VTC ascribed particular meanings to the terms "monitoring" and "plotting." Monitoring, according to VTC personnel, meant observing or watching the vessel on the radar scope; plotting had acquired a number of different meanings as equipment changes occurred in the VTC. Originally, plotting was the marking of the vessel's successive positions on a chart; but later, after installation of the Raytheon radar, only the bearing and range of each vessel were recorded on the VTC data sheet for future plotting, if required. After installation of the data logger on the slave radar, plotting meant the automatic recording of the vessel's bearing and range.

The VTC Organization Manual required the VTC watchstander to plot participating vessels in Valdez Narrows every 3 minutes and vessels outside Valdez Narrows every 6 minutes; slower vessels could be plotted less frequently. On August 31, 1987, a memorandum issued by the senior watchstander eliminated the requirement to plot vessels, except in Valdez Narrows. At this time, plotting meant the recording of the bearing and range on the VTC data sheet; thus, the memorandum eliminated the recording of bearings and ranges for vessels in Valdez Arm. Vessels transiting Valdez Arm were to be monitored, but no written guidance was issued about how far outbound vessels should be monitored, where the VTC watchstander should try to acquire an inbound vessel on the radar, or increasing the range scales on the radar to obtain the greatest range. Thus, selection of range scales and the decision about how far the vessel should be monitored were left to the discretion of each watchstander.

The former procedure of recording bearings and ranges ensured, to some extent, that someone was manning the radar and that the progress of vessels was being observed. It also allowed supervisory personnel to ascertain how far vessels were being observed on the radar and whether vessels were remaining in their assigned traffic lanes. Since neither the CO nor the operations officer appeared to be aware that vessels were regularly departing the TSS during ice conditions, the data forms probably were not being reviewed to determine what routes vessels might be following. The lack of any kind of record keeping for vessel movements beyond Valdez Narrows following the August 31, 1987, memorandum in effect eliminated a mechanism for measuring the performance of the radar and for estimating how effectively the radar was being operated by different watchstanders. The lack of definitive instructions on monitoring and the elimination of any

record of vessels, except in Valdez Narrows, allowed each VTC watchstander to determine the extent to which vessels in Valdez Arm should be monitored.

The CO, operations officer, and assistant operations officer expressed the opinion that Valdez Narrows was the VTC's area of major concern and the only area that required careful monitoring and plotting of participating vessels. They stated that the VTC's role was to provide information to vessels that was ordinarily not available to the vessels. Unlike Valdez Narrows, Valdez Arm provided a wide, straight waterway, and because navigation aids and landmarks were abundant, VTS personnel may have concluded that vessels in Valdez Arm required virtually no information or guidance. Even the use of the traffic lanes radar overlay was not required, and some watchstanders did not project the lanes onto the radar scope. Furthermore, the 1987 memorandum was designed to reduce work associated with vessels in Valdez Arm, and the effect was probably to further reduce concern about navigation in Valdez Arm. Such lack of concern might have been justified were it not for the fact that vessels were frequently departing from the TSS when ice was in the traffic lanes and in doing so, were often passing very close to Bligh Reef.

The Safety Board believes that the 1600-to-2400 VTC watchstander decided not to monitor the EXXON VALDEZ, even though the master reported that he would be leaving the TSS to avoid ice, primarily because there was no firm requirement or policy that he do so. The lack of interest in vessels transiting Valdez Arm probably was owing to the failure of the CO and the operations officer to keep themselves informed about ice conditions in Valdez Arm and about the procedures the vessels were following to avoid ice.

The EXXON VALDEZ could almost certainly have been tracked considerably farther than 7.7 miles, probably all the way to the grounding site, if the 1600-to-2400 VTC watchstander had set a higher range scale on the master radar console. Had the watchstander tracked the EXXON VALDEZ, he or the relieving 0000-0800 VTC watchstander would have recognized that the vessel had changed course to 180^{0} and that this course would cause the vessel to head out of the TSS toward shoal water east of Bligh Reef. The use of the traffic lane overlay on the radar would have enabled the watchstander to recognize more quickly that the vessel probably was going to depart the TSS and to determine where and when the departure would occur. Since the EXXON VALDEZ remained on course 180^{0} for nearly 18 minutes, the VTC watchstander had ample time to call the vessel to ascertain the intentions of the navigation watch. Any inquiry from the VTC regarding the vessel's intentions probably would have alerted the third mate to turn earlier or to use more rudder. A subsequent followup inquiry from the VTC would surely have alerted him to the fact that his vessel could be standing into danger and that a sharp right turn back toward the traffic lanes was needed. Any action by the third mate to turn earlier or to use more rudder could have been sufficient to steer the vessel clear of Bligh Reef.

The Safety Board concludes that the Coast Guard was not maintaining an effective VTS in Prince William Sound at the time of the EXXON VALDEZ grounding.

Following a firm, clear policy that all participating vessels, especially loaded tankships navigating Valdez Arm, were to be plotted could have made all VTC personnel aware that vessels occasionally were passing close to Bligh Reef. If he had had such information, the CO would probably have recognized that an unsafe situation existed and that some action by his command to improve safety was warranted. Such action might have included improved ice reporting, mandatory position reports from vessels avoiding ice, enhanced supervision of the VTC, mandatory use of the traffic lane overlays, and maximum effort to track those vessels avoiding ice. The Safety Board believes that a permanent policy of tracking and plotting all participating vessels between the pilot station south of Bligh Reef, or as close to the pilot station as possible, and the vessels' berths in Port Valdez should be adopted. The Safety Board also believes that a sufficient number of permanent VTC watchstanders should be provided to meet the workload associated with these plotting requirements.

Supervision of the Vessel Traffic Center.--The loss of seven MSO/VTS billets in 1988 necessitated the reassignment of additional duties and responsibilities to remaining VTS supervisory personnel because there had been no commensurate reduction in the functions performed by the MSO. As a result, the operations officer and the assistant operations officer both had numerous non-VTS duties and responsibilities that precluded them from spending much time overseeing the VTS. The assistant operations officer, who was a senior chief radarman, was also required to perform administrative duties outside the operations department, some involving duties in supply. Thus, the person who had the seniority, the rating specialty that had prepared him specifically for operating radar to track vessels, and the experience as a VTC watchstander was not readily available to supervise the VTC watchstanders. Consequently, the responsibility was delegated to the next most senior petty officer, the senior watchstander, who was a radarman first class. The senior watchstander was thus responsible for supervising the VTC watchstanders and for making sure that the VTS was operated according to Coast Guard regulations and VTC instructions. His duties included assigning the watchstanders to specific shifts, preparing performance evaluations, approving requests for leave, and issuing guidance by memoranda to the watchstanders.

There was still a need for the VTC watchstander to make reports and request advice at any time of the day. This was addressed in the VTC Organization Manual, which required VTC watchstanders to report certain occurrences, such as vessels deviating from the assigned traffic lanes or leaving the TSS, to the OOD. Depending on the circumstances, such as when permission might be required, the OOD occasionally referred the report to the CO or to the XO in the CO's absence. However, the VTS manual did not establish a means to ensure that such reporting would eventually be brought to the attention of the operations officer, assistant operations officer, or senior watch officer.

Such reports had previously been made to an officer-supervisor who stood watch in the VTC and later to a CDO who was on duty on a 24-hour basis and who was familiar with VTC operations. The CDO watchstanders comprised the senior personnel of the MSO, including former VTC officer-supervisors. In

addition to their other MSO/VTS duties, CDO watchstanders were responsible for overseeing the VTC during their watch shifts to ensure that all applicable Coast Guard regulations and VTS policies were followed. Moreover, the CDOs, who were familiar with the VTS, could provide a reliable communications link between the VTC watchstanders and the CO.

The elimination of the CDO duty section following the 1988 billet reductions and subsequent shift to reporting to OOD watchstanders allowed persons who had never qualified as VTC traffic watchstanders to supervise the VTC watch. What's more, several of the OODs were enlisted personnel who were junior to the civilian VTC traffic watchstanders they supervised. The fact that some OODs were not particularly familiar with the VTC probably limited any real supervision to that of relaying information to the CO for decision or simply concurring with the advice offered by the VTC watchstander on how to handle a particular situation. The station OOD on duty prior to the accident, for example, was a first class yeoman (an administration specialist) who had never qualified as a VTC traffic watchstander.

Because of the replacement of the CDO with the Station OOD, supervision of the VTC and communication between the VTC and senior MSO/VTS personnel probably declined. The diverse, heavy workload of the operations officer and assistant operations officer diminished their capability to supervise and to ascertain what was occurring in the VTC. Poor communications, together with a lack of supervision of the VTC, might explain why the CO and operations officer were unaware that vessels were departing from the TSS and that ice conditions might be so bad that loaded tankships had departed the traffic lanes to avoid ice just hours before the grounding.

The supervision of the day-to-day operation of the VTC should be the responsibility of persons who are not only senior to the watchstanders in rank and/or grade but who also have some expertise in VTC traffic watchstanding. This would ensure that supervisory personnel have both the requisite qualifications to supervise and an awareness of the use and limitations of the radar and radio systems utilized by VTC watchstanders. Had the MSO been able to maintain the CDO duty section, the CO and the operations officer might have learned that long before the EXXON VALDEZ was grounded, vessels had deviated from the TSS because of ice in the traffic lanes. The Safety Board believes that the number of supervisory personnel had been reduced to such an extent that supervision of the VTC was adversely affected and that additional supervisory personnel are therefore needed at the Valdez MSO. Moreover, there should be some officer whose primary duty is to be fully in charge of the VTC. Therefore, the operations officer should be divested of some of his duties or an additional officer should be assigned to the operations department so that an officer is in charge of the VTC who has the experience and time to manage it effectively.

Ice in the Traffic Lanes.--Even before the VTS was established in 1977, the Coast Guard was aware that ice from the Columbia Glacier was drifting into the Valdez Arm. Because vessel traffic in the area prior to 1977 consisted primarily of fishing boats, tour boats, and an occasional cruise ship, the presence of ice in this area caused little concern; however, when tankship traffic commenced, concern for safety increased dramatically. The

MSO began to receive more frequent reports of ice interfering with tankship traffic through the Valdez Arm. By the early 1980s, both the Coast Guard and the maritime industry had become increasingly concerned about the presence of ice in the traffic lanes. As a result, when ice was reported on the traffic lanes, the Coast Guard on several occasions broadcast Notices to Mariners that tankships should either reduce speed or await daylight before transiting the area. Several oil companies, including Exxon, Mobil, and Sohio, began to occasionally limit their vessels to daylight transits or to place speed restrictions on their vessels when ice was reported in Valdez Arm. About this time, the Coast Guard requested all participating vessels to provide ice reports to the VTC. By the end of 1981, the U.S. Geological Survey had predicted that calving of ice from the Columbia Glacier would continue to increase during the next 10 to 30 years. Despite warnings and concern, the port of Valdez has never been closed to vessel traffic because of ice in the traffic lanes.

From July 1 to October 31, 1981, 18 of 634 vessels transiting the VTS area (2.8 percent) deviated from the TSS because of the presence of ice in the traffic lanes. According to MSO records, between July 1984 and May 1985, the greatest number of vessels deviating from the TSS to avoid ice did so between July 23 and October 31, 1984. During this period, 76 of 403 vessels (18.9 percent) deviated from the TSS because of ice, a significant increase over 1981. Even during November and December 1984, ice continued to be a hazard, as indicated by records showing that between December 18 and 28, 1984, 32 of 57 (56 percent) tankship transits were affected by ice. Unlike previous records, however, those for the last 2 months of 1984 did not cite the number of vessels leaving the TSS.

During the summer of 1985, there was a change of command at MSO Valdez. Unlike his predecessor, the new CO did not require that the VTC maintain a record of the number of vessel transits affected by the presence of ice in the traffic lanes. As a result, no Coast Guard documentation was available for analysis of the effects of ice conditions in Prince William Sound between 1985 and the date of the accident. However, the statements made by pilots, masters, and most of the VTC watchstanders indicate that vessels continued to be forced to deviate from the TSS because of the presence of ice in the traffic lanes and that such deviation occurred regularly up to the time of the accident.

Because of heavy ice on March 23, 1989, four vessels, including the EXXON VALDEZ, operated outside of the TSS, clearly demonstrating that ice has an adverse impact on navigation safety that needs to be addressed by the Coast Guard. The U.S. Geological Survey has predicted that the destruction of the Columbia Glacier will continue and may accelerate. As a result, vessels probably will continue to depart from the TSS, and the number of vessels affected will probably increase. The Safety Board believes that ice in the traffic lanes poses a hazard to the safe navigation of vessels through Prince William Sound and that it is incumbent on the Coast Guard to ensure that participating vessels, particularly loaded tankships, are able to transit this area in the safest manner. The Board also believes that in order to increase the margin of safety for vessels transiting the area

between Potato Point and Bligh Reef, the Coast Guard should have the capability to exercise greater control of vessels passing Bligh Reef.

Ice Reporting.--The ice reports provided by the VTC were retransmissions of reports provided by vessels transiting Valdez Arm. Because several hours may elapse between transits, the information is not likely to be representative of the actual ice conditions encountered by the vessel receiving the report from the VTC. An ice report more than 4 hours old may be of little value. What's more, the observations made by different vessels may result in varying descriptions for the same ice condition.

The Coast Guard's inability to provide useful ice information was demonstrated by the experiences of the three tankships that departed Valdez on March 23, 1989. In the case of the BROOKLYN, the Coast Guard was unable to provide that tankship, which was the first one to depart the Alyeska Marine Terminal on that day, with a current ice report because the most recent report was from a vessel that had transited Valdez Arm the day before. The VTC, however, did inform the BROOKLYN that extensive ice was present in the traffic lanes and that it had been causing vessels to maneuver out of the traffic lanes. The master of the vessel stated that he had interpreted the VTC report to mean that he too had permission to deviate from the TSS should he consider it necessary. The Coast Guard was also unable to provide the ARCO JUNEAU with a current report prior to its departure from Valdez because the last vessel to report (the BROOKLYN) had transited the Valdez Arm almost 8 hours earlier. The master of the ARCO JUNEAU stated that he knew about the ice in the traffic lanes because of his inbound transit 24 hours earlier. During the outbound transit on March 23, he said that he first detected the presence of ice on the ship's radar as he was preparing to exit the Valdez Narrows.

The Coast Guard provided the EXXON VALDEZ with an ice report after the vessel got under way from the Alyeska Pipeline Terminal; however, the information provided by the VTC was incomplete. The vessel was not informed, for example, that the ice extended all the way across the traffic lanes to Bligh Reef buoy; rather, the vessel was told that ice had been reported in the traffic lanes.

In 1981, the CO of the MSO recommended the installation of radar on Bligh Island or Glacier Island. He pointed out that radar on either one could enable the VTC to determine when ice was present in the traffic lanes. Radar could provide current information about ice, thereby eliminating the common problem facing the masters of the four vessels transiting Valdez Arm on March 23, all of whom were uninformed about the ice conditions that they would encounter in the traffic lanes. According to the chief engineer, the master of the EXXON VALDEZ had seriously considered at some time during the afternoon postponing departure until daylight to be able to avoid ice. Upon arriving on the bridge, the master immediately inquired whether an ice report had been received. The pilot stated that he told the master about the ice report that he had heard the ARCO JUNEAU transmit to the VTC. However, by this time, the tugs were alongside and the pilot was on board, and it probably was too late to decide to remain in port based upon the information that was available to him. Accurate information about the ice conditions

earlier in the day would have allowed the master to make a timely decision about whether to leave port.

Columbia Glacier.--Early in the construction of the pipeline, the U.S. Geological Survey recognized that the glacier could begin a catastrophic retreat similar to that of several other Alaska glaciers. By the time oil shipments began, it had become apparent that glacial ice would affect navigation safety. The glacier is currently in rapid retreat and the number of icebergs in Valdez Arm has increased significantly. Icebergs, which were once primarily a problem in the late summer and early fall, are now a problem nearly year round.

During the midwinter months in Valdez, Alaska, the sun is above the horizon for as little as 5 1/2 hours per day, and daylight, including twilight, may total only 7 1/2 hours. Moreover, Valdez is in the region of the North Pacific storm track, and visibility there is frequently reduced by fog, precipitation, and reduced natural light owing to cloud cover. To ensure the safe passage of shipping through the Valdez Arm and to move the number of ships required to service the Alaskan pipeline adequately, parties associated with tankship movements need current, reliable information about icebergs in the waterway. This information may also enable accurate predictions of ice calving for ship scheduling and routing purposes. Such predictions can only be made if the state of the glacier and the volume of ice calving are closely monitored.

When the Port of Valdez first opened as an oil terminal, the U.S. Geological Survey was closely monitoring the Columbia Glacier, but since then, the level of monitoring has been reduced to a periodic aerial observation of the glacier terminus. The Safety Board concludes that this effort is inadequate to provide the detailed information required to estimate the number and size of icebergs expected to enter the shipping lanes.

The Safety Board believes that the safety of tankship movements in Prince William Sound requires accurate, up-to-date information about the size and amount of ice calving from the Columbia Glacier and that the U.S. Geological Survey should intensify its monitoring of the glacier.

Improved Radar Coverage of Valdez Arm.--The circumstances in which a vessel must navigate an area 1/2- to 1-mile wide that is bordered on one side by glacial ice and on the other by a dangerous reef are similar to the situation confronting vessels at Valdez Narrows and can, as this accident shows, be very dangerous. Accordingly, the vessels that may be forced to pass close to Bligh Reef merit tracking on radar by the VTC with the same degree of reliability and precision exercised by the VTC at Valdez Narrows.

The VTS radar was particularly sensitive to the effects of precipitation and sea conditions, which occasionally can prevent the monitoring of vessels south of Busby Island. The radar, nonetheless, provided accurate tracking of vessels in Valdez Narrows. During April 1989, MSO VALDEZ, at the Safety Board's request, plotted all outbound tankships in Valdez Arm to determine the effectiveness of the VTS radar. Using the 12-mile range scale, the resulting data indicated that 74 percent of the

vessels were tracked out to the grounding site about 13.2 miles from Potato Point. The number of vessels that were monitored out to Bligh Reef buoy, about 14.5 miles from Potato Point, however, was less than 61 percent. Because the survey was conducted during the spring, it cannot be used to evaluate the performance of the VTS radar during the harsh winter months. The data indicate, however, that even during favorable weather and sea conditions, the radar is not capable of providing reliable radar coverage of the Valdez Arm.

The VTC was sometimes able to monitor the movement of vessels out to Bligh Reef; however, the watchstander had to shift from the 6-mile range scale to the 12-mile range scale (in offset). Use of the 12-mile range scale may have prevented the watchstander from noting the smaller course and speed changes that are more easily observed at the lower range scales. The larger range scale also introduced a small degree of error in bearings and ranges. As a result, the monitoring of vessels using the higher range scale, while necessary, reduced the accuracy of the radar tracking. This problem, however, could be solved by installing a remote radar site closer to Bligh Reef, perhaps on Bligh Island or Reef Island. A remote radar site closer to Bligh Reef would permit the VTC to monitor the transits of vessels through the Valdez Arm using lower and more accurate range scales. The reduced distance to the traffic lanes would also greatly improve the probability of tracking vessels during inclement weather. Accordingly, the Safety Board believes that a radar site near Bligh Reef is necessary to enable the VTC to ensure that vessels avoiding ice or other hazards or navigating in poor visibility do not venture too close to Bligh Reef.

VTS Communication System.--During the evening of March 23, the Naked Island and Cape Hinchinbrook remote communications sites were inoperative. In order to maintain VHF-FM communications with vessels in the system, including the EXXON VALDEZ, the VTC was forced to route VHF-FM communications through a tertiary site near Cordova. At that time, the VTS communications system failed to meet Coast Guard Specific Operating Requirements. There was no notable improvement subsequent to the grounding, as evidenced by the fact that during the first three quarters of Fiscal Year 1989, the VTS communications system failed to meet the Coast Guard's Specific Operating Requirement of 99.9 percent operational status.

The ability of the VTS to keep the communications system operational has declined because: (1) the communications system is old (has exceeded the 10-year expected life cycle) and spare parts are no longer readily available, (2) the requested funding for the upgrade and/or replacement of the communications system has not been forthcoming, and (3) the harsh Alaskan coastal climate has continued to degrade sensitive electronic equipment at the remote sites.

The CO correctly predicted in 1985 that the reliability of the VTS communications system would begin to deteriorate if the system were allowed to operate past the end of the equipment life cycle (estimated to have occurred in 1987). These concerns regarding the system were well documented in the Planning Proposal (PP #17-012-85) that was submitted to the Commander, Seventeenth Coast Guard District, on December 3, 1985. Since

then, the system has been plagued by numerous equipment problems that have not been easily remedied because the age of the system often made it difficult for the MSO to obtain replacement parts.

The harsh Alaskan winters, with heavy snowfall and long periods of darkness, make the timely maintenance and repair of communications equipment at remote communications sites difficult. Thus, the equipment should be new enough and in good enough condition that the routine maintenance that can be performed during good weather will be sufficient to ensure reliable operation during succeeding winter months when repairs would be difficult.

The fact that the communications system had already deteriorated to a point that it no longer met Coast Guard Specific Operating Requirements indicates that eventually it will probably become impractical to keep all essential components of the system operational simultaneously. In the absence of a reliable VTS communications system, the Prince William Sound VTS could become unable to function. Should the major portions of the communication system fail during the winters, the VTS could be out of service for several days. The Safety Board believes that in order for the VTS to have an appropriate level of VHF-FM communications in Prince William Sound, PP #17-012-85, submitted by MSO Valdez to the Commander, Seventeenth Coast Guard District, for action on December 3, 1985, should be implemented as quickly as practicable.

VTS Microwave System.--On the day of the accident, the microwave system installed in Prince William Sound was more than 12 years old and needed replacement and/or upgrading. The microwave transmission system provided the essential link between the remote radar and communication sites and the VTC. Despite the age, condition, and importance of the microwave system, funding to upgrade and/or replace it has not been available.

The concerns regarding the microwave system are well documented in PP #17-012-85. In the proposal, MSO Valdez stated that the system would continue to deteriorate, resulting in more downtime, if the system were allowed to operate past the end of the equipment life cycle. In the meantime, replacement parts have become increasingly difficult to obtain, and as a result, breakdowns are no longer easily remedied.

The Safety Board believes that the microwave system in Prince William Sound should not be allowed to deteriorate further and that the Coast Guard should place a higher priority on implementing that part of PP #17-012-85 that covers the update and/or replacement of the microwave system as soon as practicable.

Pilotage

The public had two opportunities to comment on the proposed rules to reduce Federal pilotage requirements in Prince William Sound. The proposed changes would have eliminated any requirement that U.S. domestic vessels have a Federal pilot or an officer with a Federal pilotage endorsement between Cape Hinchinbrook and the former pilot station at Rocky Point. This reduction in pilotage requirements would have allowed vessels to pass Bligh

Reef, both inbound and outbound, without having a pilot on the bridge. The grounding of the EXXON VALDEZ, plus the fact that tankships frequently pass close to Bligh Reef while avoiding ice, leads the Safety Board to believe that vessels passing Bligh Reef should be under the control of an officer who has local knowledge of Valdez Arm. The requirement for Federal pilotage on almost all transits, although not adhered to by the master of the EXXON VALDEZ, ensured that a Federal pilot was in charge of each vessel throughout Valdez Arm.

On April 12, 1989, the State of Alaska Board of Marine Pilots relocated the State pilot station from Rocky Point to a position well south of Bligh Reef. The relocation ensures that a pilot will be on board while vessels proceed past Bligh Reef. Moreover, relocation of the pilot station ensures that at least two deck officers, the watch officer and the pilot, will be on the bridge between the pilot station and the Alyeska Terminal. The remainder of Prince William Sound is open waters except for the entrance to the Sound from Cape Hinchinbrook to Montague Point. The Coast Guard has required nonpilotage vessels to have an extra officer on the bridge while transiting Prince William Sound, to plot their position every 10 minutes while transiting between Cape Hinchinbrook and Montague Point, and to be prepared to inform the VTC of their position. Such a procedure ensures that vessels adhere to the TSS and thus safeguards vessels from grounding and collision. Accordingly, the Safety Board, finds no strong requirement for Federal pilotage between Cape Hinchinbrook and the pilot station at Latitude 60° 49′ N, Longitude 147° 01 W, which is south of Bligh Reef. However, the grounding of EXXON VALDEZ has demonstrated that accidents can occur and that the public should again be solicited for comments regarding the need for Federal pilotage between the entrance to Prince William Sound and the current pilot station south of Bligh Reef.

Since State pilots, while piloting domestic vessels such as the EXXON VALDEZ, are operating under a Federal license, they are required to meet the licensing standards established by the Coast Guard. A Federal license can be obtained by any mariner who has the required service and qualifications, as established in Federal regulations, and who can successfully pass the examination administered by the Coast Guard. A pilot operating under a Federal license is subject to administrative action under which his license can be suspended or revoked if he is found to have operated his vessel negligently or has violated Federal law.

In the case of foreign flag ships calling at Port Valdez and all U.S. vessels in foreign voyage, there is no requirement for a Federal pilot. On such vessels, the pilot operates under his State license and the Coast Guard cannot revoke or suspend his license in case of an infraction of Federal law or an accident owing to fault.

• This problem was addressed in the Safety Board's report entitled "Collision Between the Hong Kong Flag Bulk Carrier PETERSFIELD and the U.S. Towboat BAYOU BOEUF and Tow, New Orleans, Louisiana, October 28, 1986."[91]

As a result of its investigation of that accident, the Safety Board recommended that the Coast Guard:

> Seek legislation to require all pilots of commercial vessels on the navigable waters of the United States to have a Federal pilot's license which would be legally superior to all State-issued documents, licenses or commissions that a State may continue to employ to accredit those pilots that it desires to pilot vessels engaged in foreign commerce. (Class II, Priority Action) (M-88-1)

The Coast Guard replied on July 13, 1988:

> The Coast Guard concurs with the intent of this recommendation and recognizes the need for establishing better disciplinary control over some State-licensed pilots. However, past Coast Guard efforts to obtain the recommended authority have not been successful in Congress. Therefore, to enhance the possibility of gaining Congressional support, we intend to conduct a study of marine casualties over the past several years to determine both the extent of pilot-related accidents and their impact on marine safety. This initial step is critical to justify the need for additional legislative authority.

This safety recommendation is currently classified as "Open--Acceptable Action." The Safety Board believes that the Coast Guard should have the same authority over pilots on foreign flag vessels that it has over Federal pilots on U.S. domestic vessels and all other U.S. licensed mariners. Accordingly, the Safety Board reiterates this recommendation.

The requirements for nonpilotage vessels that were established by former COTP Order 1-80 appear to have contributed to the safety of such vessels, since there is no history of accidents attributable to nonpilotage vessels. The CO's decision to rescind the requirement for daylight passage when visibility is 2 miles or more seems to be reasonable, especially since there will be a pilot on board between a point south of Bligh Reef and Port Valdez. The requirement in the COTP Order for an extra officer to plot the vessel's position between the entrance and the pilot station is normally accomplished by the presence of the master on the bridge. The requirement that an officer be on the bridge who can speak English is considered warranted, since

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[91] Marine Accident Report--Collision Between the Hong Kong Flag Bulk Carrier PETERSFIELD and the U.S. Towboat BAYOU BOEUF and Tow near New Orleans, Louisiana, October 28, 1986 (NTSB/MAR-88/01).

reliable communications are essential to safety. The Safety Board believes that retention of the requirements of former COTP Order 1-80 (except for daylight transit) as VTS regulations would contribute significantly to navigation safety in Prince William Sound.

Global Positioning System.--The GPS, which can be augmented by land-based stations, offers a convenient means to determine vessel positions accurately during nearly all hours of the day. Vessel positions determined by GPS also can be transmitted ashore to a VTC to be displayed on an electronic chart. Such a system could enable the VTC at Valdez to monitor accurately the movements of tankships throughout Prince William Sound. The Safety Board believes that the GPS may have potential application in the Valdez VTS system.

Tank Arrangements

The 214,861-deadweight-ton EXXON VALDEZ met the MARPOL '73/'78 regulations regarding minimum protected shell area, draft, trim, cargo tank length, and allowable tank volumes. The EXXON VALDEZ was required to have approximately 68,000 square feet of total protected shell area. The vessel met this requirement by using the No. 2 and No. 4 port and starboard wing tanks as the staggered SBTs, which provided about 46,000 square feet of side protection and 23,000 square feet of bottom protection. However, this configuration only protected about 35 percent of the total cargo tank side shell area, and it covered about 20 percent of the total tank bottom area. In addition, the 20-percent bottom coverage did not protect the bottom of any tank carrying cargo oil.

The maximum vertical damage penetration measured during the Safety Board's damage survey was 10.9 feet in two locations in the No. 1 starboard cargo tank. The vertical damage in No. 3 center and No. 3 starboard tanks was 8 feet and 9.9 feet, respectively, and was less in all other tanks. Therefore, an 11.1-foot double bottom (based on the criterion of Beam/15, which has been proposed by the Coast Guard) probably would not have been breached by vertical damage in any tank if the outer hull provided the same resistance to penetration as that of a single-hull vessel. Transverse frames in No. 2 starboard ballast tanks were deformed upward from 8 to 15 feet and could have caused fracturing of an inner bottom; thus, minor leakage probably could still have occurred from this tank, which could have been a cargo tank in a double bottom tankship. Any outflow would have been expected to be considerably slower if the vessel had had a double bottom, probably enabling the crew to transfer product from the tank to reduce outflow.

Assuming that No. 2 starboard wing tank inner bottom did fail owing to the deformation of transverse frames, that no action was taken to reduce the level of cargo in the tank, and that the tank had the same capacity in a double bottom design (actually may have been smaller), the amount of cargo that might have been lost was calculated to be approximately 20,000 barrels. This amount could have been substantially reduced by transferring cargo from the damaged tank to reduce the height of the cargo in the tank. Thus, the Safety Board believes that if the EXXON VALDEZ had been fitted with a double

bottom, the oil outflow would have been significantly reduced, if not eliminated.

Design Alternatives.--The Safety Board considered three design alternatives that could reduce oil outflow:

(a) Double Bottoms.--Tank vessels can be designed and constructed with various tank arrangements that can reduce the oil outflow if there is an accident. For instance, a tank vessel can be fitted with a double bottom extending along the length of the cargo tank area as shown in figure 12b. (See page 87.)

The double bottom structure results in a smooth inner bottom, thus allowing easier, faster, and less expensive tank cleaning. A smooth cargo tank bottom also improves loading and offloading operations aboard tank vessels fitted with sluicing cargo systems, since oil flow is not restricted by internal tank members. The structural strength gained by fitting a double bottom may minimize occurrences of major spills as a result of a hull breaking during a stranding, collision, explosion, or other accident.

Groups opposed to mandatory requirements for double bottoms aboard tank vessels have stated that sometimes salvage operations of a stranded tanker can be complicated by flooded double bottoms. Furthermore, they have claimed that when a single-bottom tanker grounds and spills part of its cargo, the vessel is automatically lightened and may be able to float off without assistance. This is unlikely to occur, as the grounding of the EXXON VALDEZ illustrates, because ballast or void compartments may flood and increase the vessel's draft. Salvage experts have stated that flooded double bottoms would probably result in a firmly grounded vessel rather than a lightly grounded one, thus allowing salvors to initiate salvage operations more easily, especially under heavy weather conditions.

Opponents have also stated that double bottoms pose an explosion hazard, since cargo oil vapors may accumulate in these enclosed spaces. However, the 1975 Office of Technology Assessment study did not find any evidence supporting this hypothesis; and according to the Tanker Advisory Center, there have been no fires or explosions in the double bottoms of tank vessels during the past 25 years. Moreover, any explosion hazard could be eliminated by inerting the double bottoms with the vessel's inert gas system. Others have claimed that double bottoms will not prevent oil outflow in high energy grounding accidents because the inner bottom of cargo tanks would probably be ruptured. However, during a high-energy grounding, as in the case of the EXXON VALDEZ, a tank vessel with a double bottom probably would spill less cargo than a tank vessel with a single bottom because any breaching of the inner bottom is likely to be less extensive than the breaching of the outer hull. In the EXXON VALDEZ grounding, all center and starboard side cargo tanks, except the slop tank, which had a double bottom, were breached.

(b) Double Sides.--If all SBTs aboard a tank vessel are located in a double bottom, virtually no protection against collision damage is provided. To provide

collision protection, a tank vessel can be designed with double sides, with the longitudinal bulkheads fitted closer to the side shell and all the wing tanks dedicated to carrying water ballast, as shown in figure 12c (see page 87). This design provides maximum protection against collision damage but no protection against grounding damage.

(c) Double Hulls.--A tank vessel can be designed with a double hull in which water ballast would be placed in both double bottom and wing tanks, as shown in figure 12d (see page 87). Although this option probably entails the highest construction cost, at about 15 to 19 percent of total construction costs, it provides maximum protection against oil outflow owing to collisions and groundings. A tank vessel fitted with a double hull would have adequate ballast capacity to navigate in heavy weather without having to use any cargo tanks, thereby minimizing operational pollution. For example, in addition to the ballast in the wing ballast tanks, the EXXON VALDEZ needed to load about 25,000 long tons of water ballast into the No. 3 center cargo tank to navigate safely under heavy weather conditions.

Opponents of double hulls have taken positions similar to those who oppose double bottoms, challenging the safety and pollution prevention benefits of double hulls. As in the case of double bottoms, these challenges lack validity given the fact that tank vessels with double hulls have been built and are operating safely. Ten tank vessels fitted with double hulls are currently in the U.S. flag tank vessel fleet. Moreover, both U.S. and international standards require double hulls for tank vessels carrying hazardous cargoes to achieve the greater safety that double hulls provide.

Perhaps the most persuasive argument in favor of double hulls is an accident that occurred to the LNG tank vessel EL PASO PAUL KEYSER on July 1, 1979, when it grounded in the Strait of Gibraltar on a rocky bottom while proceeding at a speed of 18 knots. Although more than 60 percent of the bottom shell under the LNG tanks was breached, because of the double hull, no cargo was spilled and the vessel was salvaged.

Collisions usually occur in high-density traffic areas, such as the highly trafficked waters in the Los Angeles/Long Beach area, while groundings can occur in coastal waters and harbor entrances regardless of the amount of vessel traffic. The severity of the grounding damage depends heavily on the bottom condition of the area. In rocky areas, such as Alaska, a grounding can cause massive damage to the vessel.

Statistics compiled by Lloyd's of London show that significantly more tank vessel groundings than collisions have occurred since 1974. Had the EXXON VALDEZ, which was operating between Valdez and Los Angeles/Long Beach,

been fitted with a double hull, the risk of oil spills owing to collision or grounding would have been significantly reduced.

The United States has taken unilateral action and will require U.S. flag and foreign flag tank vessels entering U.S. waters to have double hulls. Although this action will not afford total protection of the U.S. coastline from accidental oil spills in international waters off the U.S. coast, it will protect U.S. coastal waters from oil spills as a result of groundings and collisions in U.S. waters. Since a large percentage of the world's tank vessels operate in U.S. waters, this action by the United States will probably promote double-hull construction of many new foreign flag tank vessels so that these vessels can be used in the U.S. market. This action by the United States may also lead to international requirements for double hulls or unilateral action by other countries.[92]

CONCLUSIONS

Findings

1. The master's decision to depart from the Traffic Separation Scheme to avoid ice was probably reasonable, even though it required a heading toward shoal water.

2. Navigating the EXXON VALDEZ between the ice field and Bligh Reef required a diligent, competent navigation watch capable of conning the vessel, watching for ice, and fixing the vessel's position frequently; hence, two officers were required on the bridge--one with conning and shiphandling experience to conn the vessel and one to fix the vessel's position frequently--to navigate the vessel safely.

3. The master's decision to leave the third mate in charge of the navigation watch was contrary to Federal regulations and Exxon policy and was improper given the course of the vessel, the uncertain extent of the ice conditions, the proximity of a dangerous reef and the fact that the third mate did not have the required pilotage endorsement.

4. The master's judgment was impaired by alcohol during the critical period the vessel was transiting Valdez Arm.

5. The performance of the third mate was deficient, probably because of fatigue, when he assumed supervision of the navigation watch from the master about 2350.

6. The third mate's failure to turn the vessel at the proper time and with sufficient rudder probably was the result of his excessive workload and fatigued condition, which caused him to lose awareness of the location of Bligh Reef.

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[92] Finland has already implemented an oil protection fee in order to minimize the number of single-bottom tank vessels in its waters.

7. The vessel was in the red sector of Busby Island Light for several minutes before grounding, which afforded a warning of the reef that apparently was not noticed by the third mate or the lookout.

8. There were no rested deck officers on the EXXON VALDEZ available to stand the navigation watch when the vessel departed from the Alyeska Terminal.

9. Many conditions conducive to producing crew fatigue on the EXXON VALDEZ exist on other Exxon Shipping Company vessels because many are three-mate vessels and because the company has pursued reduced manning procedures.

10. The Exxon Shipping Company did not adequately monitor the master for alcohol abuse after his alcohol rehabilitation program.

11. Exxon Shipping Company did not have a sufficient program to identify, remove from service, if necessary, and provide treatment for employees who had chemical dependency problems.

12. Exxon Shipping Company manning policies do not adequately consider the increase in workload caused by reduced manning.

13. The Exxon Shipping Company had incentives and work requirements that could be conducive to fatigue.

14 The Exxon Shipping Company had manipulated shipboard reporting of crew overtime information that was to be submitted to the Coast Guard for its assessments of workloads on some tankships.

15. The Coast Guard was unduly narrow in its perspective when it evaluated reduced manning requests for the EXXON VALDEZ; it based manning reductions primarily on the assumption that shipboard hardware and equipment might reduce the workload at sea but did not consider the heavier workload associated with cargo operations in port and the frequency of such operations.

16. The Coast Guard was not adequately prepared to implement the requirement to obtain toxicology samples from mariners involved in marine accidents.

17. Department of Transportation regulations for postaccident/incident drug testing of employees in safety-sensitive positions are not adequate.

18. Drug testing of Vessel Traffic Center watchstanders was not conducted in a timely manner in accordance with Department of Transportation directives.

19. The Coast Guard needs to have access to National Driver Register information and other information regarding alcohol-related traffic offenses committed by licensed maritime officers in order to better determine a merchant mariner's fitness to hold a Federal license.

20. The Alyeska Pipeline Service Company failed to meet the expected response-time objective of its approved spill plan because it failed to have an oil spill cleanup barge loaded and ready for deployment.

21. The Alyeska Pipeline Service Company should have, at a minimum, a second barge that is loaded with additional cleanup and lightering equipment so that cleanup equipment will be ready for immediate deployment at all times.

22. The National Oil and Hazardous Substance Pollution Contingency Plan and Alaska Regional Oil and Hazardous Substances Pollution Contingency Plan both lack adequate guidance for On-Scene Commanders about the use of dispersants and in-situ burning.

23. Requiring the On-Scene Commander to confer with the Regional Response Team before using dispersants or in-situ burning needlessly delays the use of these methods and complicates the decision process.

24. There was no evidence that the Federal Government (Coast Guard) or any other organization would have been capable of increasing the efforts under way during the first 24 hours after the spill.

25. The Alyeska Pipeline Service Company contingency plans lacked procedures that would allow individual companies transporting oil from the Valdez Terminal in Prince William Sound to relieve Alyeska of cleanup responsibilities in a manner that would prevent interruption.

26. The Alyeska Pipeline Service Company plan should include guidelines that describe the wind and sea conditions under which different types of skimmers, dispersants, and in-situ burning can be used most effectively for North Slope crude oil.

27. Ice in Valdez Arm is a significant hazard to navigation and requires closer monitoring and reporting.

28. The limited supervision of the Vessel Traffic Center probably contributed to the commanding officer's and operations officer's lack of awareness that tankships were departing from the traffic separation scheme to avoid ice and were passing close to Bligh Reef.

29. The Vessel Traffic Service radar was operating satisfactorily, and the detection range of the radar was not significantly reduced by weather or sea conditions while the EXXON VALDEZ was transiting Valdez Arm.

30. The Vessel Traffic Center lost radar contact with the EXXON VALDEZ about 7.7 miles from the radar site, which is about 5.5 miles from the northern part of Bligh Reef, because the Center's watchstander did not use a higher range scale and not because of any limitation or malfunction of the radar. Had he used a higher range scale, the vessel probably could have been tracked as far as the site of the grounding, but no firm policy required that he do so.

31. The monitoring of vessels in Valdez Arm was left to the discretion of the Vessel Traffic Center watchstander because the senior watchstander decided to allow the Center's watchstanders to monitor instead of plot the positions of vessels transiting Valdez Arm.

32. A firm policy requiring the Vessel Traffic Center to plot tankships transiting the full length of Valdez Arm could have alerted the commanding officer of the Marine Safety Office to the fact that tankships were departing from the traffic separation scheme in the vicinity of Bligh Reef to avoid ice.

33. Monitoring the EXXON VALDEZ by radar as it transited Valdez Arm would have revealed to the Vessel Traffic Center watchstander that the vessel had changed course to 180^{0}, had departed the vessel traffic separation scheme, and was headed for shoal water east of Bligh Reef.

34. A query or warning from the Vessel Traffic Center might have alerted the third mate to the impending danger from Bligh Reef.

35. Ice reports issued by the Vessel Traffic Center frequently are neither sufficiently timely nor sufficiently accurate to enable masters to ascertain before leaving Port Valdez the ice conditions that will be encountered in Valdez Arm.

36. The policy adopted by the Coast Guard about 1985 to discontinue independent collection of ice information and statistics about vessel deviations from the traffic separation scheme probably contributed to the commanding officer and the operations officer not knowing that ice was causing vessels to depart from the traffic lanes and pass close to Bligh Reef.

37. A radar site near Bligh Reef would enable the Vessel Traffic Center to obtain current information on ice in Valdez Arm and to reliably track vessels in Valdez Arm.

38. The communication and microwave systems for the Vessel Traffic Service, Prince William Sound, were not reliable owing to age, the scarcity of proper replacement parts, and improvised repairs.

39. The Coast Guard has not maintained an effective vessel traffic service in Prince William Sound.

40. Although moving the pilot station to Rocky Point was apparently based on a consideration for pilot safety, the move also resulted in a reduction in pilotage services past Bligh Reef, where local knowledge is needed.

41. Moving the pilot station to a position south of Bligh Reef enhanced navigation safety by ensuring the presence of an officer with local knowledge of the area on the bridge of each vessel transiting Valdez Arm past Bligh Reef.

42. Former COTP Order 1-80, which included requirements for two officers on the bridge and for plotting and position reporting by vessels, contributed to navigation safety.

43. Current monitoring of the amount and size of ice being calved from the Columbia Glacier is inadequate for the safety of tankships transiting Prince William Sound.

44. The EXXON VALDEZ met all U.S. and international segregated-ballast regulations.

45. Current standards for segregated ballast and cargo tank size do not provide sufficient protection against oil spills caused by groundings or collisions.

46. If the EXXON VALDEZ had been fitted with an 11-foot double bottom (based on the 1/15 of the beam criterion), the resulting oil spill would have been small, and possibly eliminated.

47. Double bottoms on all U.S. and foreign tank vessels (tankships and barges) that enter U.S. waters and have a capacity of more than 20,000 deadweight tons would minimize oil pollution in U.S. waters caused by groundings.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the grounding of the EXXON VALDEZ was the failure of the third mate to properly maneuver the vessel because of fatigue and excessive workload; the failure of the master to provide a proper navigation watch because of impairment from alcohol; the failure of Exxon Shipping Company to provide a fit master and a rested and sufficient crew for the EXXON VALDEZ; the lack of an effective Vessel Traffic Service because of inadequate equipment and manning levels, inadequate personnel training, and deficient management oversight; and the lack of effective pilotage services.

RECOMMENDATIONS

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

--to the Exxon Shipping Company and all shipping companies operating in Prince William Sound:

> Eliminate personnel policies, including performance appraisal criteria, that encourage marine employees to work long hours without concern for debilitating fatigue and commensurate reduction in safety of vessel operations. (Class II, Priority Action) (M-90-26)

- Implement manning policies that prevent excessively long working hours for crewmembers during cargo handling operations. (Class II, Priority Action) (M-90-27)

  Institute a written policy forbidding deck officers to share navigation and cargo watch duties on a 6-hours-on, 6-hours-off basis, except in emergencies. (Class II, Priority Action) (M-90-28)

  Require that two licensed watch officers be present to conn and navigate vessels in Prince William Sound. (Class II, Priority Action) (M-90-29)

  Implement an alcohol/drug program for seagoing employees that prevents such personnel from returning to sea until their alcohol/drug dependency problem is under control. (Class II, Priority Action) (M-90-30)

  Train persons who monitor the alcohol/drug rehabilitation program in the recognition of recidivism after treatment, in the utilization of appropriate professional referrals, and in the interpersonal skills necessary for competent rehabilitation supervision. (Class II, Priority Action) (M-90-31)

--to the Coast Guard:

  Develop a means for rigorous enforcement of 46 U.S.C.8104(a) to ensure that officers on watch during departures from ports have had at least 6 hours of off-duty time in the previous 12 hours. (Class II, Priority Action) (M-90-32)

  Expedite the study programs to establish manning levels and safeguards based on human factors, as well as on shipboard hardware and equipment, and incorporate the findings into the manning review process. (Class II, Priority Action) (M-90-33)

  Establish manning standards to ensure that crew complements reflect all expected shipboard operating situations and that procedures are in place for dealing with unusually high workloads at sea, such as tank cleaning, and with cargo handling operations in port. (Class II, Priority Action) (M-90-34)

  Seek authority for access to the National Driver Register and other driving records and make use of the information from these sources to prevent any person with a drug and/or alcohol problem from holding a merchant marine license. (Class II, Priority Action) (M-90-35)

Adopt a permanent policy to plot all vessels participating in the Valdez Vessel Traffic System between the pilot station south of Bligh Reef, or as near the pilot station as possible, and their berths in Port Valdez. (Class II, Priority Action) (M-90-36)

Increase the manning level at the Marine Safety Office, Valdez, Alaska, to provide the following: enough watchstanders to plot all participating vessels between the pilot station south of Bligh Reef and their berths in Port Valdez; an officer-in-charge of the Vessel Traffic System who will have time to manage and supervise the system effectively; and sufficient additional officers to staff a duty officer watch with officers capable of monitoring and supervising vessel traffic watchstanders outside normal working hours. (Class II, Priority Action) (M-90-37)

Install an additional radar site as close to Bligh Reef as feasible to enable the Vessel Traffic Center to accurately monitor and plot all participating vessels and ice in the area of Valdez Arm from Busby Island to the pilot station south of Bligh Reef. (Class II, Priority Action) (M-90-38)

Initiate procedures to collect information on ice conditions in Valdez Arm so that all participating vessels receive accurate and timely ice reports before departing port and so that all supervisory personnel associated with the Valdez Traffic System are cognizant of ice conditions in Valdez Arm. (Class II, Priority Action) (M-90-39)

Improve the communications system operated by the Marine Safety Office in Valdez, Alaska. (Class II, Priority Action) (M-90-40)

Improve the microwave system operated by the Marine Safety Office in Valdez, Alaska. (Class II, Priority Action) (M-90-41)

Limit any proposed reduction in Federal pilotage to that part of Prince William Sound from the entrance outside Cape Hinchinbrook to the current pilot station at latitude 69°49'N, longitude 174° 01'W, which is south of Bligh Reef, thus ensuring that Federal pilots will be required between the entrance to Valdez Arm south of Bligh Reef and the berths in Port Valdez. (Class II, Priority Action) (M-90-42)

Incorporate into the Vessel Traffic Service regulations for all vessels the provisions of former COTP Order 1-80

(except the requirement for daylight transit), including the requirements about vessel condition, crews, navigation equipment, and publications, as well as the requirement that a licensed officer in addition to the licensed officer on watch be available to plot the vessel's position. (Class II, Priority Action) (M-90-43)

--to the Environmental Protection Agency:

Develop guidance in the National Contingency Plan for Regional Response Teams and On-Scene Coordinators about dispersant use. (Class II, Priority Action) (M-90-44)

Develop guidance for Regional Response Teams and On-Scene Coordinators about in-situ burning of oil and include the guidance in the National Contingency Plan. (Class II, Priority Action) (M-90-45)

Develop procedures that would eliminate the need for the On-Scene Coordinator to obtain burn permits from a State after the Regional Response Team has agreed that the spilled oil can be burned in situ. (Class II, Priority Action) (M-90-46)

Develop guidance for Regional Response Teams that enables them to establish the minimum amount of cleanup equipment that must be immediately available to initiate a cleanup response. (Class II, Priority Action) (M-90-47)

--to the Alaska Regional Response Team:

Develop clearer guidance for dispersant use in order to eliminate the need for a dispersant test before dispersants are used on an oil spill and include that information in the Alaska Regional Contingency Plan. (Class II, Priority Action) (M-90-48)

Develop guidelines and procedures for in-situ burning of oil, identify the range of wind and sea conditions for which in-situ burning of oil can be used effectively, and incorporate that information into the Alaska Regional Contingency Plan. (Class II, Priority Action) (M-90-49)

--to the State of Alaska:

Require that the oil spill contingency barge or barges at the Alyeska Pipeline Service Company Terminal at Valdez be loaded at all times with the response equipment specified in the plan. If a barge is unloaded and unavailable for immediate deployment, require that a replacement barge be provided and loaded with the

equipment specified in the plan. (Class II, Priority Action) (M-90-50)

Require that the companies loading oil at the Alyeska Pipeline Service Company Terminal in Valdez provide a plan for assuming cleanup responsibility from Alyeska Pipeline Service Company in the event of a major oil spill or potential major oil spill of more than 100,000 gallons. (Class II, Priority Action) (M-90-51)

Develop and require minimum levels of mechanical oil spill cleanup equipment, fire- or burn-proof boom, air-deployable dispersant system packs, and other dispersant application equipment to be stockpiled and immediately available at the Alyeska Pipeline Service Company's Valdez Terminal. (Class II, Priority Action) (M-90-52)

--to Alyeska Pipeline Service Company:

Provide at its Valdez terminal two or more oil spill contingency barges that are loaded with pollution-response cleanup equipment, lightering equipment, and fire- or burn-proof booms that are maintained and ready for immediate deployment, thus facilitating an effective response to different spill conditions. (Class II, Priority Action) (M-90-53)

Identify the range of wind and sea conditions for which dispersants can be used effectively and incorporate that information into company contingency plans. (Class II, Priority Action) (M-90-54)

In conjunction with each of the companies that load oil at its terminal in Valdez, develop a plan or procedures for relieving Alyeska Pipeline Service Company of primary cleanup responsibility in the event of a major oil spill or potential major oil spill of more than 100,000 gallons and include the procedures in its contingency plan after they have been approved by the State of Alaska. (Class II, Priority Action) (M-90-55)

In its company contingency plans, list also the companies that do not have a plan for relieving Alyeska Pipeline Service Company of cleanup responsibility. (Class II, Priority Action) (M-90-56)

Store air-deployable dispersant system packs and other dispersant application equipment at its Valdez Terminal, as agreed upon with the State of Alaska, for use with fixed wing aircraft, or helicopters, or vessels. (Class II, Priority Action) (M-90-57)

Store fire- or burn-proof booms at its Valdez Terminal, as agreed upon with the State of Alaska, and include procedures for their use in the company's oil spill contingency plan. (Class II, Priority Action) (M-90-58)

--to the US Geological Survey:

Intensify efforts to monitor the state of the Columbia Glacier, particularly to identify the amount of ice calving from the glacier and any changes in the rate that might affect the number and size of icebergs emanating from the glacier, and make this information available to agencies, such as the U.S. Coast Guard, tasked with assuring the safety of shipping into and out of Valdez Harbor. (Class II, Priority Action) (M-90-59)

Also, the Safety Board reiterated the following safety recommendations:

--to the Department of Transportation:

I-89-1

Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety.

I-89-2

Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest.

I-89-3

Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues.

I-89-4

Develop postaccident and postincident testing regulations that are separate from the pre-employment, random, and reasonable suspicion testing regulations in all modal agencies.

I-89-5

Adopt uniform regulations for all drug and alcohol testing, other than postaccident and postincident testing, in all transportation modes, including U.S. Department of Transportation employees who are in safety sensitive positions.

Adopt uniform regulations on postaccident and postincident testing of private sector employees for alcohol and drugs in all transportation modes. Use the Federal Railroad Administration's (FRA) current regulation as a model regulation for all transportation modes except for the permissible blood alcohol level of less than 0.04 percent. Using the FRA regulation as a model for other transportation modes refers only to the collection of blood and urine and the screening and confirmation of positives in blood. As a minimum, the drugs identified in FRA screen should be used in the other modes. Reference to the FRA model does not refer to the administration or implementation of the regulation. The Safety Board recognizes that the implementation of the regulation may be different in the various transportation modes. The regulations for all modes should provide:

I-89-6

- for the collection of blood and urine within 4 hours following a qualifying incident or accident. When collection within 4 hours is not accomplished, blood and urine specimens should be collected as soon as possible and an explanation for such delay shall be submitted in writing to the administrator.

I-89-7

- testing requirements that include alcohol and drugs beyond the five drugs or classes specified in the Department of Health and Human Services (DHHS) guidelines and that are not limited to the cutoff thresholds specified in the DHHS guidelines. Provisions should be made to test for illicit and licit drugs as information becomes available during an accident investigation.

Adopt uniform regulations in postaccident and postincident testing of U.S. Department of Transportation employees in safety sensitive positions. The regulations should provide:

I-89-8

- for the collection of blood and urine within 4 hours following a qualifying incident or accident. When collection within 4 hours is not accomplished, blood and urine should be collected as soon as possible and an explanation for such delay shall be submitted in writing to the administrator by the local official making the decision to test.

I-89-9

- testing requirements that include alcohol and drugs beyond the five drugs or classes specified in the Department of Health and Human Services (DHHS) guidelines and that are not limited to the cutoff thresholds specified in the DHHS guidelines. Provisions should be made to test for illicit and licit drugs as information becomes available during an accident investigation.

I-89-10

- that toxicological results from Federal employees be made available to investigators of the National Transportation Safety Board.

I-89-11

- procedures by which Federal employees are sent to the nearest hospital or medical facility for obtaining blood and urine specimens for toxicological testing following a qualifying incident or accident.

Issue rules specifying zero (no alcohol) as the blood alcohol concentration for private sector employees in safety sensitive positions in all transportation modes and for Federal employees in safety sensitive positions. (Class II, Priority Action) (I-89-12)

--to the U.S. Coast Guard:

Seek legislation to require all pilots of commercial vessels on the navigable waters of the United States to have a Federal pilot's license which would be legally superior to all State-issued documents, licenses or commissions that a State may continue to employ to accredit those pilots that it desires to pilot vessels engaged in foreign commerce. (Class II, Priority Action) (M-88-1)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ James L Kolstad
Chairman

/s/ Susan Coughlin
Vice Chairman

/s/ John K. Lauber
Member

/s/ Jim Burnett
Member

July 31, 1990

JIM BURNETT, Member, filed the following concurring and dissenting statement:

> I concur with the probable cause as adopted but would have added that "contributing to the severity of the environmental damage was: (1) the lack of a double bottom on the EXXON VALDEZ and (2) the failure to initiate early in-situ burning of released crude oil due to lack of an appropriate boom." I would also favor the adoption of a recommendation to require that all U.S. tank vessels over 20,000 deadweight tons, and foreign-flag tank vessels entering U.S. waters over 20,000 deadweight tons, have double hulls.

APPENDIXES

APPENDIX A

INVESTIGATION HEARING

Investigation

The National Transportation Safety Board was informed by the Coast Guard of the accident on March 24, 1989. Three marine accident investigators and one human performance specialist were dispatched to Valdez, Alaska, to commence the field phase of the investigation. Subsequently, the Chief of the Safety Board's Marine Accident Division and an additional human performance specialist were dispatched to augment the investigation. The first four investigators boarded the vessel on March 26 to inspect the vessel's condition with particular emphasis given to the navigation equipment and the instrumentation on the vessel's bridge.

Eight members of the EXXON VALDEZ crew were interviewed during the next 2 days. They included four personnel performing lookout and steering duties immediately prior to and during the grounding, two of the three deck officers, the chief engineer, and the radio electronics officer. The master and third officer met with Safety Board investigators, but on advice of their attorneys, refused to discuss the vessel's movements or any events pertaining to the grounding. Previously these two officers were interviewed by a Coast Guard investigating officer who boarded the vessel a few hours after the grounding. These interview statements were provided to the Safety Board and are a part of the record. The State pilot who conned the vessel out of Valdez was also interviewed.

More than 30 documents and operating records from the vessel were obtained. Of particular importance were the charts that were used by the vessel, deck logs, the depth sounder printout, the course recorder printout, and the engineroom automatic bell logger printout that lists the time of speed changes.

The on-scene investigation also focused upon the operation and effectiveness of the Coast Guard Vessel Traffic System (VTS) for Valdez and Prince William Sound. Eleven personnel attached to the U.S. Coast Guard Marine Safety Office, which operates the Vessel Traffic Center, were interviewed. They included the Commanding Officer and Executive Officer of the Marine Safety Office, Valdez, Alaska and two Vessel Traffic Center watchstanders who were on duty during the departure of the EXXON VALDEZ.

In order to ascertain the effective range and reliability of VTS radar, the Safety Board requested that the Coast Guard plot and keep records of all outbound tank vessels for 30 days. To further determine the effectiveness of the radar, the Coast Guard project officer in charge of the radar replacement program during 1984-85 was also interviewed. A computer analysis of the effective merits of the new radar and the old radar was conducted by the Coast Guard at the request of the Safety Board. This analysis revealed that

the present VTS radar has a range comparable to the previous VTS radar that was replaced in 1984.

Toxicology samples taken by the Coast Guard from the master of the EXXON VALDEZ were analyzed by a private laboratory. The analysis revealed that the master of the EXXON VALDEZ had a level of alcohol in his blood of .06 percent, which exceeded the permissible limit.

The director of operations for the Alyeska Marine Terminal was interviewed to obtain a description of the initial response to the emergency.

Public Hearing

The Safety Board convened a 5-day public hearing on May 16, 1989, at Anchorage, Alaska, as part of the investigation. The investigation considered the following: (1) the grounding; (2) the role of the U.S. Coast Guard VTS at Valdez, Alaska; (3) Coast Guard and Exxon Shipping Company practices for determining manning levels on oceangoing ships; (4) alcohol and drug testing programs; and (5) the response to the oil spill during the first 24 hours. Parties at the public hearing included the Coast Guard, the State of Alaska, the Exxon Shipping Company, and the Alyeska Pipeline Service Company. Testimony was taken from 27 witnesses, and 115 exhibits were accepted into the record.

Deposition Hearing

Depositions were taken from two officers of the Exxon Seamen's Union in Baton Rouge, Louisiana, on June 1, 1989.

APPENDIX B

PERSONNEL INFORMATION

Master

Captain Joseph J. Hazelwood, 42, of Huntington, New York, had been one of two permanently assigned masters on the EXXON VALDEZ since 1987. He first sailed as master on Exxon Shipping Company vessels in 1979, and he had about 10 years experience in the Alaskan oil trade. He graduated from the State University of New York Maritime College in May 1968, earning a degree in marine tansportation and a third mate's license. He was employed as a third mate in June 1968 by Humble Oil Company, later Exxon Shipping Company, and had served continuously on Humble/Exxon vessels until the accident.

Third Mate

Mr. Gregory T. Cousins, 39, began sailing as an ordinary seaman on National Oceanic and Atmospheric Administration (NOAA) vessels about 1977. In 1980, he obtained employment with Exxon Shipping Company as an able seaman (AB) and served as AB on several Exxon vessels. He participated in a Page Navigation School course part-time to prepare for the third mate's examination. He acquired a third mate's license in March 1986. Since January 1987, he has served as third mate on five Exxon vessels, with no break in service longer than 3 1/2 months. He stated that he had made six trips in and out of Port Valdez, Alaska, with Captain Hazelwood on the EXXON VALDEZ and one prior trip to Valdez with the alternate master of the vessel. He had rejoined the vessel on February 20, 1989. He had upgraded his license to second mate in January 1989.

AB Helmsman

Mr. Robert M. Kagan, 46, obtained a merchant mariner's document in 1965. Between 1965 and 1970, he acquired 25 days of documented marine work, all in the steward's department. He began working for Exxon Shipping Company in 1975. His assignments aboard Exxon vessels were in the steward's department, as a wiper in the engineroom, and as an ordinary seaman in the deck department. In 1981, he obtained an AB document; however, most of his subsequent assignments were as an ordinary seaman. On January 18, 1989, he was assigned to the EXXON VALDEZ as an AB.

AB Lookout

Ms. Maureen L. Jones, 24, graduated from the Maine Maritime Academy in April 1987, earning a Bachelor of Science degree and a third mate's license. In September 1987, she obtained employment with Exxon Shipping Company as an AB and had served on four Exxon vessels. She also had served temporarily for 1 month as a third mate. She had reported on board the EXXON VALDEZ on February 5, 1989.

APPENDIX C

PERFORMANCE APPRAISALS OF THE MASTER

Performance evaluation records provided by Exxon Shipping Company are not continuous over the master's employment period from June 1968 to March 1989. Information excerpted from his performance evaluations is provided in the table below:

DATE	EVALUATOR	POSITION	EVALUATION COMMENTS
8/73	Master EX. BALT.	2d Mate	Above average, would not accept him in next higher rank.
2/74	Master EX. CHESTER	2d Mate	Capable officer.
12/74	Master EX. SAN FRAN.	2d Mate	Stands good watch, negative attitude, must be ordered to keep logs and then checked, misinforms on navigational data. I would not want him on the ship as chief mate. His system of not insisting on good work from his watch while serving as 2d mate will cause him trouble getting things done well when he is chief mate, if he continued the same crew approach. Rating: 2-high, considerably above average.
10/75	Master EXXON BALT.	Chief Mate	Good sound training, occasional flare of temper.
1/76	Master EX. BALT.	Chief Mate	Handles everything on deck in a seamanlike manner, does do slow burn but keeps it to himself (good way to develop an ulcer).
8/76	Master EX. WASH.	Chief Mate	Constantly reading to upgrade his license, should be given shore side job for a short period.
9/76	Master EX. WASH.	Chief Mate	Good cargo mate, needs to improve in housekeeping, weak point is does only minimum required.
1/77	Master EX. SAN FRAN.	Chief Mate	Ambitious and capable.

DATE	EVALUATOR	POSITION	EVALUATION COMMENTS
10/78 12/78	Master	Chief Mate	Maintains a high level of cooperation, plans loading and discharge.
No Date	(unsigned)	Chief Mate	Done excellent job, good chief mate, needs more experience, and tends to do too much himself.
12/78 1/79	(unsigned)	Chief Mate	Knows ship, good cargo mate, lack of patience with personnel in certain situations.
3/80- 3/81	Shoreside Supervisor	Master	Well trained, highly motivated good judgement, poor communicator, needs to mature and grow in managing assets and resources, overcome being one of the boys, progress limited to current level, has not taken action to control costs.
82-83	(unsigned)	Master	Very good ship handler, makes good judgement, weak in administration, needs counseling to improve effort, lacks initiative and effort, suggest shore assignment, needs improvement in dependability, recommend shore assignment.
6/83- 6/84	(unsigned)	Master	Does not try to achieve potential, excellent technically, decision-making ability, suggest shore assignment.
Present -4/8	Master	Master	Excellent technical, decisionmaking ability, good judgement, lacks initiative to develop full potential, needs to take more objective view when evaluating subordinates.

APPENDIX D

EXXON SAFETY INFORMATION

HISTORIC IMPACT OF REDUCED MANNING UPON PERSONNEL SAFETY AND OIL SPILL PERFORMANCE

From 1974 through 1988, Exxon's U.S. flag fleet has varied from a total of 17 to 20 ocean tankers. During this 15-year period, 7 older non-automated vessels were retired while 10 new automated vessels were added to the fleet. The older vessels were manned by crews of approximately 30 while the automated replacement vessels were manned by crews of 20 to 24. The current range is 18 to 24 as a result of further demanning in unlicensed and radio officer positions. Thus during this 15-year period, the average manning per vessel declined from 30 to 20.

Over this same period, the rates of personnel injuries per million workhours has declined from 14.5 to 5.5 This represents a 62% reduction in the personnel injury ratio.

Over this same period, the ratio of oil spills per vessel per year has also declined from 0.8 to 0.4. This represents a 50% reduction in the oil spill ratio.

From this data, it is clear that lower vessel complements have not resulted in a reduction in personnel safety or environmental conservation. On the contrary, the normalized ratios show a very pronounced improvement in both categories during a 15-year period when average crew size was reduced from 30 to 20.

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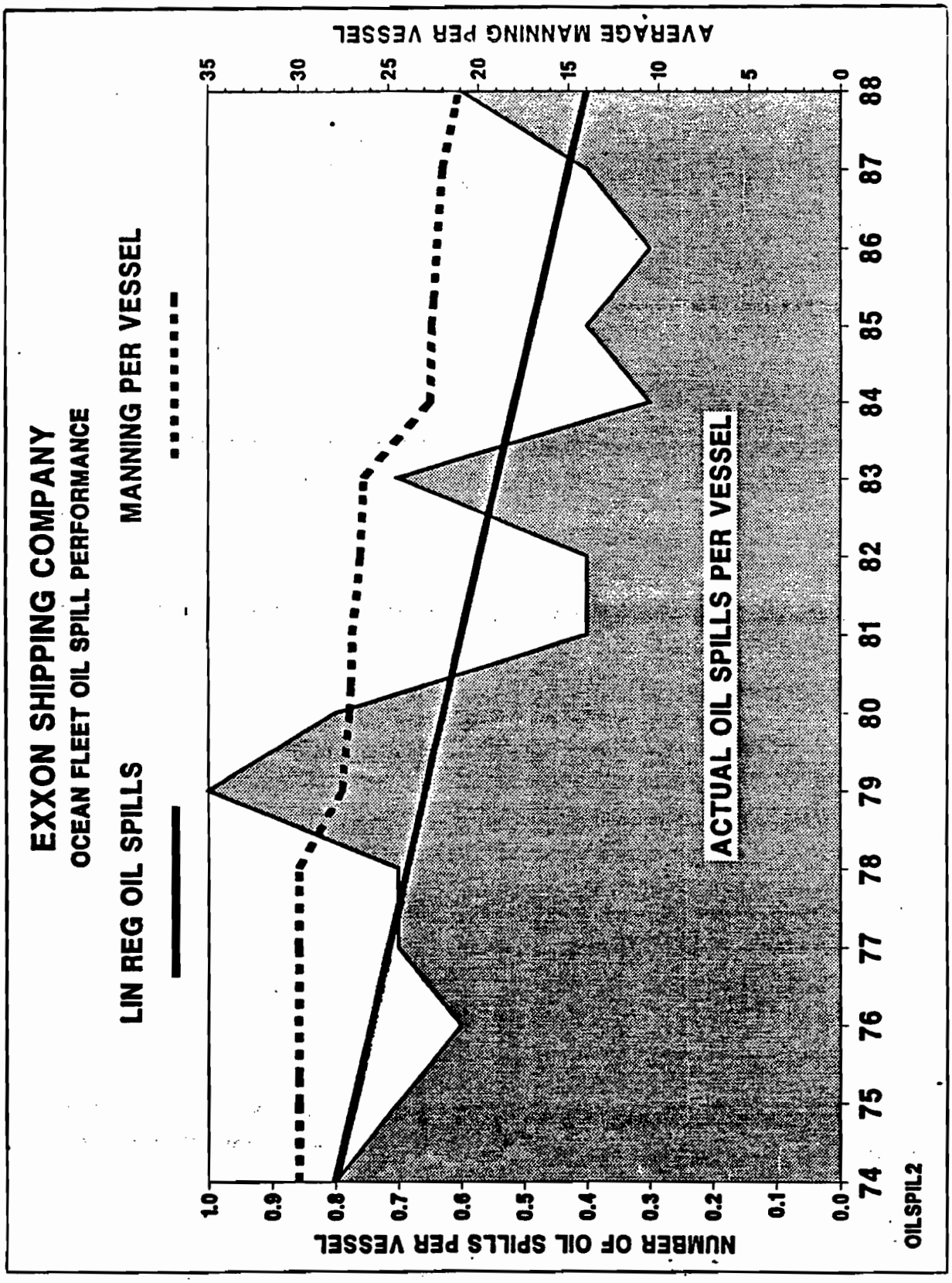
EXXON SHIPPING COMPANY
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LIN REG OIL SPILLS
MANNING PER VESSEL
ACTUAL OIL SPILLS PER VESSEL
NUMBER OF OIL SPILLS PER VESSEL
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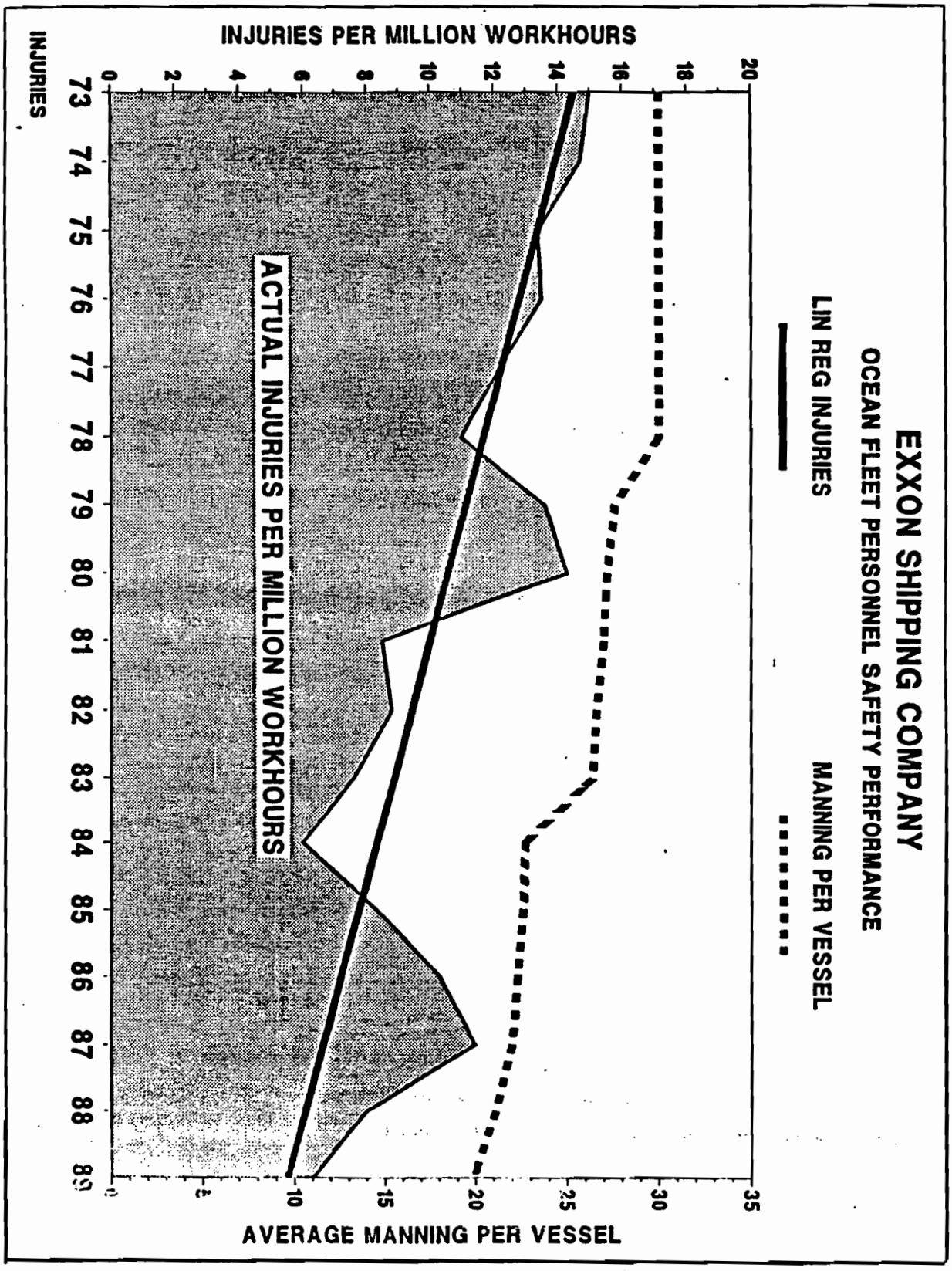
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73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89
10 15 20 25 30 35

OCEAN FLEET

PERSONNEL SAFETY PERFORMANCE

1973 - 1989 (MAY)

- Safety performance does not decline when the size of the crew is reduced; rather, our experience indicates that the rate of injury decreases when crew size is reduced.

- The indicated crew size, referred to in the attached graph, represents the average prevailing vessel complement (rounded to the nearest whole number).

- In 1988, with an average vessel complement which was 30% smaller than in 1973, there were 55.7% fewer reportable incidents (31 vs. 70), and the frequency of incidents per million workhours was 48% lower (7.8 vs 15.0). In fact, if a comparison is made between performance prior to 1982, and recent performance, it is clear that the frequency of injuries has been reduced by more than 35%, despite fewer people working on board each vessel.

- It is our conclusion that, when addressing improved safety performance, management focus, leadership and effective supervision are more critical elements than crew size. The data also support this conclusion. At the end of 1986, we responded to a two year trend in declining personnel safety performance and we refined certain elements of our safety program. A "Safety Intitiative", which focussed on supervisory practices and emphasized the concept of "Take Time For Safety", was implemented. As part of this effort, management teams, frequently accompanied by officials of the unlicensed union, visited every ship in the fleet to train personnel in new safety concepts. This was supplemented by one full day of safety training provided to all senior officers during each of the next two annual fleet management conferences (1987 and 1988). A joint management and labor Health and Safety Education Advisory Committee was also established. The results of this reintensified safety focus can be seen in the improved safety performance during 1988, and so far in 1989. Articles describing Exxon Shipping Company's recent safety initiatives have been attached.

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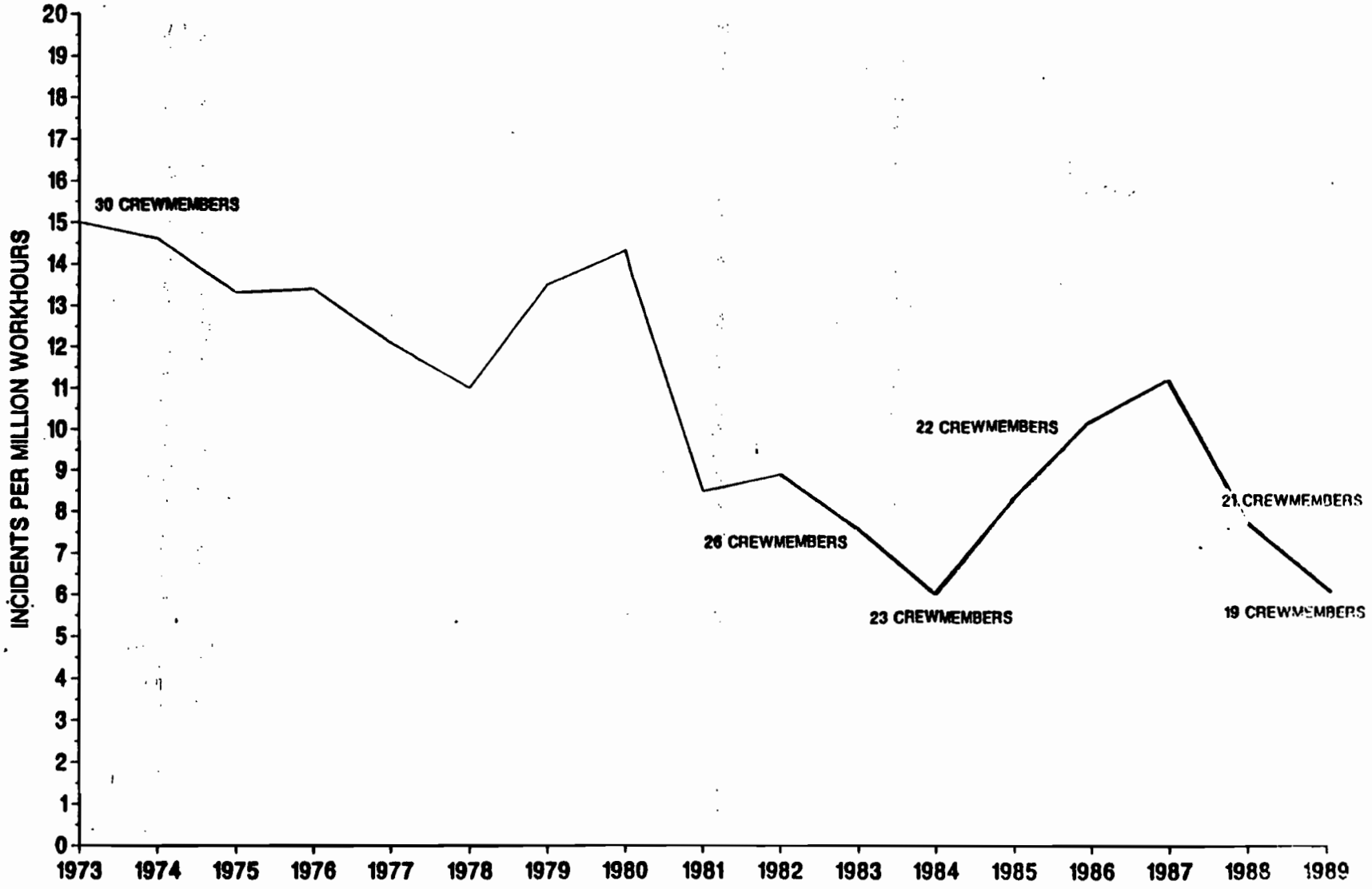
EXXON
EXHIBIT
NO. 4

EXXON SHIPPING COMPANY

OCEAN FLEET PERSONNEL SAFETY PERFORMANCE

1973 - 1989 (MAY)



APPENDIX E

HISTORY OF THE EFFECTS OF GLACIAL ICE ON VESSEL OPERATIONS

In 1975, a U.S. Coast Guard Marine Safety Detachment (MSD) existed in Valdez, Alaska. On September 1, 1975, the Coast Guard, in a message from the Commanding Officer, MSD Valdez, to the Commander, Seventeenth District, reported:

> Tug POLAR MERCHANT reports sighting of numerous icebergs in vicinity of shipping lanes west of Bligh Reef during transit approx 0500 local. Approx location 60°-51'N and 146°-55'W.
>
> Vessel had been alerted of their presence by another tug. Bergs acquired by radar and would have been interpreted as a fishing fleet if not for warning and final sighting.
>
> Several (icebergs) reported as large as own 115-foot vessel.
>
> Recommend info be passed to M Division as this is first report of ice in future VTS system.

Shortly thereafter, the Commander, Seventeenth District, issued a Broadcast Notice to Mariners (NR510) that stated:

> Reports of numerous icebergs in vicinity of shipping lanes west of Bligh Reef approx location 60°-51'N, 146°-55'W. Mariners are urged to exercise caution when transiting the area.

On September 3, 1975, MSD Valdez was directed by the Commander, Seventeenth District, to investigate and obtain photos. On September 4, a charter flight confirmed the existence of scattered icebergs (ranging from 20 to 40 feet across and 5 to 10 feet high) from Point Freemantle to Goose Island. Over the years, reports of icebergs extending from Point Freemantle across the traffic lanes to Bligh Reef have continued.

About the time that the Trans-Alaskan Pipeline was completed and placed into operation during 1977, MSD Valdez was upgraded to a Marine Safety Office (MSO). With the upgrade, the unit assumed many additional responsibilities, including officer-in-charge, marine inspection, and Vessel Traffice System (VTS) responsibilities.

In a December 1, 1981, letter to the Coast Guard Commandant (via the Commander, Seventeenth District), the Commanding Officer, MSO Valdez, expressed his concern about the existence of ice in Prince William Sound; he stated:

Increased concern should be directed toward the potential iceberg threat now being posed by the current irreversible retreat of the Columbia Glacier.

The period July-October 1981 saw the largest concentration of ice enter the VTS Traffic lanes at Valdez Arm since this traffic service began during July of 1977. A total of 634 tank vessel transits of Valdez Arm were monitored during the above period, with 72 reporting sizable ice near the traffic lanes, 12 reducing speed due to ice, and 18 departing the lanes to avoid the ice.

Two oil companies Exxon and Mobil, limited their tank vessels to daylight transit of the Valdez Arm, and one company, Sohio, placed a 6 knot speed limit on their tank vessel transits.

With the current U.S. Geological Survey predictions for continued increases in the calfing [calving] of Columbia Glacier over the next 10-30 years, placement of a radar site on either Glacier Island or Bligh Island could prove to be an invaluable tool during the iceberg season June-November. Further, this radar could assist Vessel Traffic Control during the adverse weather extremes experienced during the months November-May.

Though the individual size and concentration of the calfing ice has not forced a temporary closing of the Valdez Arm area to shipping, indications are that this could be a very real future possibility. Looking toward expanded radar coverage in this area is strongly recommended, and should be in the next phase of any planned future development of the Prince William Sound Vessel Traffic Service.

On July 23, 1984, at 2245, the inbound tankship EXXON PHILADELPHIA provided an ice report to the VTC that stated that both traffic lanes were congested and recommended that vessels proceed through the area only during daylight hours. The VTC forwarded the ice report and recommendation to the tankship ARCO ANCHORAGE and the tankship GLACIER BAY, which were berthed at the Alyeska Marine Terminal. Early on the morning of July 24, the GLACIER BAY departed the Alyeska Marine Terminal for sea. At 0400, the GLACIER BAY reported to the VTC that ice extended to within 0.5 nmi of the Bligh Reef buoy and that the vessel was forced to navigate within 500 yards (less than two shiplengths) of the buoy in order to avoid the ice.

On July 24, 1984, MSO Valdez received reports that ice extended across the traffic lanes in the Valdez Arm. The ice reportedly covered more than 20 nmi and obstructed vessel traffic through the lanes. As a result, tankships were reportedly diverting from the traffic lanes and navigating

within 500 yards of Bligh Reef buoy in order to remain clear of the ice. MSO Valdez issued the following Broadcast Notice to Mariners (August 7, 1984):

> Large concentrations of ice ranging from brash ice to icebergs have been reported between Point Freemantle and Bligh Reef. Ice is not always detected by radar and daylight transit is recommended.
>
> Conditions change rapidly and all mariners are advised to exercise caution when transiting the area

A copy of this Notice to Mariners was provided to Coast Guard Headquarters via the Commander, Seventeenth Coast Guard District.

Between July 23 and July 29, 1984, the Coast Guard reported 28 tankship transits. Ice reports were received from 22 of the 28 tankships. Coast Guard records indicate that 16 of the 28 tankships had to depart from the TSS because of the ice in the traffic lanes. Three vessels reportedly were able to maneuver around the ice without leaving the traffic lanes and the transits of three other tankships were unaffected by ice. In addition, several vessels slowed while transiting the area and several masters delayed their departures based on ice reports relayed by the VTC.

Coast Guard documents indicate that between July 23 and August 9, 1984, MSO Valdez received ice reports from 83 tankships. The Coast Guard reported that 39 of the 83 were forced to depart from the TSS because of ice in the lanes.

On August 8, 1984, MSO Valdez issued a Situation Report (SITREP One) to the Commander, Seventeenth District, which stated:

> The Columbia Glacier appears to be in the initial stages of its predicted drastic retreat. During the period 30 July - 07 August 1984 an unusually large number of icebergs, ranging from small brash ice to large bergs, have drifted from Columbia Bay and into the Valdez Arm across the traffic lanes.
>
> During this period, 18 tankship transits required diverting from the traffic scheme (TSS) and/or reducing speed due to ice conditions.
>
> * * *
>
> The vessel traffic center continues to receive ice reports as to location and size from vessels in the traffic system and passes this information to other vessels in the traffic system and passes this information to other vessels prior to their arrival into the ice area. The VTC is also actively seeking ice reports from

vessels previously not used for ice reporting (i.e., local tour boats).

Daily overflights in conjuction with Coast Guard Auxiliary sunset patrols to determine the ice limits and concentration.

* * *

Under normal weather conditions the pattern of ice flow appears to remain westward between Glacier Island and Columbia Bay. During deviations from the normal weather pattern, transits of all vessels have still been possible.

Vessels have opted on their own to reduce speed or make daylight transits without the Coast Guard having to impose any restrictions. This prudent approach will continue and keep things orderly unless the lanes become impassable or until we get to the point of only a few hours of daylight. At that time, we will have to be more direct in our advice and control.

In order to maintain control over the situation, the Commanding Officer, MSO Valdez, made the following recommendations:

(1) Continue to provide ice reports from the VTC. Ice conditions can rapidly change and report more than a few hours old may be worthless;

(2) Continue overflights as conditions and CG AUX. resources permit;

(3) Utilize CG resources (32 PWSB, CG A/C, CG AUX) to fill-in any significant gaps in the ice reports and/or to gather additional information;

(4) Continue to recommend tank vessels make daylight transits of the ice area during heavy ice concentrations; and,

(5) Schedule a meeting with principal participants to discuss contingencies/options if lack of daylight or ice conditions become a factor.

Reports of ice in the traffic lanes continued throughout August 1984. According to the Coast Guard, on August 12, 1984, large concentrations of ice extended across the Valdez Arm from Point Freemantle to a point 2 nmi north of Bligh Reef and south from Bull Head to Bligh Reef.

A meeting between the Coast Guard and members of the local maritime community (i.e., local oil company officials, ship masters, State pilots, shipping company executives, U.S. Geological Survey personnel, etc.) was scheduled for August 22, 1984. The purpose of the meeting was to gather views and proposals from interested members of the local maritime community and to discuss how the presence of large quantities of ice in the traffic lanes would affect shipping into Port Valdez, particularly since winter was approaching and daylight hours would be fewer. The Coast Guard was concerned that with fewer daylight transits, the number and quality of ice reports would diminish. The conference was held at the MSO on August 22, 1984.

In a letter to the District Commander, Seventeenth District, the Commanding Officer, MSO Valdez, expressed his surprise that so many people who were not from Valdez attended the meeting. Representatives from Valdez Maritime Services (vessel agent), Alaska Maritime (vessel agent), U.S. Geological Survey, Standard Oil (SOHIO), Exxon Shipping, Mobil, ARCO, Alyeska Marine Terminal, and Southwest Alaska Pilots Association attended the conference.

The major concern of all parties was the continued safe and efficient movement of vessel traffic to and from Port Valdez. Issues discussed included: (1) the continuing retreat of the Columbia Glacier; (2) the timeliness and accuracy of ice information; (3) the degree of Coast Guard control over shipping in Prince William Sound (particularly Port Valdez); (4) the ability of masters to take appropriate precautions; (5) the ability of the Alyeska Marine Terminal to handle throughput if the port was closed because of ice; and (6) possible solutions and recommendations.

During the conference, a representative of the U.S. Geological Survey presented his findings on the activity of the Columbia Glacier. According the Coast Guard account of the meeting, he stated:

> Columbia Glacier is destroying itself as it advances 10-11 meters (about 33 feet) a day and calves ice from the face at a rate of 16 meters (about 53 feet) a day, a net retreat of 5 meters a day. This translates into 10,000,000 tons of ice per day, and this figure is expected to increase along with the predicted increase in rate of retreat over the coming years.

According to the Coast Guard, a general consensus emerged from the discussions with the conferees that the timeliness and accuracy of ice information available to the mariner by the VTC was one of the weak links in the VTS. The Coast Guard expressed concern that the quality of ice information provided to the mariner was entirely dependent on the quality of ice information received by the VTC. According to the Coast Guard:

> Gaps in time between transits, darkness, and low visibility decrease the chances of current ice sightings. Any ice information over four hours old is of little practical use to the mariner.

The Coast Guard also discussed with industry ways to provide the mariner with more accurate ice information. Some suggestions put forward included: (1) additional radar; (2) a video system to monitor the ice area; and (3) the installation of a manned observation platform.

The Exxon shipping representative stated that he believed that the safety record and safety precautions of the masters could be relied on and that he did not foresee that the ice would cause problems for shipping; he said that he preferred to see things continue as before. The ARCO representative and the representative from the Southwest Alaska Pilots Association agreed with Exxon.

At the conclusion of the conference, the Coast Guard and industry generally agreed that tankship operations would continue as before. According to a letter from the Commanding Officer, MSO Valdez, to the Commander, Seventeenth Coast Guard District:

> Because there has not been any case where ice has prevented a vessel transit, the Coast Guard has no plans to commit additional resources.
>
> The goal of the Coast Guard is to work past the critical stage of the glacier recession without imposing additional regulations on the traffic system. It is hoping for flexibility and cooperation from the Alyeska Terminal and operators to work out solutions as situations develop.

As a result of the meeting, the Coast Guard implemented the following policies for vessels transiting the VTS area:

(1) Ice reports will be requested from 100 percent of the vessels transiting the area;

(2) Vessels will be allowed to divert out of the lanes to transit around ice plumes;

(3) If the situation develops, the lanes will be considered closed to a specific vessel if the master of that vessel feels a transit of the ice field is unsafe; and

(4) The Coast Guard will continue to provide the best information available to vessels transiting the system and then let the master make his own decisions.

On August 27, 1984, MSO Valdez issued a Situation Report (SITREP Four) to the Commander, Seventeenth District, which stated that between August 20 and 26, 28 tankships transited the area and 4 (14.28 percent) had to deviate from the TSS because of ice in the traffic lanes.

During September 1984, the Coast Guard reported that 30 percent of all tankship transits (133 tankships transited the area during the period) through the Valdez Arm were affected by the presence of ice in the lanes. The Coast Guard stated that of the 39 tankships affected by ice, 33 were forced to deviate from the TSS and 6 were forced to reduce speed but were able to remain in the lanes. The following data were collected by the Coast Guard during this period:

DATES	# OF T/V AFFECTED	TOTAL TRANSITS
1-9 September	19 (56%)	34
10-12 September	(0%)	16
13 September	3 (75%)	4
14-20 September	(0%)	33
21-23 September	10 (71%)	14
24-26 September	(10%)	10
27 September	7 (88%)	8
28-30 September	(0%)	14
	39	133

During October 1984, the Coast Guard reported that 29 percent of the 159 tankship transits through the Valdez Arm were affected by the presence of ice in the lanes. This report, unlike the one for September, did not state how many vessels affected by ice were forced to deviate from the lanes. According to the October ice report:

> There were no delayed arrivals or departures reported or required due to ice concentrations. The number of days that ice was present and the percentage of vessels affected during October was very close to that of September. These statistics indicate that there have not been recent increases or decreases in the amount of ice being generated by the glacier [referring to the Columbia Glacier] or released from the moraine.
>
> The recession of the glacier has not been producing drastic changes to operating conditions in the Valdez Arm. Unless there are major changes or problems, or a specific notable event, this monthly report will be published quarterly. The next scheduled report will be forwarded around the first of January, 1985.

The Coast Guard collected the following data:

DATES	NUMBER OF T/V AFFECTED	TOTAL TRANSITS
1-9 October 1984	1 (2%)	44
10-20 October 1984	38 (61%)	62
21-29 October 1984	2 (5%)	41
30-31 October 1984	5 (42%)	12
	46	159

According to the quarterly ice report, the Columbia Glacier continued to produce large quantities of ice and the effect of the ice on traffic remained relatively constant when compared to monthly data for the previous 6 months. In addition, the report stated that when ice was present in the lanes, vessels usually diverted out of the traffic lanes or slowed their speed and maneuvered around the ice. The report also stated that diverting traffic from the lanes had not created any problems or safety hazards and that permission for vessels to divert from the lanes was usually given by the VTC. The following data were collected by the Coast Guard:

DATES 1984		NUMBER OF T/V AFFECTED		TOTAL TRANSITS
1-11	November	26	(50%)	52
12-14	November	0		12
15-21	November	7	(16%)	45
22-29	November	0		41
30	November	2	(40%)	5
1-7	December	7	(14%)	50
9-17	December	0		49
18-28	December	32	(56%)	57
29-31	December	0		10
		74		321

During January, February, and March 1985, the Coast Guard issued a quarterly ice report which stated that 7 percent of the 470 tankship transits through the Valdez Arm were affected by the presence of ice in the lanes. The Coast Guard report did not state how many of the 34 tankships, if any, were forced to deviate from the TSS because of ice in the traffic lanes. The following data were collected by the Coast Guard during 1985:

DATES	NUMBER OF T/V AFFECTED		TOTAL TRANSITS
January	6	(3%)	172
February	12	(9%)	138
March	16	(10%)	160
	34		470

APPENDIX F

METEOROLOGICAL INFORMATION

Surface observations.--The following are the surface observations from Valdez from 2100 on March 23 through 1200 on March 24 at 3- hour intervals:

> Time--2051; clouds--300 feet scattered, ceiling estimated 1,500 feet overcast; visibility--4 miles; weather--light snow and fog; barometric pressure--1010.7 millibars; temperature--33°F; dew point--32°F; wind--calm.
>
> Time--2350; clouds--300 feet scattered, ceiling estimated 1,500 feet overcast; visibility--3 miles; weather--light snow and fog; barometric pressure--1010.3 millibars; temperature--33°F; dew point--32°F; wind--calm.
>
> Time--0250; clouds--partial obscuration, estimated 400 feet broken, 1,500 feet overcast; visibility--1 mile; weather--fog; barometric pressure--1009.1 millibars; temperature--33°F; dew point--32°F; wind--calm.
>
> Time--0555; clouds--300 feet scattered, 1,500 feet scattered, ceiling estimated 5,000 feet overcast; visibility--6 miles; weather--fog; barometric pressure--1007.8 millibars; temperature--33°F; dew point--32°F; wind--calm.
>
> Time--0852; clouds--500 feet scattered, ceiling estimated 8,000 feet overcast; visibility--15 miles; weather--none; barometric pressure--1007.1 millibars; temperature--35°F; dew point--33°F; wind--calm.
>
> Time--1150; clouds--ceiling estimated 8,000 feet overcast; visibility--15 miles; weather--none; barometric pressure--1006.8 millibars; temperature--38°F; dew point--32°F; wind--130 degrees 3 knots.

Climatological information.--Figure 1 shows the climatological means and extremes for Valdez as recorded in Local Climatological Data, Annual Summary, 1988, published by the National Climatic Data Center of the National Oceanic and Atmospheric Administration.

Tide and current information.--The following are the tides at Rocky Point (60°57'N, 148°46'W) 028°, 6.3 miles from the accident site, as computed from the Tide Tables, West Coast of North and South America, published by the U.S. Department of Commerce:

NORMALS, MEANS, AND EXTREMES

VALDEZ, ALASKA

LATITUDE: 61°08'N LONGITUDE: 146°21' W ELEVATION: FT. GRND 37 BARO 52 TIME ZONE: YUKON WBAN: 26442

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		29.3	30.0	36.2	43.9	51.1	57.5	62.1	61.5	54.1	43.2	33.8	25.1	44.0
-Daily Minimum		20.9	19.4	24.1	31.4	38.2	44.5	47.8	46.6	41.3	34.5	25.5	16.8	32.6
-Monthly		25.1	24.7	30.2	37.7	44.7	51.0	55.0	54.1	47.7	38.9	29.7	21.0	38.3
Extremes														
-Record Highest	17	46	51	51	61	73	74	85	81	73	56	50	52	85
-Year		1980	1982	1974	1983	1982	1986	1979	1977	1979	1986	1977	1983	JUL 1979
-Record Lowest	17	-20	-3	-6	5	21	31	33	32	25	8	5	-6	-20
-Year		1972	1972	1972	1972	1972	1972	1972	1984	1983	1975	1982	1980	JAN 1972
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1237	1128	1079	819	629	420	310	338	519	809	1059	1364	9711
Cooling (base 65°F)		0	0	0	0	0	0	0	0	0	0	0	0	0
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	9	7.8	7.4	7.3	7.7	8.2	8.4	8.4	7.5	7.8	8.2	7.4	8.0	7.8
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	9	5.1	6.1	7.0	4.9	3.3	2.0	2.6	5.7	4.4	4.4	5.7	5.3	56.6
-Partly Cloudy	9	3.2	2.2	3.2	4.2	4.4	5.0	4.6	5.0	5.1	2.4	3.8	1.7	44.9
-Cloudy	9	22.7	20.0	20.8	20.9	23.2	23.0	23.9	20.3	20.4	24.1	20.6	24.0	263.9
Precipitation .01 inches or more	16	16.6	14.3	16.0	14.1	15.7	15.4	16.9	17.3	19.4	20.1	14.9	17.3	197.8
Snow, Ice pellets 1.0 inches or more	16	9.6	8.9	10.1	5.1	0.3	0.0	0.0	0.0	0.0	2.8	8.2	11.8	56.8
Thunderstorms	11	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.0	0.0	0.5
Heavy Fog Visibility 1/4 mile or less	11	1.0	1.5	0.6	0.2	0.0	0.1	3.5	4.5	2.2	1.5	2.2	0.5	17.8
Temperature °F														
-Maximum														
70° and above	16	0.0	0.0	0.0	0.0	0.3	0.9	3.2	2.9	0.1	0.0	0.0	0.0	7.5
32° and below	16	18.2	13.4	6.2	1.1	0.0	0.0	0.0	0.0	0.0	1.4	12.6	19.2	72.1
-Minimum														
32° and below	16	29.3	27.4	29.3	19.3	1.2	0.1	0.0	0.1	1.4	11.4	27.4	30.1	176.8
0° and below	16	1.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.4
AVG. STATION PRESS. (mb)	9	1004.4	1005.5	1006.7	1007.2	1012.1	1013.5	1015.8	1014.0	1010.7	1005.5	1002.6	1007.1	1008.7
RELATIVE HUMIDITY (%)														
Hour 03	13	80	76	79	81	86	90	92	93	90	83	78	78	84
Hour 09 (Local Time)	16	77	75	75	73	75	78	84	85	86	81	75	78	79
Hour 15	16	76	70	67	63	63	66	72	72	73	74	72	76	70
Hour 21	12	80	75	77	75	74	76	83	87	86	80	77	77	79
PRECIPITATION (inches):														
Water Equivalent														
-Normal		5.05	4.10	3.46	3.13	2.44	2.13	3.95	3.72	8.26	9.12	6.00	5.34	56.70
-Maximum Monthly	17	12.53	9.76	9.99	8.11	4.74	6.05	8.96	18.23	16.69	15.43	20.59	16.87	20.59
-Year		1981	1988	1979	1977	1985	1987	1981	1981	1982	1979	1976	1985	NOV 1976
-Minimum Monthly	17	0.01	1.00	0.81	0.57	0.71	0.93	1.44	2.08	2.78	3.77	0.42	1.34	0.01
-Year		1974	1979	1983	1981	1984	1983	1972	1987	1973	1985	1975	1983	JAN 1974
-Maximum in 24 hrs	11	3.75	2.69	2.20	1.44	0.97	1.51	1.98	3.42	3.26	3.96	2.05	3.05	3.96
-Year		1981	1986	1981	1983	1985	1981	1981	1981	1982	1983	1979	1985	OCT 1983
Snow, Ice pellets														
-Maximum Monthly	17	128.0	100.8	113.9	71.4	5.8	0.0	0.0	0.0	T	39.0	75.6	110.0	128.0
-Year		1987	1984	1985	1977	1985				1981	1983	1981	1988	JAN 1987
-Maximum in 24 hrs	11	31.1	27.5	32.3	15.7	5.8	0.0	0.0	0.0	T	15.3	19.9	29.2	32.3
-Year		1986	1978	1982	1983	1985				1981	1982	1981	1981	MAR 1982
WIND:														
Mean Speed (mph)	8	7.2	7.9	5.7	5.6	5.6	5.7	4.7	4.2	4.3	6.2	7.0	6.3	5.9
Prevailing Direction														
Fastest Obs. 1 Min.														
-Direction (!!)	11	01	34	02	29	01	27	01	36	01	12	01	35	34
-Speed (MPH)	11	38	56	46	33	28	23	23	32	46	30	53	54	56
-Year		1975	1979	1986	1977	1986	1974	1987	1987	1988	1975	1978	1979	FEB 1979
Peak Gust														
-Direction (!!)	9	N	NE	N	N	N	W	N	N	N	NE	N	N	N
-Speed (mph)	9	94	81	61	53	41	38	41	56	63	66	61	74	94
-Date		1980	1987	1986	1986	1986	1987	1987	1984	1988	1984	1985	1984	JAN 1980

(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH INDIVIDUAL MONTHS MAY BE MISSING.
LESS THAN .05
NORMALS - BASED ON THE 1951-1980 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.

Figure 1.--Climatological Information for Valdez, Alaska.

March 23	1945 low	1.2 feet
March 24	0004 high	10.1 feet
	0155 high	12.5 feet
	0811 low	0.0 feet

The following are the currents at locations in the vicinity of the accident as computed from the Tidal Current Tables, Pacific Coast of North America and Asia, published by the U.S. Department of Commerce:

Busby Island, west-northwest of (60°53.65'N, 146°52.25W) 357°, 2.2 miles from the accident site.

Current weak and variable

Ship Channel, west of Bligh Island (60°53.65'N, 146°52.25W) 357°, 2.2 miles from the accident site.

March 23	2137	slack	0.0K	
March 24	0004	flooding	0.1K	355°
	0027	flood	0.1K	355°
	0440	slack	0.0K	
	0652	ebb	0.1K	124°

Columbia Bay, east entrance (60°55.45'N, 147°02.75W) 306°, 6.4 miles from the accident site.

March 23	2250	slack	0.0K	
March 24	0004	flooding	0.6K	297°
	0125	flood	0.7K	297°
	0501	slack	0.0K	
	0757	ebb	0.6K	122°

APPENDIX G

VESSEL TRAFFIC SERVICE REGULATIONS FOR PRINCE WILLIAM SOUND, ALASKA

coordinates without the NAD 83 reference may be plotted on maps or charts referenced to NAD 83 only after application of the appropriate corrections that are published on the particular map or chart being used.

[CGD 80-010, 46 FR 34580, July 2, 1981, as amended by CGD 86-082a, 53 FR 7739, Mar. 10, 1988]

PRINCE WILLIAM SOUND VESSEL TRAFFIC SERVICE

SOURCE: Sections 161.301 through 161.387, CGD 80-010, 46 FR 34580, July 2, 1981, unless otherwise noted.

GENERAL RULES

§ 161.301 Purpose and Applicability.

(a) Sections 161.301 through 161.387 prescribe rules for vessel operation in the Prince William Sound Vessel Traffic Service Area (VTS Area) to prevent collisions and groundings and to protect the navigable waters of the VTS Area from environmental harm resulting from collisions and groundings.

(b) The General Rules in §§ 161.301 through 161.311 excepting § 161.306 and the Traffic Separation Scheme (TSS) Rules in §§ 161.350 through 161.354 and 161.356 (b) and (c) apply to the operation of all vessels.

(c) General Rule § 161.306, the Communications Rules in §§161.320 through 161.332, the Vessel Movement Reporting Rules in §§ 161.334 through 161.342, the TSS Rules in §§ 161.348 and 161.356(a), and the Valdez Narrows Rules in § 161.372 and 161.374 apply only to the operation of:

(1) Each vessel of 300 or more gross tons that is propelled by machinery;

(2) Each vessel of 100 or more gross tons that is carrying one or more passengers for hire;

(3) Each commercial vessel of 8 meters or over in length engaged in towing another vessel astern, alongside, or by pushing ahead; and

(4) Each dredge and floating plant.

(d) Geographic coordinates expressed in terms of latitude or longitude, or both, are not intended for plotting on maps or charts whose referenced horizontal datum is the North American Datum of 1983 (NAD 83), unless such geographic coordinates are expressly labeled NAD 83. Geographic

§ 161.303 Definitions.

As used in §§ 161.301 through 161.387:

"ETA" means estimated time of arrival.

"Person" includes an individual, firm, corporation, association, partnership, and governmental entity.

"Separation zone" means an area of the TSS that is located between two traffic lanes to keep vessels proceeding in opposite directions a safe distance apart.

"Traffic lane" means an area of the TSS in which all vessels ordinarily proceed in the same direction.

"Traffic separation scheme" (TSS) means the network of traffic lanes and separation zones in the VTS Area.

"Vessel Traffic Center" (VTC) means the shore based facility that operates the Prince William Sound Vessel Traffic Service.

"Vessel Traffic Service Area" (VTS Area) means the area described in § 161.380.

"Tank Vessel" means any vessel specially constructed or converted to carry oil or other hazardous substances in bulk in the cargo spaces.

"Laden Tank Vessel" means a tank vessel having cargo on board in excess of normal clingage or residual.

§ 161.304 Vessel operation in the VTS Area.

No person may cause or authorize the operation of a vessel in the VTS Area contrary to the rules in §§ 161.301 through 161.387.

§ 161.305 Laws and regulations not affected.

Nothing in §§ 161.301 through 161.387 is intended to relieve any person from complying with:

(a) International Regulations for Preventing Collisions at Sea, 1972;

(b) Vessel Bridge-to-Bridge Radiotelephone Regulations (Part 26 of this chapter);
(c) The Federal Boat Safety Act of 1971 (46 U.S.C. 1451 through 1489); and
(d) any other law or regulation.

§ 161.306 VTS Operating Manual.

The master of a vessel listed in § 161.301(c) shall insure that a copy of the current edition of the Prince William Sound Vessel Traffic Service Operating Manual is available on board the vessel when it is in the VTS Area.

NOTE: The Prince William Sound VTS Operating Manual includes VTS regulations, navigation information, and guidelines for the efficient operation of the VTS system. The manual may be obtained in person or by writing: Prince William Sound Vessel Traffic Service, c/o USCG Marine Safety Office, P.O. Box 486, Valdez, Alaska 99686; or Commander, Seventeenth Coast Guard District, Federal Building, P.O. Box 3-5000, Juneau, Alaska 99802. Temporary changes to the operating manual are promulgated by the Commander, Seventeenth Coast Guard District, in local notices to mariners.

§ 161.307 VTC directions.

(a) During conditions of vessel congestion, adverse weather, reduced visibility, or other hazardous circumstances in the VTS Area, the VTC may issue directions specifying times when vessels may enter, move within or through, or depart from ports, harbors, or other waters in the VTS area.
(b) The master of a vessel in the VTS area shall comply with each direction issued to the vessel under this section.

§ 161.309 Authorization to deviate from these rules.

(a) The Commander, Seventeenth Coast Guard District may, upon written request, issue an authorization to deviate from any rule in §§ 161.301 through 161.387 if he finds that the proposed operation under the authorization can be done safely. An application for an authorization must state the need for the authorization and describe the proposed operations.
(b) The VTC may, upon request, issue an authorization to deviate from any rule in §§ 161.301 through 161.387 for a voyage or part of a voyage on which a vessel is embarked or about to embark.

§ 161.311 Emergencies.

In an emergency, any master may deviate from any rule in §§ 161.301 through 161.387 to the extent necessary to avoid endangering persons, property, or the environment.

COMMUNICATIONS RULES

§ 161.320 Radio listening watch.

The master of a vessel in the VTS Area shall continuously monitor the radio frequency designated in the current edition of the Prince William Sound VTS Operating Manual for the sector of the VTS Area in which the vessel is operating, except when transmitting on that frequency.

§ 161.322 Radiotelephone equipment.

Each report required by the Prince William Sound VTS rules to be made by radiotelephone must be made using a radiotelephone that is capable of operating on the navigational bridge of the vessel, or in the case of a dredge, at its main control station.

§ 161.324 English language.

Each report required by the Prince William Sound VTS rules must be made in the English language.

§ 161.326 Time.

Each report required by the Prince William Sound VTS rules must specify time using:
(a) The zone time in effect in the VTS Area; and
(b) The 24-hour clock system.

§ 161.328 Radio failure.

Whenever a vessel's radiotelephone equipment fails:
(a) Before entering or while underway in the VTS Area:
(1) Compliance with §§ 161.320 and 161.338 is not required; and
(2) Compliance with §§ 161.334, 161.336, and 161.342 is not required unless the reports can be made by other means;
(b) Before getting underway in the VTS Area permission to get underway must be obtained from the VTC;

(c) The master shall restore the radiotelephone to operating condition as soon as possible.

§ 161.330 Report of emergency or radio failure.

Whenever the master of a vessel deviates from any rule in §§ 161.301 to 161.387 because of an emergency or radio failure, he shall report the deviation to the VTC as soon as possible.

§ 161.332 Report of impairment to the operation of the vessel.

The master of a vessel in the VTS Area shall report to the VTC as soon as possible:

(a) Any condition on the vessel that may impair its navigation, such as fire, defective steering equipment, or defective propulsion machinery; and

(b) Any tow that the towing vessel is unable to control, or can control only with difficulty.

VESSEL MOVEMENT REPORTING RULES

§ 161.334 Initial report.

Three hours before a vessel enters or begins to navigate in the VTS Area through Hinchinbrook entrance or at least 30 minutes before a vessel enters or begins to navigate in the VTS Area from other points, the master of the vessel shall report to the VTC:

(a) Name, type, and draft of the vessel;

(b) Position of the vessel;

(c) Estimated time and place of entering or beginning to navigate in the VTS Area;

(d) Estimated vessel speed to transit the VTS Area;

(e) ETA to the destination in the VTS Area and name of the destination;

(f) If the vessel is a towing vessel, the overall length of the tow, including the towing vessel;

(g) Whether or not any dangerous cargo listed in § 161.3 of this chapter is on board the vessel or its tow;

(h) Any impairment to the operation of the vessel as described in § 161.332;

(i) Alternate communications, if any;

(j) Any other information requested by the VTC.

§ 161.336 Follow-up report.

At least 60 minutes before a vessel enters or begins to navigate in the VTS Area through Hinchinbrook entrance the master of the vessel shall report the following information to the VTC:

(a) Name of the vessel;

(b) Position of the vessel;

(c) Course and speed of the vessel;

(d) ETA at Hinchinbrook Entrance;

(e) ETA of the vessel at its destination if changed from the preliminary report.

§ 161.338 Movement reports.

(a) While navigating in the VTS Area the master of a vessel shall report the following information to the VTC by radiotelephone:

(1) Any increase or decrease of speed of more than 1 knot;

(2) The intent to cross through the TSS at least 10 minutes (for vessels with a tow at least 30 minutes) before beginning to cross the TSS;

(3) When the vessel clears the TSS after crossing;

(b) When the vessel passes a reporting point listed in § 161.340, the master of a vessel shall report the following information to the VTC by radiotelephone:

(1) The name of the vessel;

(2) The reporting point.

§ 161.340 Reporting points.

The reporting points are:

(a) When entering or departing the VTS Area at Hinchinbrook Entrance; and

(b) When abeam of Naked Island.

§ 161.342 Final report.

Whenever a vessel anchors, moors in, or departs from the VTS Area, the master shall report the place and time of anchoring, mooring, or departing to the VTC, except:

(a) When mooring or anchoring in Port Valdez, unless requested to do so by the VTC; or

(b) When departing the VTS Area at Hinchinbrook Entrance and the movement report for the reporting point in § 161.340(a) is made.

TRAFFIC SEPARATION SCHEME RULES

§ 161.348 Vessels required to use the TSS.

All vessels described in § 161.301(c) must sue the TSS when en route to or from Valdez via Hinchinbrook Entrance or navigating any portion of that route.

§ 161.350 Vessel operation in the TSS.

(a) The master of a vessel shall operate the vessel in accordance with the TSS rules prescribed in §§ 161.352, 161.354 and 161.356(b) and (c).

(b) The master of a vessel described in § 161.301(c) shall, in addition to paragraph (a), operate the vessel in accordance with § 161.356(a).

§ 161.352 Direction of traffic.

A vessel proceeding in a traffic lane must keep the separation zone to port.

§ 161.354 Anchoring in the TSS.

No vessel may anchor in the TSS.

§ 161.356 Joining, leaving, and crossing a traffic lane.

(a) A vessel described in § 161.301(c) may join, cross, or leave a traffic lane only after the VTC has been notified of the point at which the vessel will join, cross, or leave the traffic lane.

(b) A vessel crossing a traffic lane shall, to the extent possible, maintain a course that is perpendicular to the direction of the flow of traffic in the traffic lane.

(c) A vessel joining or leaving a traffic lane shall steer a course to converge or diverge from the direction of traffic flow in the traffic lane at as small an angle as possible.

(d) A vessel engaged in fishing shall not impede the passage of any vessel following a traffic lane.

(e) A vessel of less than 20 meters in length or a sailing vessel shall not impede the safe passage of a power-driven vessel following a traffic lane.

VALDEZ NARROWS RULE

§ 161.370 One-way traffic in Valdez Narrows.

(a) The area described in § 161.387 is designated as the Valdez Narrows One-way Traffic Area and is restricted to one-way traffic whenever a tank vessel of 20,000 dead weight tons (DWT) or more is navigating therein.

(b) A tank vessel of 20,000 DWT or more may not enter Valdez Narrows One-way Traffic Area unless:

(1) It complies with § 161.372; and

(2) It complies with § 161.376(a)(1), (3), and (4).

§ 161.372 Entering Valdez Narrows.

A vessel described in § 161.301(c) may not enter the Valdez Narrows One-Way Traffic Area unless:

(a) Permission to enter is obtained from the VTC;

(b) Any directions from the VTC to remain separated from another vessel are complied with;

(c) The radio equipment on the vesel that is used to transmit the reports required by the Prince William Sound VTS rules is in operation;

(d) The radar on a vessel equipped with radar is in operation and manned; and

(e) The vessel is free of any condition that may impair its navigation, such as fire, defective steering equipment, or defective propulsion machinery.

§ 161.374 Communications in Valdez Narrows.

Before a vessel meets, overtakes, or crosses ahead of any vessel in Valdez Narrows One-Way Traffic Area, the master or person designated by the master to pilot or direct the movement of the vessel shall transmit the intentions of his vessel to the master or the person designated by the master to pilot or direct the movement of the other vessel on the frequency designated under the Bridge-to-Bridge Radiotelephone Act for the purpose of arranging safe passage.

SPECIAL REQUIREMENTS FOR TANK VESSELS

§ 161.376 Tank vessels in the VTS Area.

(a) Each tank vessel of 20,000 DWT or more operating in the VTS Area must:

(1) Have two separate marine radar systems for surface navigation, one of which is operating and the other

either operating or capable of immediate operation;

(2) Have an operating LORAN-C receiver;

(3) Have an operating rate of turn indicator; and

(4) Have at least two radiotelephones capable of operating on the designated VTS frequency, one of which is capable of battery operation.

(b) No laden tank vessel of 20,000 DWT or more may transit that portion of Valdez Narrows between Middle Rock and Potato Point at a speed in excess of 6 knots.

(c) No tank vessel of 20,000 DWT or more may transit the Valdez Narrows One-Way Traffic Area in excess of 12 knots.

(d) While in the VTS Area, if a tank vessel of 20,000 DWT or more is unable to comply with paragraph (a) the master shall immediately notify the VTC.

§ 161.378 Tug assistance for tank vessels.

(a) For the purposes of this section, tug assistance means the use of a sufficient number of tugs properly manned and positioned, with enough power and maneuverability to enable the vessel to accomplish the intended maneuvers safely. Factors to be considered in dermining the amount of tug assistance needed are:

(1) Existing and expected conditions of wind, tide and current; and

(2) Size, displacement, and maneuvering capability of the vessel.

(b) No laden tank vessel of 20,000 DWT or more may transit the Valdez Narrows One-Way Traffic Area unless:

(1) A sufficient number of tugs, as determined by the VTC, are standing by the northern entrance to Valdez Narrows: and

(2) Tug assistance is utilized when directed by the VTC.

(c) The master of any tank vessel required to use tug assistance shall insure that there are sufficient persons positioned on the vessel to handle lines to tugs as needed.

DESCRIPTIONS AND GEOGRAPHIC COORDINATES

§ 161.380 VTS area.

The VTS Area consists of the navigable waters of the United States north of a line drawn from Cape Hinchinbrook Light to Schooner Rock Light, comprising that portion of Prince William Sound between longitudes 146°30′ W. and 147°20′ W. and includes Valdez Arm, Valdez Narrows, and Port Valdez.

§ 161.383 Separation zone.

The separation zone is 1,830 meters wide from Hinchinbrook Entrance to Valdez Arm west to Bligh Reef and decreases in width from 1,830 meters to 915 meters from the entrance to Valdez Arm to where it terminates and is bounded by lines connecting the following latitudes and longitudes:

(a) 60°58′43″ N., 146°47′50″ W.
(b) 60°49′47″ N., 147°02′06″ W.
(c) 60°34′43″ N., 147°05′16″ W.
(d) 60°17′05″ N., 146°49′18″ W.
(e) 60°16′20″ N., 146°46′28″ W.
(f) 60°34′53″ N., 147°03′14″ W.
(g) 60°49′23″ N., 147°00′08″ W.
(h) 60°58′26″ N., 146°47′02″ W.

§ 161.385 Traffic lanes.

The traffic lanes are 1,375 meters wide from Hinchinbrook Entrance to Valdez Arm west of Bligh Reef, and decrease in width from 1,375 meters to 915 meters from the entrance to Valdez Arm to where they terminate. The traffic lanes are as follows:

(a) The inward bound traffic lane is between the separation zone and a line connecting the following latitudes and longitudes:

(1) 60°58′09″ N., 146°46′16″ W.
(2) 60°49′07″ N., 146°58′42″ W.
(3) 60°35′00″ N., 147°01′42″ W.
(4) 60°15′45″ N., 146°44′20″ W.

(b) The outward bound traffic lane is between the separation zone and a line connecting the following latitudes and longitudes:

(1) 60°59′01″ N., 146°48′37″ W.
(2) 60°50′04″ N., 147°03′35″ W.
(3) 60°34′36″ N., 147°06′48″ W.
(4) 60°17′38″ N., 146°51′20″ W.

Coast Guard, DOT

§ 161.387 Valdez Narrows one-way traffic area.

Valdez Narrows One-Way Traffic Area consists of the navigable waters of the United States in Valdez Arm, Valdez Narrows, and Port Valdez northeast of a line bearing 307° true from Tongue Point at 61°02'06" N., 146°40'00" W., and southwest of a line bearing 307° true from Entrance Island Light at 61°05'06" N., 146°36'42" W.

APPENDIX H

HISTORY OF AND RECENT REDUCTIONS IN THE VESSEL TRAFFIC SERVICE

Harbor Advisory Project: During the late 1960s, about 3 1/2 years before the passage of the Ports and Waterways Safety Act, the Coast Guard established the Harbor Advisory Radar (HAR) Project in San Francisco, California, under the management of the Office of Research and Development. The prime objective of this project was to "investigate the capability of HAR services to meet the present and future navigational requirements of U.S. ports in terms of collision avoidance."

In 1971, the term "Harbor Advisory Radar" was dropped in favor of the more encompassing term "Vessel Traffic Service (VTS)." In its Vessel Traffic System Study Final Report issued in 1973, the Coast Guard estimated that the VTS system could lead to a 70-percent reduction in accidents caused by collisions, rammings, and groundings.[1]

Ports and Waterways Safety Act: Prince William Sound VTS was established under the authority of the Ports and Waterways Safety Act of 1972 (PWSA). The PWSA authorized the Secretary of the department in which the Coast Guard is operating (hereafter referred to as the Secretary) to establish, operate, and maintain vessel traffic services and systems for ports, harbors, and other waters subject to congested vessel traffic and to control vessel traffic in areas that the Secretary determines to be especially hazardous or under conditions of reduced visibility, adverse weather, vessel congestion, or other hazardous circumstances.

Trans-Alaska Pipeline Authorization Act: The Trans-Alaska Pipeline Authorization Act was enacted into law on November 16, 1973. It required that the Coast Guard establish and operate a VTS in Prince William Sound in order to ensure the safe transit of tank vessels transporting North Slope crude oil from the Alyeska Marine Terminal in Port Valdez.

Ports and Tanker Safety Act of 1978: The Ports and Tanker Safety Act of 1978 was enacted into law on July 11, 1978. Among other things, the statute authorized the Secretary to establish, operate, and maintain VTSs in order to control and supervise vessel traffice. The legislation covered reporting and operating requirements, surveillance and communications systems, routing systems, and fairways. The Act also gave the Secretary the authority to control traffic in those areas considered particularly hazardous to the safe navigation of vessels.

Reduction of VTS Program: Between 1972 and 1978, the Coast Guard had either planned or established some level of VTS protection in the ports of San Francisco, California; Puget Sound, Washington; New York, New York; New Orleans, Louisiana; Berwick Bay, Louisiana; Houston, Texas; and Prince

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[1]U.S. Coast Guard, "Vessel Traffic Systems Issue Study," Department of Transportation, Washington, D.C., 1973.

William Sound, Alaska. The commissioning of the New York VTS, scheduled for 1977, was delayed owing to problems experienced by the contractor, but the radar was manned after that date, providing limited service. In 1982, the New York VTS was closed, but it was reopened in 1985.

In 1986, Congress approved funding to add an improved radar system, closed circuit television, and an expanded VHF-FM communications link to the New Orleans VTS. By the summer of 1987, however, the Coast Guard had announced plans to decommission both the New Orleans and New York VTSs. In addition, steps were taken to reduce the number of VTS billets assigned to MSO VALDEZ. The VTS closures and subsequent reduction in force were scheduled to take effect in 1988.

In a letter to the Secretary of Transportation on June 2, 1988, the Safety Board expressed its concern about the closing of the New Orleans VTS, the scheduled closing of the New York VTS, and the planned staff reductions at the Valdez VTS and issued the following safety recommendation to the Secretary:

> M-88-39
>
> Maintain the services currently provided by the New York, New York, and Valdez, Alaska, Vessel Traffic Services (VTS), and not only to reestablish the services originally provided by the New Orleans VTS but also to upgrade the equipment using the allocated funds.

The Safety Board at that time also sought improvement in the New York VTS radar coverage and issued the following safety recommendation:

> M-88-40
>
> Eliminate blind spots in radar coverage in the New York Vessel Traffic Service by installing new radar sites.

On September 13, 1988, the Commandant of the Coast Guard responded to the Safety Board's June 2, 1988, letter on behalf of the Secretary as follows:

> The Coast Guard does not concur with either recommendation. The VTSs at New York and New Orleans have been disestablished for the reasons discussed below. The personnel reduction at VTS Valdez was a manning change to one person watches due to the port's low volume of shipping (seven ships per day).
>
> We are aware that the National Transportation Safety Board (NTSB) has long supported the operation of fully staffed, expanded, mandatory Vessel Traffic Service. Your letter of March 11, 1988, to the Honorable Earl Hutto notes that the NTSB has made over 50 safety

> recommendations concerning the Coast Guard's Vessel Traffic Services, but for funding reasons we have been unable to comply with many of them. We agree with NTSB's position. "The Coast Guard's VTS operations provide valuable safety protection to the traveling public." No doubt about it, VTSs are a navigation safety enhancement - closing them will have a safety impact.
>
> Our FY 1988 budget shortfall was the deciding factor in closing and reducing some of our operational units. We took cuts in many areas ... Search and Rescue, Marine Safety, Law Enforcement and VTS. All of the cuts affect safety in some manner. However, we carefully considered the impact of each candidate and chose only those with the least public safety impact. In most cases the disestablished unit had a nearby "parent unit" that could provide a similar capability. In the case of VTS, the local Coast Guard Captain of the Port (COPT) has broad vessel traffic management authority and can still take actions to ensure safe navigation if conditions warrant.

In a letter to the Secretary dated January 12, 1989, the Safety Board stated:

> The Safety Board appreciates the Coast Guard's position of having to meet budget constraints which have been imposed on that agency. We also recognize but do not agree with the rational for choosing the VTS units as the activities to be sacrificed in attempting to meet those budget constraints. Therefore, the Board would appreciate an initiative by the Department of Transportation to seek funding for the Coast Guard to restore the full services of the VTSs that have been disestablished or reduced.

As a result, Safety Recommendation M-88-039 was classified as "Open--Unacceptable Action" pending DOT's response.

GAO Report to Congress: In November 1988, the General Accounting Office[2] issued a report that examined the Coast Guard's decommissioning of VTS facilities in New York and New Orleans. According to the report, the factors used by the Coast Guard to select VTSs for closure "were chosen primarily to resolve its immediate problem of reducing operating expenses and gave little consideration to the effectiveness of each VTS in enhancing

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[2]General Accounting Office, "Report To The Chairman, Subcommittee on Coast Guard and Navigation, Committee on Merchant Marine and Fisheries, House of Representatives," November 1988 (GAO/RECD-89-38).

safety." The report stated that the Coast Guard considered the following factors when it selected the VTSs to close:

(1) whether the VTSs were mandated by statutes;

(2) participation rate of VTSs--those with the lowest participation rates for the fourth quarter of 1987 were chosen;[3] and

(3) local resistance to closing.

According to the GAO report, the Coast Guard did not consider the number of accidents, VTS activity levels (volume of vessel traffic and communications handled by the VTS), participation rates, or the complexity of vessel traffic patterns in selecting the VTSs for closure.

After the grounding of the EXXON VALDEZ, Congress included $5.6 million in the Coast Guard's FY 1990 budget to reactivate the New York VTS. The unit is expected to become operational on December 1, 1990. However, no permanent augmentation of the manning of the Valdez VTS has occurred.

[3]Unlike the VTSs located in Prince William Sound, Alaska; Puget Sound, Washington; San Francisco, California; and Houston, Texas, participation in the New York and New Orleans VTSs was not mandatory.

APPENDIX I

CAPTAIN OF THE PORT ORDER 1-80

September 19, 1986

To: Whom it may concern

Fm: Alaska Maritime Agencies

RE: New Pilotage Requirements

Effective Sept. 1, 1986 the USCG requirement for daylight passage in Prince William Sound for vessels without pilotage has been waived. All non-pilotage vessel will be able to transit from Cape Hinchinbrook to the pilot station at all hours as long as visibility remains at 2 miles or greater. The same remains true for the outbound leg from the pilot station to Cape Hinchinbrook.

The USCG will require each vessel to advise them of the visibility prior to arrival at Cape Hinchinbrook on the inbound leg and just prior to dropping the pilot on the outbound leg.

Please note that the Coast Guard is treating each instance on a case by case basis. Events such as oil spills, severe weather, traffic within the VTS and a vessels past operating record may dissuade the USCG from granting permission to transit Prince William Sound without pilotage.

All other requirements for vessels in the TAPS trade remain the same:

1. Notify USCG 3 hours prior to arriving Cape Hinchinbrook.
2. Full complement of crew to be onboard, all navigation equipment to be in working order.
3. A bridge navigation team consisting of an extra watchstander under the direction of a deck officer (other than the one on watch), must report the vessels position every 10 minutes while navigating from Cape Hinchinbrook to Montague point.

We hope this information is of assistance to you.

Sincerely,

Alaska Maritime Agencies

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS
Commanding Officer
Marine Safety Office
P.O. Box 486,
Valdez, Alaska 99686
(907) 835-4791

25 FEB 1980

CAPTAIN OF THE PORT ORDER NO. 1-80

SUBJECT: Prince William Sound Pilotage

AUTHORITY: 33 CFR 160

DISCUSSION: Since establishment of the Trans-Alaska Pipeline System (TAPS) all tankers operating in this trade have been required to have a federally licensed pilot onboard between Cape Hinchinbrook and Valdez, Alaska. This requirement has been under considerable reevaluation and proposed rulemaking is pending to revise or rescind the requirement. Further, on 7 January 1980 the M/V BLUE MOON, which had been employed as a pilot vessel for boarding at Hinchinbrook Entrance, foundered and sank. Attempts by the Southwest Alaska Pilots Association and vessel agents to temporarily employ a suitable replacement vessel have been unsuccessful. Long term commitments are also hampered by the pending rulemaking change. Use of a helicopter is deemed unsafe due to unstable weather conditions and further limited by reliable availablity. Therefore, to facilitate orderly TAPS tanker traffic, and to continue to preserve the safe and incident free transit from Hinchinbrook Entrance to the Valdez Pilot Station, the following order has been established.

ORDER: Each TAPS tanker when conducting the required three hour preliminary report, (33 CFR 161.334) prior to entering Hinchinbrook Entrance, or 30 minute initial report, (33 CFR161.336) from Alyeska Terminal prior to departure, will be queried if an officer is on board holding applicable federal pilotage for Prince William Sound. If a pilot will not be aboard for the transit between Hinchinbrook and the Pilot Station, inbound or outbound, the following will apply:

1. Status of all machinery, personnel, charts, publications and navigation equipment required by 33 CFR 164 will be reported.

2. Based upon satisfactory condition, entry of the vessel into Prince William Sound will be permitted providing transit to or from the pilot station can be completed during daylight hours and during a period of predictably good visibility.

3. Further, a licensed officer, in addition to the licensed officer on watch, will be employed as a navigator to continuously plot the position of the vessel during the transit of Hinchinbrook Entrance and Prince William Sound. This position will be reported on request to Valdez VTC.

4. Further, the Valdez Port Pilot will board or depart the vessel at the entrance to Valdez Arm, off Bligh Reef, in lieu of the established pilot station at Busby Island.

5. Further, transit to the anchorage area off Knowles Head, during other then emergency conditions, will be evaluated on a case basis, considering weather, vessel traffic, and operating conditions.

25 FEB 1980

CAPTAIN OF THE PORT ORDER NO. 1-80 (Page Two)

SUBJECT: Prince William Sound Pilotage

6. Further, an English speaking officer will be on watch during the entire Prince William Sound Transit period.

APPLICATION: The above policy will apply until modified by rulemaking, or on a special case basis by the Captain of the Port, Valdez. This policy does not apply to TAPS tankers who have an officer aboard with federal pilotage for Prince William Sound, or who obtain the services of a pilot prior to transit of Prince William Sound.

J. K. WOODLE
Commander, U. S. Coast Guard
Captain of the Port
Valdez, Alaska

NON-PILOTAGE TANK-VESSEL CHECK IN

DATE_____ VESSEL NAME_____WATCH INT__

The following questions should be asked, when applicabel, of all Non-pilotage TAPS Trade tankers on their Initial Call-up.

_____1. "Pilots are no longer required to board vessels at Hinchinbrook Entrance. Your vessel will be permitted to enter Prince William Sound without pilotage if certain conditions and additional requirements are satisfied."

_____2. "Does your vessel have all equipment, in good working order, which is required by the Navigation Safety Requlations, 33 CFR part 164?"

_____3. "Does your vessel have a full complement of required crew members aboard and are all fit for duty?"

_____4. "Do you have any casulties to your propulsion, steering gear, or deck machinery which would affect the manuvering or anchoring of your vessel?"

_____5. "Do you have the following charts and publications aboard your vessel:

charts	16700
	16708
	16709
publications	U.S. Coast Pilot No.9
	U.S. Light List, Vol 6 7
	Tide and Current Tables for the West Coast of North America

And what is the latest Local Notice to Mariners they are corrected thru?

_____Latest LNTM_____

_____6. Pass to the vessel any pertaintant information published in the Local Notice to Mariners that has come out since the vessels latest LNTM posting.

_____7. Notify the OOD of the above information and if the OOD and/or CO decides to allow the vessel to enter PWS, make the following statements:

_____8. "You are granted permission to enter Prince William Sound subject to the following conditions, under the authority of 33CFR, Part 164, you are required to utilize a bridge navigation team under the supervision of a licensed deck officer, other than the mate on watch, to continuously plot the position of the vessel's position to the Vessel Traffic Center when requested. Position reports are normally requested at ten minute intervals commencing when the vessel is abeam Cape Hinchenbrook to abeam Montague Point."

_____9. "On Non-US flag vessels, an English speaking officer shall be on watch during your entire transit of Prince William Sound."

____10. "Your transit of Prince William Sound from Hinchinbrook Entrance to Bligh Reef shall be made only during periods of good visibility of two miles or greater."

____11. "Your vessel is required to embark a quilified pilot when abeam of Bligh Reef Lighted Bouy #6."

____12. "It is recommended that your vessel approach Hinchinbrook entrance from the ESE, following the recommended track as indicated on chart 16700."

NOTE: Obtain the remainder of the required information for the Initial and Follow-up Reports.

Memorandum

U.S. Department of Transportation
United States Coast Guard

Subject NON-PILOTAGE VESSELS; INFORMATION CONCERNING Date 3 September 1986

From Commanding Officer Reply to Attn of

To ALL OOD'S AND VTS OPERATORS

1. I have decided to cancel COTP Order 1-80, which dealt with the requirements for non-pilotage vessels entering and departing Prince William Sound.

2. Instead of issuing a new COTP Order, I want each request to transit Prince William Sound without pilotage to be handled on a case by case basis. The primary determining factor for approval will be visibility. If a tanker entering the system at Cape Hinchinbrook has less than two miles visibility, they will not normally be allowed to enter Prince William Sound until the visibility improves to two miles or greater. Of course, claims of adverse weather or sea conditions effecting the safety of his vessel would cause reassessment of the 2 mile criteria. In regards to tankers departing Prince William Sound the visibility requirements will apply when they reach Bligh Reef. If visibility is less than two miles at Bligh Reef, the pilot would be required to remain aboard the vessel until visibility improves to two miles or greater.

3. The non-pilotage vessel check-in sheet will continue to be utilized for tankers entering Prince William Sound. Item number 9, which deals with transits during daylight hours and good visibility, will be changed to eliminate the daylight restriction and require visibility of two miles or greater. When a non-pilotage vessel makes the 30 minute recall prior to departing the terminal, they will be advised at that time, that because they are non-pilotage they will only be allowed to transit from Bligh Reef to Cape Hinchinbrook without a pilot if the visibility is two miles or greater.

S. A. McCALL

APPENDIX J

SPEECH EXAMINATION INFORMATION

This appendix comprises (1) a transcript of statements by the master of the EXXON VALDEZ, (2) a letter report dated November 13, 1989, from the Addiction Research Foundation of Toronto, Ontario, Canada, prepared by Dr. Mark B. Sobell and Dr. Linda C. Sobell, and (3) a report dated May 10, 1990, from the Speech Research Laboratory, Indiana University, Bloomington, Indiana.

Transcript (and numbering) of all recorded statements by Captain Hazelwood.

Thirty-three hours before the accident:

1. Ah, W-H-C-B. EXXON WALDEZ back.

2. Okay. She's going to depart at twenty three hundred, ah, all right yeah. We'll, ah, get with the pilot, see if we can go with two tugs instead of three (and) take an escort boat. We'll work that out amongst ourselves. Okay. Thank you very much. Ah, we'll give you a shout at one hour from, ah, Cape Hinchinbrook. EXXON VALDEX off. Standing by channel thirteen and sixteen.

One hour before the accident:

3. Ah, Valdez Traffic. EXXON BA ah VALDEZ.

4. Yes, We've ah departed the pilot or disembarked the pilot. Excuse me. And this time hooking up to sea speed and ETA Naked Island oh one hundred. Over.

5. Okay. I was just about to tell you that, ah, judging by our radar, I we'll probably divert from ah, the TSS and end up in the, ah, inbound lane if there's no conflicting traffic. Over.

6. That'd be fine. Yeah. We we may end up over in the, ah, inbound lane, outbound transit. Ah, we'll notify you when we leave the, ah, TSS and, ah, cross over the separation zone. Over.

7. Okay. EXXON VALDEZ over. Standing by thirteen and sixteen.

8. Ah, Valdez Traffic. EXXON VALDEZ. W-H-C-B. Over.

9. At the present time, I'm going to alter my course to two, zero, zero and reduce speed to about twelve knots to, ah, wind my way through the ice, and, ah, Naked Island ETA might be a little out of whack but, ah, once we're clear of the ice out of Columbia Gla...Bay, we'll give you another shout. Over.

Immediately after the accident;

10. Yeah, Valdez Traffic. EXXON VALDEZ. Over.

11. Yeah. Ah, it's VALDEZ back. Ah, we've -- ah, should be on your radar there -- we've fetched up, ah, hard aground north of, ah, Goose Island off Bligh Reef. And, ah, evidently, ah, leaking some oil, and, ah, we're gonna be here for awhile. And, ah, if you want, ah, so you're notified. Over.

12. Yeah. That's correct. Over.

13. Okay, I'll give you a status report, ah, ascertain the situation. Over.

14. EXXON VALDEZ back. Over.

15. Ah, its blowing, ah, northerly a little bit, ah, drizzle, visibility, ah, two miles. Over.

16. Ah, ten knots right now. Over.

17. Yeah, its kinda indeterminate, ah, right now. It's...ah, slight sea. Over.

One hour after the accident:

18. EXXON VALDEZ back. Over.

19. Ah, not at the present, ah, Steve. Ah ... or ah, a little problem here with the third mate but, ah, we are working our way off the reef. We've, ah, the vessel's been holed and, ah, we're ascertaining--right now we're trying to just get her off the reef and, ah, we'll get back to you as soon as we can. Over.

20. Okay, We're, ah, pretty good shape right now stability-wise. We're, ah, just trying to extract her off the, ah, shoal here, and, ah, you can probably see me on your radar and, ah, once we get under way. I'll let you know. Do another, ah, damage control assessment. Over.

21. Okay. Yeah, I think it's, ah, major damage is kinda been done. We kinda rock and rolled over it, and, ah, we're just kinda hung up in the stern here. We're just, ah, we'll drift over it. I'll get back to ya. We'll be standing by thirteen sixteen. EXXON VALDEZ clear.

22. Yeah. VALDEZ back. Over.

23. Ah, not at this time. Ah, got a pilot aboard us? Over.

24. Ah, okay. Ah, we'll...there'll be a ladder on the port side. Over.

25. Ah, no. Not at this time. Ah, I do have the pilotage for this area, but, ah, no pilot, ah, Southwest Pilot on board. Over.

26. Very well. EXXON VALDEZ standing by thirteen and sixteen.

Nine hours after the accident;

27. Yeah. You got -- we're lying at about a two eighty heading here, Barry. Ah, ...ah, there's that thirty-five, thirty-six foot lump right off our manifold, ah, a couple hundred yeards out, but everything else to the northern is pretty clear. To the southern we haven't sounded yet. I wouldn't suggest going down there. There's a lot of rocks and junk, but, ah, what kind of draft you coming in with?

28. Yeah. Okay. Just, ah, go by us there to the northern, make your turn, and, ah, I guess we'll just get the tugs and you can settle her downwind, ah, be the easiest way rather than get in towards the beach too much.

29. Okay. Thanks a lot. We'll talk to you when you get here. We'll have that pilot boat run around and get some more soundings for you off the starboard quarter area.

30. The, ah, STALWART's out there. The other two, I guess will be coming from town--the SEA FLYER and the, ah, PATHFINDER.

31. Yes, the VALDEZ back.

32. Nine.

33. EXXON BATON ROUGE. EXXON VALDEZ.

34. Yeah, Lloyd just said, ah, what do you want to put a couple wire springs, and the rest soft lines?

35. Yeah, okay, ah, ah ... Yeah, that will be all right. We'll just have to run it through the hand rails. It's a little too late to worry about the cosmetics right now.

36. Ah, we're all buttoned up. We'll, we'll go with the wires. We'll just, ah, probably have to land her first before we can test any lines. Just, ah, pull her in with the boats and then we can, ah, get the springs out and then position her as necessary.

37. Yeah, okay. I guess it's best if you could, ah, just leave that forward spring down the waterway a bit, ah, and ah, by the shear strake there. So just pick it up, and, ah, if you want to drop it back as far.

38. Yeah, okay. Will do.

39. Very well.

40. Ah, the EXXON BATON ROUGE. EXXON VALDEZ. Thirteen.

41. EXXON BATON ROUGE, EXXON VALDEZ. Channel Thirteen.

42. Channel Nine for a second.

Addiction Research Foundation
33 Russell Street
Toronto, Ontario
Canada M5S 2S1
Tel: 416-595-6002
Fax: 416-595-5017

13 November 1989

Malcolm Brenner, Ph.D.
Human Performance Investigator
National Transportation Safety Board
Washington, D.C. 20594 U.S.A.
Fax: 202-382-6819

Dear Dr. Brenner:

The following is a brief summary of our qualifications for commenting on the audio tape containing transmissions from the EXXON VALDEZ. We were both trained as experimental psychologists. Mark received his Ph.D. in 1970 from the University of California, Riverside, and Linda received her Ph.D. in 1976 from the University of California, Irvine. We have conducted experimental and clinical research in the alcohol and substance abuse fields since 1969, and we are widely recognized professionally for our research and clinical contributions. Our curriculum vitaes document our scientific and professional accomplishments.

Among our publications are two of the very few scientific studies that have ever investigated the effects of alcohol on speech. One of these was conducted with normal drinkers (college student volunteers), and the other with inpatient chronic alcoholics. The study involving normal drinkers raised subjects' blood alcohol levels to an average of about .10 mg %. Blood alcohol levels were not measured in the study using chronic alcoholics, but in the article we estimate that the dose used (equivalent to 10 oz. of 86-proof whiskey) would have raised the subjects' blood alcohol levels to around .25 mg %, well above the legal definition of intoxication in most states in the U. S.

In addition to having performed formal research concerning the effects of alcohol on speech, we have had considerable clinical experience dealing with individuals who were under the influence of alcohol. For two years, we conducted experimental intoxication research on an inpatient unit. In that research, chronic alcoholics in treatment participated in research that involved them consuming amounts of alcohol ranging as high as the equivalent of 16 oz. of 86-proof whiskey in a 4-hour period. Over the course of two years, more than 200 individuals participated in studies, so we had ample opportunity to contrast intoxicated and sober behavior in the same alcoholic individuals.

From 1972-1974 we both worked in a community outpatient alcoholism treatment program that was one of the first to use breath analysis for ethanol as a routine intake and clinical procedure. By administering breath alcohol tests to a large number of individuals who had alcohol problems, we became well aware of the phenomenon of acquired tolerance. Acquired tolerance to ethanol refers to the fact that with repeated episodes of ethanol consumption, an organism (human or animal) manifests a change such that a set dose of

ethanol produces a smaller effect on behavior or, put another way, a larger dose is required to produce the same behavioral effect previously produced by a smaller dose. This means that it is more difficult to identify that an experienced drinker has a positive blood alcohol level, and that such an individual's blood alcohol level will usually be underestimated by an observer who is not personally familiar with that individual's sober and intoxicated comportment.

From 1974 until 1980 we worked in two different primary settings. One was an outpatient alcohol treatment program that again utilized breath alcohol testing as a routine intake and clinical procedure. The other was a university setting. The study on effects of alcohol on the speech of normal drinkers was conducted at this time, as was a large amount of other experimental research involving administration of alcohol to normal drinkers. In 1980, we joined the Addiction Research Foundation where we hold senior positions and continue to conduct clinical and experimental research on alcohol abusers and normal drinkers; the research often involves breath testing. For example, clients in treatment research projects are breath tested at the start of each clinical session. All in all, we have had considerable experience studying intoxicated and sober behavior both among normal drinkers and among persons who have alcohol problems.

With regard to the present case, we have been apprised of some information that is relevant to our conclusions. In particular, it seems clear that the individual involved does have an alcohol problem history: an arrest in 1984 where he refused to take a breath test, voluntary participation in an alcohol treatment program in 1985, and an arrest in 1988 in which he was breath tested for ethanol and found to have a 190mg/100ml (.19%) blood alcohol level. Given that these occurrences happened over several years, it would be expected that the subject would have acquired a fair amount of tolerance to ethanol. Any intervening period of abstinence would reverse the subject's tolerance somewhat, but we understand that he was observed to be drinking heavily while the ship was in port. If this was the case, then it seems reasonable that we should take into account that he is likely to be fairly tolerant to ethanol, i.e., he would be likely to show less impairment at a given blood alcohol level than would an individual who did not have a heavy drinking background. What this means is that if our conclusions are in error, they are likely to err by underestimating extent of intoxication.

<u>Evaluation of EXXON VALDEZ Special Tape</u> (We each listened to the tape on several occasions).

The key question in evaluating the speech samples provided was whether at any time the speaker was under the influence of ethanol. As the following report reflects, a constellation of factors suggests that the individual probably had consumed an amount of ethanol sufficient to effect his speech in several ways. Based on our experience, which involves individuals in laboratory situations and in alcohol treatment programs, various selections on the tape definitely sound impaired. The speech characteristics are consistent with those we have observed in highly intoxicate individuals whom we have evaluated in our laboratory.

The most striking observation about the tape is the dramatic vocal quality changes (both qualitative and quantitative) over the course of several selections. Specifically, comments in Section 1 and 2 appear rapid, fluent, without hesitation, and with few word interjections (i.e., ah) in relation to the length of the sample. Beginning with Section 3 and continuing through Section 18 there is a marked difference in the vocal sample which we evaluate as having characteristics of a speech sample recorded under the influence of ethanol. The speech sample sounds so impaired that, based on the research literature, even untrained raters should be able to reliably ascertain a difference between these selections and Selections in 1 and 2. In this regard, crew members who could also be considered untrained raters, would probably have noticed changes in the person's speech.

One alternative explanation regarding the speech sample is the possibility that it relates to fatigue and/or stress from the accident. Presently, it is unknown whether changes in speech production that serve as indices of sensory-motor impairment due to ethanol intoxication are affected by factors such as the talker's level of stress and fatigue. The present tape, however, affords an opportunity to evaluate the speaker in the absence of the accident's potential stress/fatigue factor. The comparison involves Selections 1 and 2 (24 hours before the accident) as compared to Selections 3 through 9 which occurred one hour before the accident. Since the accident had yet to occur, these speech samples are free of any accident induced stress/fatigue factor. Nevertheless Selections 3 through 9 sound impaired such as occurs with ethanol intoxication.

The most noticeable vocal quality changes we observed begin in Selection 3 and continue through Selection 25. The types of changes observed were:

(a) considerable word interjections (i.e., ah)
(b) broken words (e.g., gla Selection 9; "BA" in Section 3)
(c) incomplete phrases (e.g., end of Selection 11, Selections 13 and 15)
(d) corrected errors (e.g., "I we'll" Selection 5; "we we" Selection 6; "departed the pilot or disembarked the pilot excuse me" Selection 4);
(e) speaking time and hesitations appear to increase (this can be empirically evaluated by measuring syllable length).

All the above noted changes have been observed in intoxicated speakers (see various published studies). In our judgment, these changes probably reflect sensory-motor impairment due to ethanol intoxication. While we noted several corrected errors, we would further suggest that someone evaluate the tape for other contextual errors (e.g., whether the vessel's position was reported correctly) and inconsistencies in reports that would be obvious to someone familiar with the operation of such a ship. The intent would be to establish whether the speaker's verbal responses reflect behavioral errors and/or aberrant judgments that normally would not be expected from someone with considerable past experience in captaining such a ship.

The word interjection "ah" occurs frequently for this speaker across all the selections. However, a comparison of the various selections reveals a considerable increase in such word interjections. For example, Selection 2 has three "ahs" whereas Selection 11, a comparable length passage, has 10 "ahs." These types of word intrusions continue at a high rate until about Selection 27.

A second perceptible change in the selections appears beginning with Selection 27 where the speaker sounds more fluent (more rapid speech, more responsive) and makes fewer word interjections (ahs).

Although sober as compared to alcohol impaired free speech is usually difficult to evaluate because there are few comparable passages, the present tape provides a unique opportunity as there are a few phrases that are repeated throughout the transcript. Those phrases are "Valdez traffic EXXON VALDEZ," "VALDEZ back over," and "thirteen and sixteen." These phases could be acoustically evaluated and compared. Since these are what might be considered "rote" (i.e., well practiced) phrases, it could be argued that they should be less influenced by alcohol, stress and other factors.

When individuals are under the influence of ethanol, the published research studies have used two evaluation methods to demonstrate vocal impairment: human perceptual judgments (i.e., trained and untrained raters evaluating types of errors and making judgments about whether the speaker was intoxicated) and acoustical analyses (e.g., fundamental frequency, waveforms).

In the absence of perfect measures, one suggested way to draw conclusions about the transcript is to base conclusions on a convergence of indicators (e.g., human perceptual judgments both from

experienced and untrained raters; multiple acoustical variables; behavioral errors or other errors in judgment made while operating the ship). If there are a constellation of different factors that are unusual both in terms of the individual's speech as well as his behavior, then it strengthens the overall conclusions.

It should be noted that drugs other than ethanol could also affect sensory-motor performance and account for the speech samples. However, drugs that might be expected to mimic the effects of ethanol on speech have a sufficiently long half-life such that detectable metabolites should have been detected by toxicological evaluation of bodily fluid or tissue samples drawn many hours after the accident.

Finally, with respect to the toxicology report, it might be useful to compare the ethanol concentrations from the urine and blood samples. It is possible that differences in urine and blood levels could allow an evaluation of whether the samples were obtained on either the ascending or descending limb of the blood alcohol curve.

If you have any further questions please contact us.

Sincerely,

Mark B. Sobell, Ph.D.
Senior Scientist and
Head, Sociobehavioural Research
and
Professor
Departments of Psychology and
Behavioural Science
University of Toronto

Linda C. Sobell, Ph.D.
Senior Scientist and
Head, Behavioural Treatment Research
and
Professor
Departments of Psychology and
Behavioural Science
University of Toronto

Final Report to the NTSB on the Speech Produced by the Captain of the Exxon Valdez[1]

Keith Johnson, David B. Pisoni and Robert H. Bernacki

Speech Research Laboratory
Department of Psychology
Indiana University
Bloomington, IN 47405

May 10, 1990

[1]The analyses reported in this paper were carried out in connection with the National Transportation Safety Board (NTSB) investigation of the Exxon Valdez accident that occurred on March 24, 1989.

Abstract

In this report we consider the possibility that speech analysis techniques may be used to determine whether an individual was intoxicated at the time that a voice recording was made, and discuss an analysis of the speech produced by the Captain of the Exxon Valdez recorded at several points around the time of the accident at Prince William Sound, Alaska. A review of previous research on the effects of alcohol and other effects on speech production suggests that it may be possible to attribute a certain, unique pattern of changes in speech to the influence of alcohol. However, the rate of occurrence of this pattern or the reliability of a decision based on observations such as these is not known. Acoustic-phonetic changes observed in a small number of tokens of Captain Hazelwood's speech recorded before, during and after the accident revealed a number of changes in speech behavior which correlate well with the findings of previous research on the effects of alcohol on speech production.

Final Report to the NTSB on the Speech Produced by the Captain of the Exxon Valdez

In this report, we briefly summarize previous research on the effects of alcohol on speech production and previous research on other effects on speech production. We then discuss an analysis of the speech produced by the Captain of the Exxon Valdez recorded at several times before, during and after the accident at Prince William Sound.[1]

The Problem of Unique Specification

Before discussing this particular case, we wish to place the present investigation within a general framework. The question which we are implicitly attempting to address in this report is whether it is possible to determine if an individual was intoxicated at a particular point in time based on acoustic analyses of voice recordings. This question hinges crucially on whether there are properties of speech which occur when a speaker (any speaker) is intoxicated and which do not occur in any other circumstance. We will call this the problem of unique specification.

In the following section, we review several studies which have found that there are a number of acoustic-phonetic characteristics of speech which occur when individuals are intoxicated. This research is an important first step in determining whether speech patterns may uniquely specify alcohol intoxication, but, to our knowledge, there is no published research which directly addresses the problem of unique specification. In spite of this lack of previous research, there are at least two reasons to believe that voice recordings may contain reliable information which uniquely indicates that an individual was intoxicated at the time of the recording. These have to do with the physiological and pharmacological effects of alcohol and the complexity of speech motor control.

Although the effects of alcohol at a cellular level in the nervous system are not fully understood[2], the general functional effects are clear. "The principal effects of acute dosage of ethyl alcohol are observed in the nervous system, where there is a progressive and simultaneous impairment of function at many levels" (Berry & Pentreath, 1980, p. 43). Ethanol diffuses easily through cell boundaries (Wallgren & Barry, 1970, p. 36), and results in a biphasic neural response. At low concentrations, nerve cell excitability is increased, while at high concentrations there is a progressive reduction of excitability (p. 254). This reduction

[1]The tapes that we analysed and information concerning the communications/recording equipment, the times of the recordings and the results of the blood alcohol test were provided to us by the staff of the National Transportation Safety Board.

[2]Berry & Pentreath (1980) review some of the data having to do with the effects of alcohol on neural membrane permeability and the synthesis and release of neurotransmitter. They note a variety of specific cellular effects and affected sites in the nervous system.

in nerve cell excitability leads to behavioral responses to alcohol which (particularly relevant for speech) include decreased motor coordination.

In addition to the neurological effects of alcohol when it reaches the brain through the blood stream, it is likely that the local contact of alcohol with the surfaces of the mouth and throat have some effect on speech production. It is well known that local concentrations of alcohol in the stomach irritate the mucosa and paralyze the muscles of the stomach wall (Wallgren & Barry, 1970, pp. 40, 61). There is also some evidence which suggests that alcohol applied to the tongue (at least the tongues of cats) can produce a biphasic sensitivity to mechanical stimulation (Hellekant, 1965). These local effects of alcohol in the mouth and throat may result in effects on speech production which differ from the effects which result from other central nervous system depressants or other factors, although we are aware of no previous research which has attempted to test this hypothesis.

Tests of motor coordination (such as walking a straight line or standing on one foot with eyes closed) are commonly used to indicate whether a person is intoxicated. Speech production is another complex motor activity which requires a high degree of coordination and so may also be affected by alcohol consumption. Two types of motor complexity in speech production can be distiguished. First, speech production requires very precise inter-gestural coordination. For example, the main difference between /d/ and /t/ in English is the timing of a gesture of the vocal folds relative to a gesture performed by the tip of the tongue. The relative timing of these two gestures ("voice onset time") is measured in milliseconds (ms) (Lisker and Abramson, 1964). The onset of voicing (vocal cord vibration) for /d/ in word initial position occurs approximately simultaneously with the release of oral stop closure, while the onset of voicing for /t/ occurs 40 to 60 ms after the release of oral stop closure. Mistiming the two gestures by as little as 20 ms results in a perceptually different consonant. Second, speech involves fine motor control in moving the articulators to the target positions for different speech sounds. For example, the fricative /s/ is produced by pressing the sides of the tongue against the upper molars and depressing the center of the tongue, creating a narrow groove with the tip of the tongue. The articulatory difference between /s/ and /sh/ is very subtle even though the acoustic difference is quite large. The location of the tongue relative to the front teeth and the length of the constriction at the roof of the mouth (the tongue groove) distinguish these two sounds in speech production (Subtelny, Oya & Subtelny, 1972). If the tongue tip is kept close to the front teeth and the constriction at the roof of the mouth is relatively short (2.5 cm), an /s/ is produced However, if the constriction is slightly longer or wider, or the tongue tip is held a little further back in the mouth, the resultant sound is more like /sh/. These observations suggest that small variations in speech timing or gestures can have acoustically reliable consequences for speech production (Stevens, 1972). Alcohol's effects on the central nervous system and the local effects of alcohol on the muscles and proprioceptors of the vocal aparatus, coupled with the inherent complexity of speech production, suggest that there may be patterns of speech production which are uniquely attributable to alcohol intoxication.

Previous Findings on Alcohol Impaired Speech

This section is a brief review of previous research on the effects of alcohol on speech production. For more complete reviews of the literature see Pisoni, Hathaway and Yuchtman (1986), Klingholz, Penning and Liebhardt (1988) and Pisoni and Martin (1989). The effects of alcohol on speech production that have been observed in controlled laboratory studies can be divided into three types: gross effects, segmental effects and suprasegmental effects. Examples of each of these effects are listed in Table 1.

Insert Table 1 about here

Gross effects involve word level alterations in speech production. These effects are very noticeable when intoxicated subjects are instructed to read a passage. Subjects may revise, omit or interject words (Sobell and Sobell, 1972; Sobell, Sobell and Coleman, 1982). It has been assumed that this class of errors reflects changes or modifications in speech planning. As neural function is depressed by alcohol, the speaker's ability to control the articulators is impaired which in turn may affect the planning stage in speech production. Thus, word level alterations occur when the subject is required to read a passage. In spontaneous speech, however, it is much harder to decide what should count as a gross error because the speaker's intended utterance is not known. Therefore, gross effects are less valuable for the evaluation of spontaneous speech and diagnosis of any impairment due to alcohol.

Segmental effects involve the misarticulation of specific speech sounds. The segmental effects which have been most often reported are: misarticulation of /r/ and /l/, misproduction of /s/ (more like /sh/), final devoicing of obstruents, and deaffrication. Examples of the last two effects are given in Table 1. Obstruent devoicing involves a problem of timing and glottal control similar to the example of /d/ and /t/ given in the previous section. The other segmental effects involve the control of the tip of the tongue. Lester & Skousen (1974) found that segmental effects such as these did not appear until subjects had consumed about 10 ounces of 86 proof straight bourbon over a period of about 3 and 1/2 hours.

Phonetic theory makes some predictions about the changes/modifications of speech articulation after alcohol consumption. These predictions derive from the study of articulatory ease (see for example Lindblom, 1983) which suggests that not all speech sounds are equally easy to produce. Evidence of this comes from studies of the development of speech in children (de Villiers & de Villiers, 1978), the patterns of historical language change (Antilla, 1972). and patterns of language dissolution in aphasia (Jakobson, 1941), as well as model studies of articulation (Lindblom, 1983). Most of the segmental effects observed in speech produced while intoxicated have analogs in these data. For instance, it is common for children to misarticulate /r/ and /l/ as in the production of "train" as /twen/. Also, final devoicing

Table 1

Summary of previous research on the effects of alcohol on speech production.

Gross effects	word/phrase/syllable interjections[1]
	word omissions[14]
	word revisions[1]
	broken suffixes[1]
Segmental effects	misarticulation of /r/ and /l/[45]
	/s/ becomes /sh/[34]
	final devoicing (e.g. /iz/ – > /is/)[35]
	deaffrication (e.g. 'church' – > 'shursh'[345])
Suprasegmental effects	reduced speaking rate[1235]
	decreased amplitude[2]
	increase of unvoiced to voiced ratio[356]
	decreased spectral tilt[6]
	mean change in pitch range (talker dependent)[4567]
	increase in pitch variability[56]

[1]Sobell & Sobell (1972). 16 alcoholics, 5–10 ounces, 86 proof alcohol.
[2]Sobell, Sobell & Coleman (1982). 16 talkers, 0.05 < BAL < 0.1%.
[3]Lester & Skousen (1974). Number of talkers not mentioned, 86 proof straight bourbon, one ounce/20 min. up to 14 ounces.
[4]Trojan & Kryspin-Exner (1968). 3 talkers, 1 to 1.38 liters of heavy Austrian wine (13% alcohol).
[5]Pisoni, Hathaway & Yuchtman (1986) and Pisoni & Martin (1989). 5 talkers, 0.1 < BAL < 0.17%.
[6]Klinghols, Penning & Liebhardt (1988). 16 talkers, 0.067 < BAL < 0.16%.
[7]Dunker & Schlosshauer (1964). 1 talker, "consuming alcoholic beverages liberally" and shouting.

and deaffrication are very common in child speech and in historical language development. The substitution of /sh/ for /s/, however, is not typically found in child speech, and /s/ is more common than /sh/ in the languages of the world. Therefore, this segmental effect, rather than being the result of a general loss of motor coordination (as is most likely the case for the other segmental effects), seems to have a different cause. The change of /s/ to /sh/ may be related to loss of responsiveness of the surface muscles of the tongue or a loss of proprioceptive feedback from the tongue after direct contact with ethanol during consumption.

Suprasegmental effects are perhaps more perceptually salient than segmental effects, but require quantification. These effects involve the rate and amplitude of speech and vocal cord function. Trojan & Kryspin-Exner (1968) reported an increase in voice fundamental frequency (rate of vocal cord vibration). Pisoni & Martin (1989) found that fundamental frequency decreased for some, but not all subjects. Klingholz et al. (1988) also found a tendency for decreased fundamental frequency. Fundamental frequency (F0) is also more variable in speech produced while intoxicated when compared to a control condition (Pisoni & Martin, 1989; Klingholz et al., 1988). Klingholz et al. (1988) also found that the speech harmonics-to-noise ratio decreased after alcohol intoxication. This measure reflects a change in the mode of vocal cord vibration indicative of increased breathiness after alcohol intoxication. They also found a change in the long-term average (LTA) spectrum in intoxicated speech. There was an increase in high frequency energy, which may reflect an increase in the unvoiced/voiced ratio after alcohol consumption (as reported by Pisoni & Martin, 1989). All of these effects can be measured directly using digital signal processing techniques (see Pisoni & Martin, 1989 and Klingholz et al., 1988).

The effects on speaking rate and F0 can be related to the general physiological effects of alcohol in the following ways. The reduction in speaking rate may be the result of an attempt to compensate for the loss of motor coordination which accompanies intoxication. The effect of alcohol on F0 seems to have an origin in the interaction of alcohol and the tissue of the vocal cords. Klingholz et al. (1988) suggest that the effect of alcohol on F0 may be the result of irritation and swelling of the mucous membranes of the vocal cords and desensitization of the proprioceptors of the vocal cords. They cite evidence from Dunker & Schlosshauer (1964) which indicates that vocal cord vibration after alcohol consumption (like vocal cord vibration for people with hoarse voices) is more variable and lower in pitch. Klingholz et al. posited a connection between vocal cord swelling due to mechanical stress (shouting or speaking for an extended time) and swelling due to alcohol consumption. This explanation may also account for the increase in the unvoiced/voiced ratio in intoxicated speech.

Other Effects on Speech Production

In this section, we briefly review some of the previous research on environmental and emotional effects on speech production and compare these effects with the effects of alcohol on

speech production. Table 2 is a summary of some previous research addressing environmental and emotional effects on speech production. As indicated in this table, most researchers who have investigated the effects of these factors on speech production have focussed on suprasegmental phenomena. Only occassionally have segmental phenomena other than vowel formant measures been investigated. This research focus reflects a practical concern for the design of automatic speech recognition devices for use in a variety of circumstances, where suprasegmental changes and some types of segmental changes could be detrimental to the performance of recognition systems. Therefore, the data-base we are reviewing here is not entirely comparable to that collected in the study of the effects of alcohol on speech.

Insert Table 2 about here

Hansen (1988) and Summers et al. (1988) studied the effects of *noise* on speech production (the Lombard effect). These studies found that speech produced with a high level of noise at the ears had increased fundamental frequency (F0) and duration, and reduced spectral tilt.[3] The spectral tilt measure indicates that there was a relative increase of high frequency glottal energy in the Lombard condition. Surprisingly, Hansen (1988) found no change in amplitude. The Summers et al. (1988) result is in better agreement with earlier research. Finally, the studies indicate some individual variability in the effect of noise on vowel formant values.

Moore & Bond (1987) studied the effects of *acceleration* and *vibration* on speech produced by two subjects. The two situations resulted in comparable effects on F0, intensity and vowel formants. F0 increased relative to that found for the same subjects in benign environments, vocal intensity was unchanged and vowels were less distinctive (more like /ə/). There was individual variability in the effect of acceleration on segmental duration, while speaking rate increased (reduced segmental durations) in the vibration condition. The small number of subjects in these studies is problematic, but this is the only available data on these environmental effects.

A large number of studies have employed *workload* tasks to simulate environments with high cognitive demands such as airplane cockpits. These studies have generally found that speech produced while performing a cognitively demanding task has higher F0, decreased spectral tilt and increased intensity. Data on the variability of F0 (SD F0) is mixed. This reflects a problem in the use of this measure due to the fact that F0 variability can be affected

[3]Hansen (1988) measured the tilt of the glottal spectrum (after inverse filtering) while the other authors listed in Table 2, who reported spectral tilt changes, measured changes in the spectral tilt of the unfiltered speech signal. There is general agreement between studies using the two measures, although note that valid tilt comparisons using the simpler method require careful control of the phonetic content (particularly vowel qualities) of the tokens being compared.

Table 2

Summary of some recent research on environmental and emotional effects on speech production.

Condition	F0	SD F0	Jitter	Tilt	Duration	Intensity	Formants
Noise[1]	⇑	⇑		⇓	⇑	NC	F1 ⇓
Noise[2]	⇑			⇓	⇑	⇑	F1 ↑
Acceleration[3]	⇑				⇕	NC	centralized
Vibration[3]	⇑				⇓	NC	centralized
Workload[1]	⇑	⇑		⇓	NC	↑	F1 & F2 ⇑
Workload[4]	↑	↓		⇓	↓	↑	NC
Workload[5]	⇑	↑			⇓	⇑	
Stess[6]	↑		↓		⇓	⇑	
Stress[7]	↑		⇓				
Stress[8]	⇕				⇕	↑	
Perceived Stress[8]	⇑				⇑	⇑	
Fear[9]	⇑	⇑	⇑	NC	⇑		NC
Fear[1]	⇑	⇑		⇓	NC	⇑	F1 & F2 ⇑
Anger[9]	⇑	⇑	NC	⇓	NC		F1 ⇑
Anger[1]	⇑	⇑		⇓	⇑	⇑	F1 ↑
Sorrow[9]	⇓	⇓	⇑	⇑	⇑		NC
Depressed[1]					⇑		centralized
Intoxicated[10]	⇕	⇑		⇓	⇑	↓	

⇑= reliable *increase* for all subjects.
↑= increase for some, but not all subjects.
⇓= reliable *decrease* for all subjects.
↓= decrease for some, but not all subjects.
⇕= some subjects showed a reliable increase, while some a reliable decrease.
NC = no change.

[1]Hansen, 1988 (8 talkers).
[2]Summers, et al., 1988, see also Pisoni, et al., 1985 (2 talkers).
[3]Moore & Bond, 1987 (2 talkers).
[4]Summers, et al., 1989 (5 talkers).
[5]Griffin & Williams, 1987 (20 talkers).
[6]Brenner & Shipp, 1988 (17 talkers).
[7]Brenner, Shipp, Doherty & Morrissey, 1985 (7 talkers).
[8]Streeter, et al., 1983 (2 talkers).
[9]Williams & Stevens, 1972, see also Williams & Stevens, 1981 (3 talkers).
[10]See Table 1.

in two very different ways. Variability will be reduced if the F0 contour of utterances are more monotonic in the workload condition (as suggested by Summers et al., 1989) or if there is less period-to-period variation in the vibratory cycle of the vocal cords (as suggested by Brenner et al., 1987, who also used a cognitively demanding task). On the other hand, F0 variability could be increased if utterances in the workload task had more extreme fluctuations in their F0 contours even if vocal cord jitter (period-to-period variation of F0) were reduced. Williams & Stevens (1972) provide a good example of the conceptual distinctions which need to be maintained in this area, although they did not have digital signal processing techniques at their disposal. They reported both changes in F0 range and (inferences about) changes in F0 jitter. In the absence of this distinction in some of the research on the effects of cognitive workload, it is impossible to determine whether the reported differences in F0 variablity in speech under workload reflect real individual differences or merely differences in data collection techniques. Table 2 also indicates some differences across studies in the effects of workload on segmental duration, although it is interesting that the study on the effects of workload which employed the greatest number of subjects (Griffin & Williams, 1987) reported a consistent decrease in duration. Finally, there is also some discrepancy concerning the effects of workload on vowel formant frequencies.

The term *psychological stress* has been used to describe situations ranging from lying to being in a fatal airplane crash. Scherer (1981) outlined some predictions for speech production in stressful situations based on the general physiological response to stress (similar to the discussion above of physiological predictions for the effects of alcohol) and then concluded that "virtually all of the studies in this field have found very strong individual differences in terms of the number and kind of vocal parameters that seem to accompany stress" (p. 179). He focussed on two problems in the literature, (1) the likelihood that subjects in laboratory studies of stress were differentially stressed, and (2) the fact that "subjects may differ in terms of the degree of control they can exert as far as their vocal production under emotional arousal is concerned" (p. 180).[4] In spite of these problems, some general trends emerge from studies of stress in laboratory and real-life emergency situations. These are indicated in Table 2 and include an increase in F0, an increase in intensity, and a decrease in F0 jitter. Brenner, Shipp, Doherty & Morrissey (1985) examined F0 jitter in situations of high stress by analyzing voice recordings of pilots involved in aircraft crashes. They found that speech in stressful situations had increased F0, and decreased F0 jitter. In a related laboratory study, Brenner et al. (1985) also found that the activity of the cricothyroid muscle, which is the primary muscle of the larynx involved in controlling F0, increased as stress increased. This provides an explanation of both the increased F0 and decreased F0 jitter found in the other studies.

Streeter, MacDonald, Apple, Krauss and Gallotti (1983) reported a case of individual

[4]Both of these problems have analogues in studies of the effects of alcohol on speech. Although, it is possible to objectively measure the subjects' blood alcohol level, not all previous research on the effects of alcohol on speech production have reported BALs. Also, subjects may differ in the degree of articulatory control they can exert while intoxicated.

variability in the vocal effects of stress. They examined a recorded telephone conversation between a system operator and chief system operator for Consolidated Edison during the New York City blackout, July, 1977. One talker had increased F0, duration, and amplitude as the situation developed (and presumably stress increased), while the other showed a different pattern (decreased F0 and duration, and no change in amplitude). This study illustrates Scherer's (1981) point about individual differences in response to stressful situations, and suggests that there may be no consistent phonetic pattern for any but the most extremely stressful, life-threatening situations. Interestingly, though, Streeter et al. found that naive listeners used phonetic cues consistently in making judgements about the degree of stress being experienced by the talker. Listeners judged utterances with higher F0, higher amplitude and longer segment durations as more stressed even though, for one speaker, these judgements were not correlated with degree of experienced stress. The speech parameters which were found in this study to be correlated with *perceived stressed* are listed in Table 2. Streeter et al. concluded that listeners have stereotyped expectations for vocal responses to stress, which evidently are accurate for the most extreme levels of stress, but speakers who are actually experiencing some less than maximal degree of stress do not always fit the perceptual stereotype.

Table 2 also presents a summary of several studies on the effects of emotional state (fear, anger and sorrow) on speech production. The study of the effects of emotion on speech production involves methodological problems that are not involved in the study of environmental effects on speech, where it is possible for the experimenter to create conditions which can be carefully controlled and described. In order to study the effects of emotion on speech production, however, it is necessary to rely on subjective measures of the emotional (mental) state of the speaker or have speakers simulate various emotions. In spite of these methodological difficulties, we are including this summary of previous research in an attempt to present a complete review of the factors that may affect speech production.

Williams & Stevens (1972, 1981) hired three actors to perform short plays in which the characters displayed various emotions. Their data are summarized in Table 2 and compared with some recent data from Hansen (1988), who studied the effect of *fear* by having his subjects read a prepared wordlist as they were decending steep drops on a roller-coaster. There is good agreement between these two studies concerning the effects of fear on F0. Both found that F0 increased and that F0 variability increased. Williams & Stevens also suggested that, in addition to increased F0 range, F0 jitter increased. Whereas Williams & Stevens reported no change in spectral tilt, Hansen found that the glottal spectrum was flatter in the fear condition. The more sophisticated signal processing techniques employed by Hansen may have allowed him to detect a small change not seen by Williams & Stevens. The two studies also found different effects on segmental duration. Hansen found no change, while Williams & Stevens found an increase in word duration of about 30 ms. This seems to reflect a real difference, and again may be a result of methodological differences. Hansen reported that intensity increased in the fear condition. This effect is consistent with findings for psychological stress and increased workload and seems to reflect a change in arousal

(Scherer, 1981). Finally, Hansen found changes in the first two vowel formants which were not found by Williams & Stevens.

Hansen (1988) and Williams & Stevens (1972) also studied the effects of *anger* on speech production. Here the two studies had similar methodologies and very similar results. They both found that F0, F0 varibility and F1 increased, and that spectral tilt decreased. Williams & Stevens found no changes in F0 jitter, although they were using a somewhat crude measure (fluctuation in narrow-band spectrograms). Hansen found an increase in intensity. The only discrepancy between the two studies has to do with the effect of anger on speaking rate. Where Williams & Stevens found no reliable change, Hansen also found that speaking rate decreased (increased segmental durations) in the anger condition. Notice the similarities between the effects of anger and the effects of workload and fear.

The final emotion listed in Table 2 is *sorrow*. Again, the data listed in the table are from Williams & Stevens (1972) and Hansen (1988).[5] Speech produced by actors protraying sorrow was characterized by decreased F0, decreased F0 range but increased F0 jitter. Williams & Stevens also found that spectral tilt increased in the sorrow condition (i.e. that there was a reduction of high freqency energy). Both Hansen and Williams & Stevens found an increase in segmental durations, but they found different effects on vowel formants. Williams & Stevens found no change in vowel formants while Hansen suggested (based on very few measurements) that vowels were more centralized in the depressed condition.

We have also included in Table 2 a summary of the suprasegmental effects found in the studies of alcohol and speech which were listed in Table 1. There are no situations or emotions listed in Table 2 which have exactly the same pattern of effects found in the studies of alcohol and speech, and so, given adequate measures of these acoustic correlates, it would be possible to classify the changes observed across two or more samples of speech as more like the pattern found for intoxicated speech than, for instance, speech produced in noise. It is not possible, however, to give any kind of confidence rating to such a classification, because there is not enough published data on individual differences which would allow the calculation of hit rates and false alarm rates for classifications based on these measures (this is true of the other effects shown in Table 1 also).

Another problem with classifying speech samples is that there are some possible physiological effects on speech production, which have not been previously studied. The effect of fatigue on speech production has not been examined in any controlled study of speech production. Also, we lack any data on speech production just after the speaker has been awakened. Our subjective impression is that speech produced in these circumstances may involve changes in vocal cord activity (extremely low F0 or pulse register phonation), decreased speaking rate and perhaps some effects related to dehydration of the mucous membranes in

[5]The data reported by Hansen are based on a small number of observations. These data are included in the table because they come from a real life situation (recordings made during counselling sessions in a psychiatrist's office) and as such offer some degree of validation of the observations of Williams & Stevens.

the mouth, which may be similar to the effects seen after alcohol consumption. However, the relevant controlled laboratory studies haven't been done. There are also no data on more complex situations involving combinations of effects. For instance, no one has studied what happens to speech when the speaker is both tired and under stress.

The Speech of Captain Hazelwood

We have analyzed five different samples of speech provided to us by NTSB. Also, we examined a small number of utterances from Captain Hazelwood's televised interview with Connie Chung which was broadcast on March 31, 1990. We will refer to the speech samples according to the times at which they were recorded: (-33) 33 hours before the accident[6], (-1) one hour before the accident, (0) immediately after the accident, (+1) one hour after the accident, (+9) nine hours after the accident and (CC) televised interview. We will discuss gross errors, segmental changes, and suprasegmental changes.

Insert Table 3 about here

Gross Errors

Several of the speech errors in the NTSB tapes may be classified as gross phonetic errors. These are listed in Table 3. Note, however, that such phenomena are not uncommon in spontaneous speech regardless of alcohol consumption. What is needed in order to evaluate the condition of the speaker is a large amount of speech in which it is possible to compare the rate of occurrence of such errors across speech samples. Also, since the talker was not reading a prepared text, it is a matter of subjective judgement to say that something is or is not an error. To attempt to control for this problem, we are only reporting cases in which

[6]It is important to note here that the recording made 33 hours before the accident has a different history than the other recordings. All of the NTSB recordings were initially recorded using the same Coast Guard equipment, but this sample was then re-recorded onto a handheld cassette recorder before the original tape was mistakenly erased. The recording which we analyzed was produced by playing back the cassette tape using the same cassette recorder which had been used to record the sample. We investigated the possibility that the recording was corrupted by analyzing an unidentified background sound which seemed to be present in both the -33 sample and in the -1 sample. In the -33 recording, the sound had a higher average fundamental frequency (480 Hz, n=4 versus 472 Hz, n=10) and a greater F0 range (438 Hz to 588 Hz versus 456 Hz to 481 Hz) as compared with the -1 recording. The variability of the F0 in the -1 recording suggests that the sound was not constant in frequency and, thus, is not an adequate benchmark for determining the validity of the -33 recording. However, even if the -33 recording is corrupted by tape speed fluctuations of the magnitude indicated by these measurements (-9% to +22%), this degree of difference is not enough to account for the changes in speech production we report below.

Table 3

Summary of phenomena found in the analysis of the NTSB tape. Numbers in parentheses indicate the time of recording.

Gross effects	revisions (-1) Exxon Ba, uh Exxon Valdez (-1) departed – > disembarked (-1) I, we'll (-1) columbia gla, columbia bay
Segmental effects	misarticulation of /r/ and /l/ (0) northerly, little, drizzle, visibility /s/ becomes /sh/ see Figure 3 final devoicing (e.g. /z/ – > /s/) (-1,0,+1) Valdez – > Valdes
Suprasegmental effects	reduced speaking rate see Figures 4 & 5 mean change in pitch range (talker dependent) see Figure 6 increased F0 jitter see Figure 6

the speaker corrected himself. As indicated in the table, the only examples of gross speech effects which we found in the NTSB tapes occurred in the recording made one hour before the accident.

Segmental Phenomena

Also in Table 3, we have listed some examples of segmental errors. The problem with these data is that the recordings are noisy. Identifying most of the examples listed in the table required repeated listening and phonetic transcription (the exception is the /s/ − > /sh/ example). The amount of noise on the tape increases the probability that the transcriptions are inaccurate. Therefore, we performed acoustic analyses of several productions of /s/.

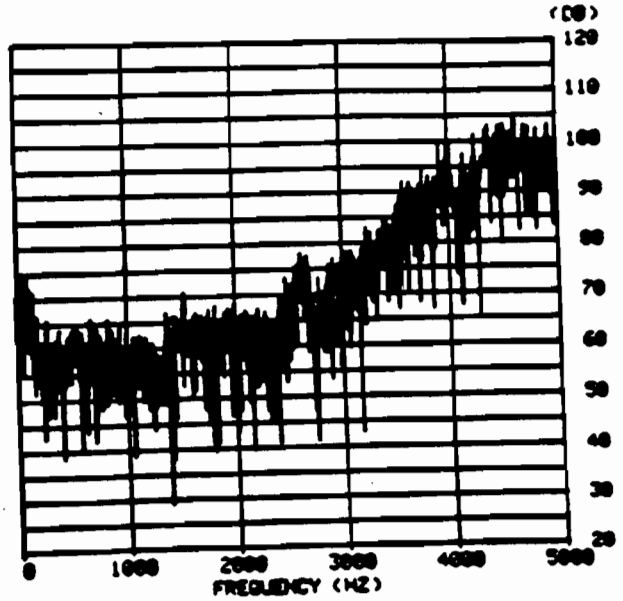
Figure 1 shows power spectra of /s/ and /sh/ produced by the first author (KJ). The horizontal axis in these graphs shows frequency from 0 to 5000 Hz and the vertical axis shows amplitude in decibels. Many speech sounds (including /s/ and /sh/) can be distinguished by their amplitude spectra because they have differing amounts of energy at different frequencies. In particular, /s/ is characterized by a peak of energy in the range from 4000 to 5000 Hz, while /sh/ has a lower frequency peak (in the range from 3000 to 4000 Hz) and a lower amplitude peak of energy in the range from 2000 to 3000 Hz. The spectra in Figure 1 illustrate what the power spectra of /s/ and /sh/ look like in recordings which have a high signal-to-noise ratio and frequency information up to 5000 Hz (see also Borden and Harris. 1984, p. 189).

Insert Figure 1 about here

Figure 2 shows power spectra of the /sh/s of *shout* and *she's* (and spectra of background noise near the fricative) as spoken by Captain Hazelwood in the recording made 33 hours before the accident. The spectra in Figure 2 give an indication of what this speaker's /sh/ will look like in this type of display. The lower amplitude peak between 2000 to 3000 Hz, illustrated in Figure 1, is present in the spectra in Figure 2, but the higher frequency information which would serve as the most reliable information distinguishing /s/ and /sh/ is not present in these spectra because the radio transmission equipment was band limited at 3000 Hz[7]. In making these comparisons, we had to be concerned also about the spectral shape of the background noise in the NTSB recordings. The spectra in Figure 1 were calculated from recordings made in a quiet recording booth, while the NTSB recordings have background noise which may be confused with fricative noise. Therefore, paired with each fricative spectrum from the recordings, we also show a spectrum of nearby background noise as a baseline against which the fricative spectrum can be compared.

[7]Energy above 3000 Hs was attenuated at approximately 50 dB per octave with a noise floor 50 dB below maximum signal level.

/s/



/sh/

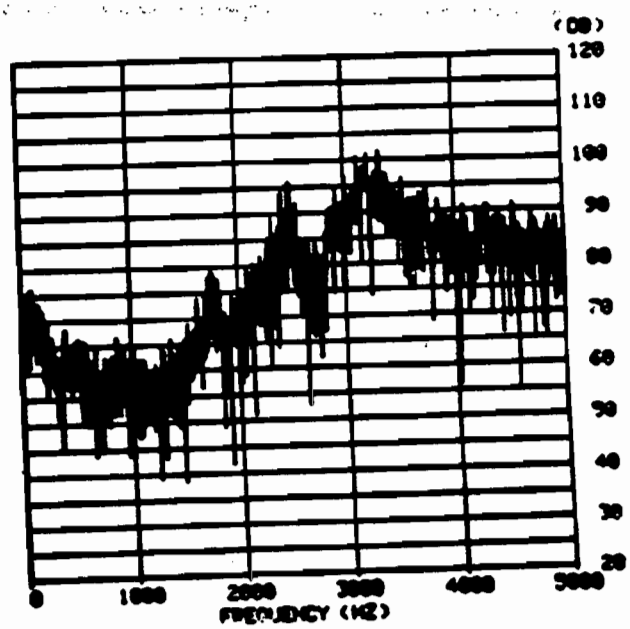


Figure 1. Power spectra of /s/ (top) and /sh/ (bottom) produced by KJ in a quiet recording booth with recording equipment responsive up to 5000 Hz.

Insert Figure 2 about here

Figure 3 shows power spectra of the /s/ of *sea* (or *see*) from the five different recordings paired with spectra of background noise from the same recording. The noise spectra were taken from nearby, open-mike background noise. On average the noise segments were 1.3 seconds from the /s/ segments[8]. The /s/ spectrum from the earliest recording (33 hours before the accident) has the same basic shape that the background noise has, suggesting that the /s/ is buried beneath the noise, or more accurately, that the main spectral energy for /s/ is not within the frequency range of the transmission system. The same is true for the /s/ of *sea* recorded one hour before the accident. The spectra of /s/ from the recordings made immediately after the accident and one hour after the accident have peaks of energy (relative to the background noise) in the region from 2000 to 3000 Hz. Finally, the spectrum of /s/ recorded 9 hours after the accident does not have a peak of energy in the region from 2000 to 3000 Hz. We interpret the peaks in the /s/ spectra from samples recorded immediately before the accident and one hour after the accident as evidence for a segmental change from /s/ to /sh/. There is no evidence in these spectra, nor in the other /s/ spectra which we examined, for this segmental change between the earliest recording and the one made one hour before the accident. These spectral changes reflect a change in the articulation of /s/ which has been observed in earlier studies of the effects of alcohol on speech production (Lester & Skousen, 1974; and Trojan & Kryspin-Exner, 1968).

Insert Figure 3 about here

Suprasegmental Properties

Finally, we examined the suprasegmental properties of the speech samples. Because the communication equipment had an automatic gain control and the distance between the microphone and the speaker's lips was (presumably) variable, it is inappropriate to compare measurements of speech amplitude or long-term average spectra. Therefore, we focussed our attention on speaking rate and voice fundamental frequency. We took care to control for discourse position and the position of words within sentences because these factors can

[8]We estimate that the signal-to-noise ratio in these samples ranges from 5 to 10 dB. This estimate of signal-to-noise ratio was taken from measurements of background noise during stop closures because the transmission equipment had an automatic gain control making amplitude measures from pauses inappropriate. Note also that this means that the amplitudes of the background noise spectra in Figures 2 and 3 do not accurately reflect the amplitude of background noise in the fricative spectra.

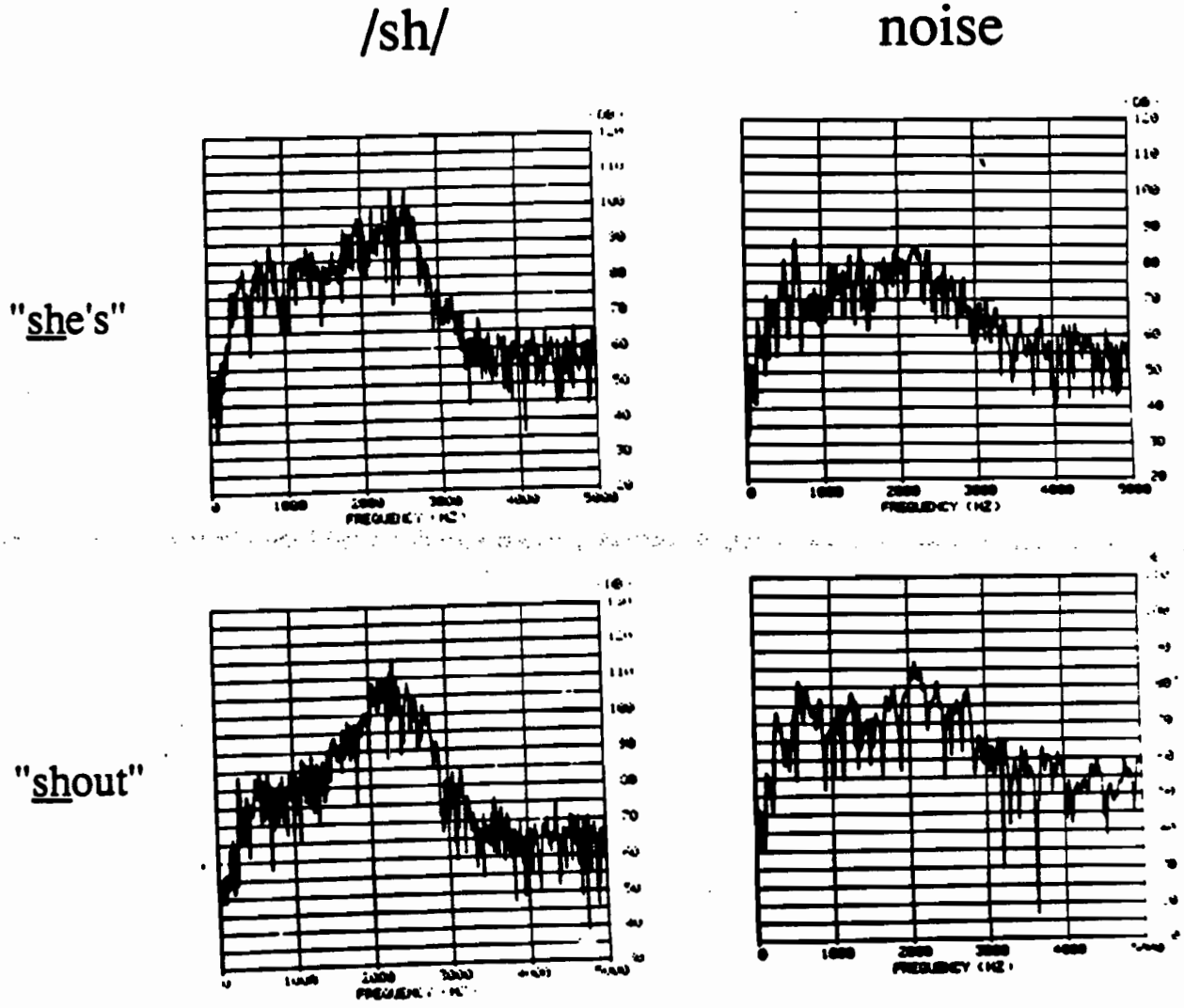


Figure 2. Power spectra of /sh/ produced by Captain Hazelwood in the words *she's* and *shout* recorded 33 hours before the accident. Each spectrum is paired with a spectrum of the background noise from a nearby open-mike pause.

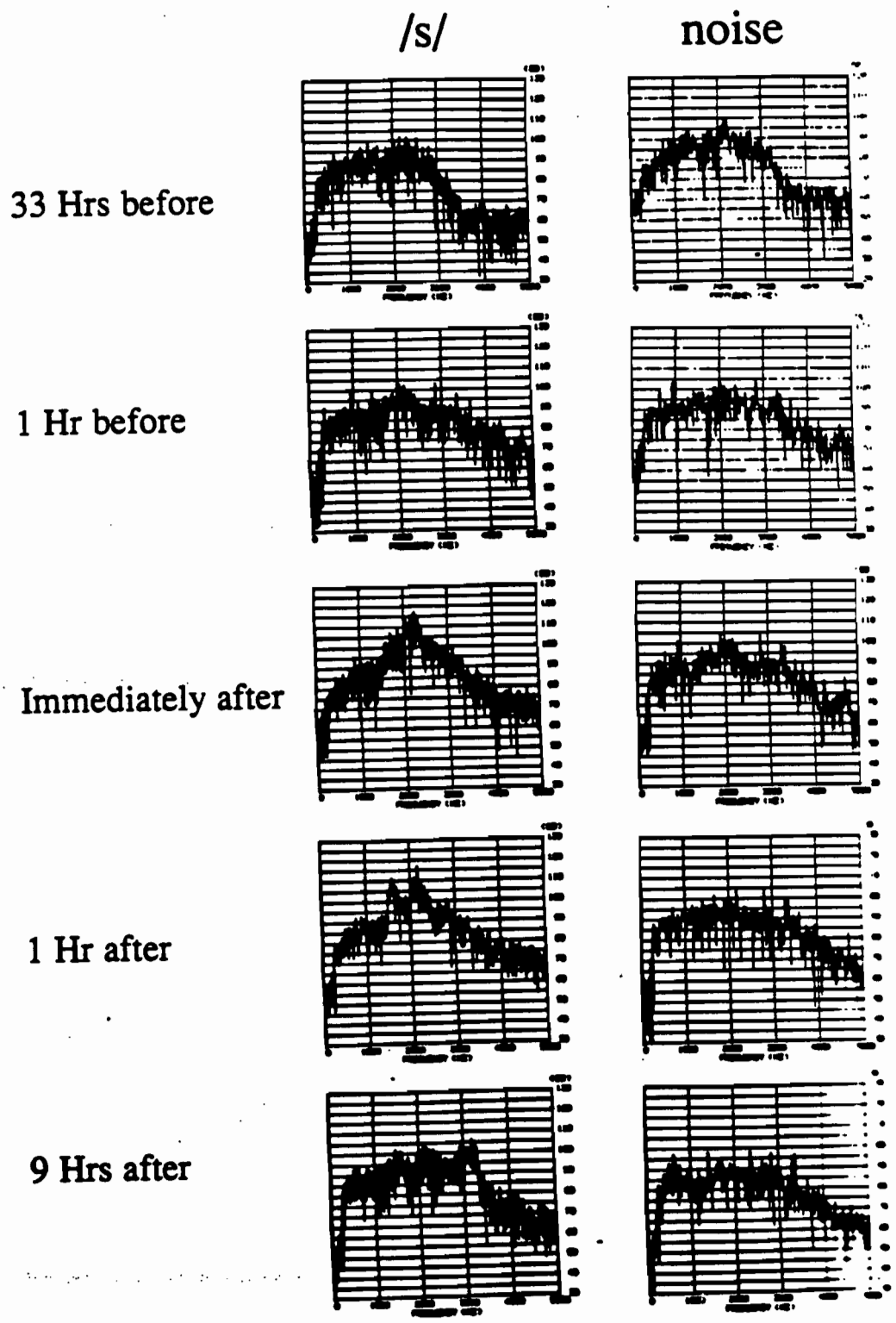


Figure 3. Power spectra of /s/ paired with spectra of nearby open-mike pauses from each of the NTSB recordings.

effect the suprasegmental properties of speech (Lehiste, 1970; Klatt, 1976). We analyzed two phrases, "*Exxon Valdez*" and "*thirteen and sixteen*", because these phrases were repeated several times during the recordings and occupied comparable positions in discourse and sentence contexts across the different recordings. Thus, these phrases provide a measure of control which is needed in making valid suprasegmental comparisons across speech samples.

Figure 4 shows durations of the speech segments in *Exxon Valdez* from each of the recordings. Each bar in this figure is the average of two occurrences of the phrase. As indicated in the top panel, it took longer to say the phrase in the samples recorded near the time of the accident. The bottom panel of Figure 4 (which is another plot of the same data) shows that this effect was more pronounced for the vowels and the /v/ of *Valdez*. If we take this as an index of speaking rate, it is reasonable to conclude from these measurements that the Captain was speaking more slowly in the samples recorded around the time of the accident than in the other samples on the NTSB tape.

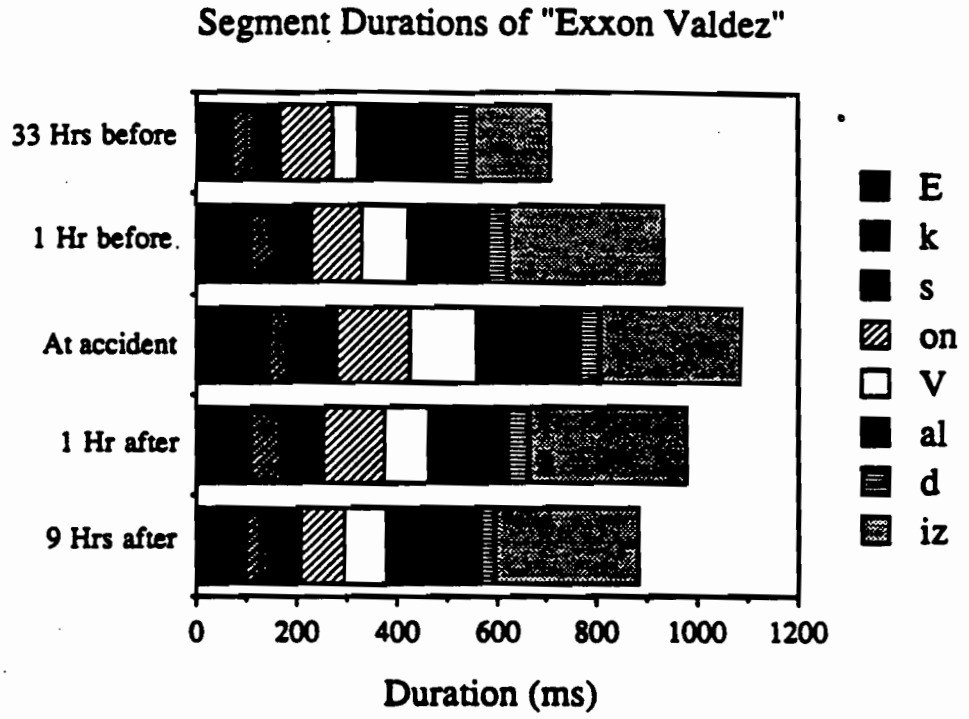
Insert Figure 4 about here

One occurrence of the word *Valdez* occurred in the televised interview. This word was spoken in a discourse position which was comparable to that of *Exxon Valdez* in the NTSB recordings (utterance initial position in a short sentence). The top panel of Figure 5 compares the duration of *Valdez* in the interview with the occurrences of this word in the NTSB recordings. This comparison suggests that the Captain was speaking at his normal rate in the recording made 33 hours before the accident, and more slowly in the recordings made around the time of the accident.

We also measured the duration of the phrase *thirteen and sixteen* which occurred in discourse final position in three of the recordings (33 hours before the accident, one hour before the accident and one hour after the accident). These measurements are shown in the bottom panel of Figure 5. As with the durations of the phrase *Exxon Valdez*, this analysis indicates that Captain Hazelwood was speaking more slowly in the recordings made around the time of the accident than in the recording made 33 hours before the accident.

Insert Figure 5 about here

Durational changes are perhaps the most reliable effects we have found in the NTSB recordings and they suggest that Captain Hazelwood was speaking more slowly than normal around the time of the accident. These changes in duration are consistent with the laboratory



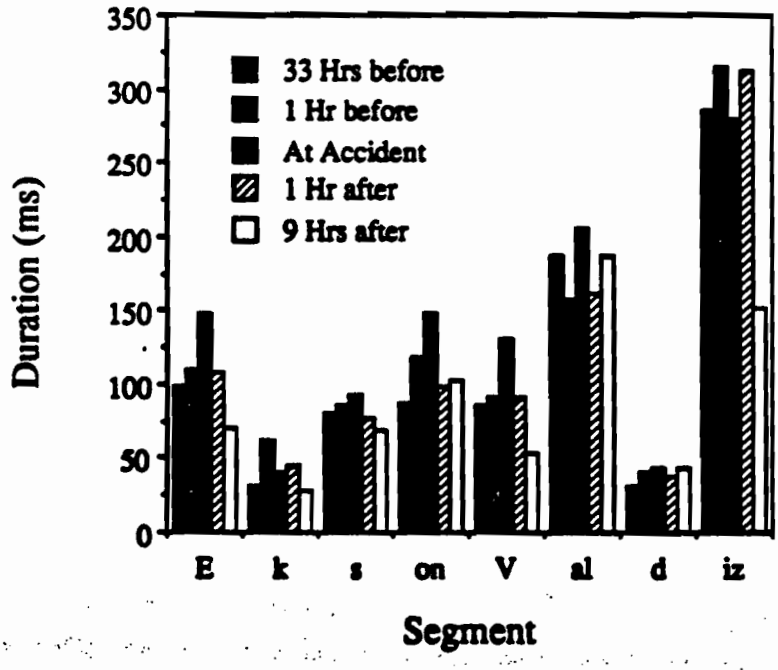


Figure 4. Durations of speech segments in the phrase, *Exxon Valdez* at the different times of recording. Top panel: cumulative durations indicating the overall increase in duration. Bottom panel: durations grouped by segments showing which segments had increased duration around the time of the accident.

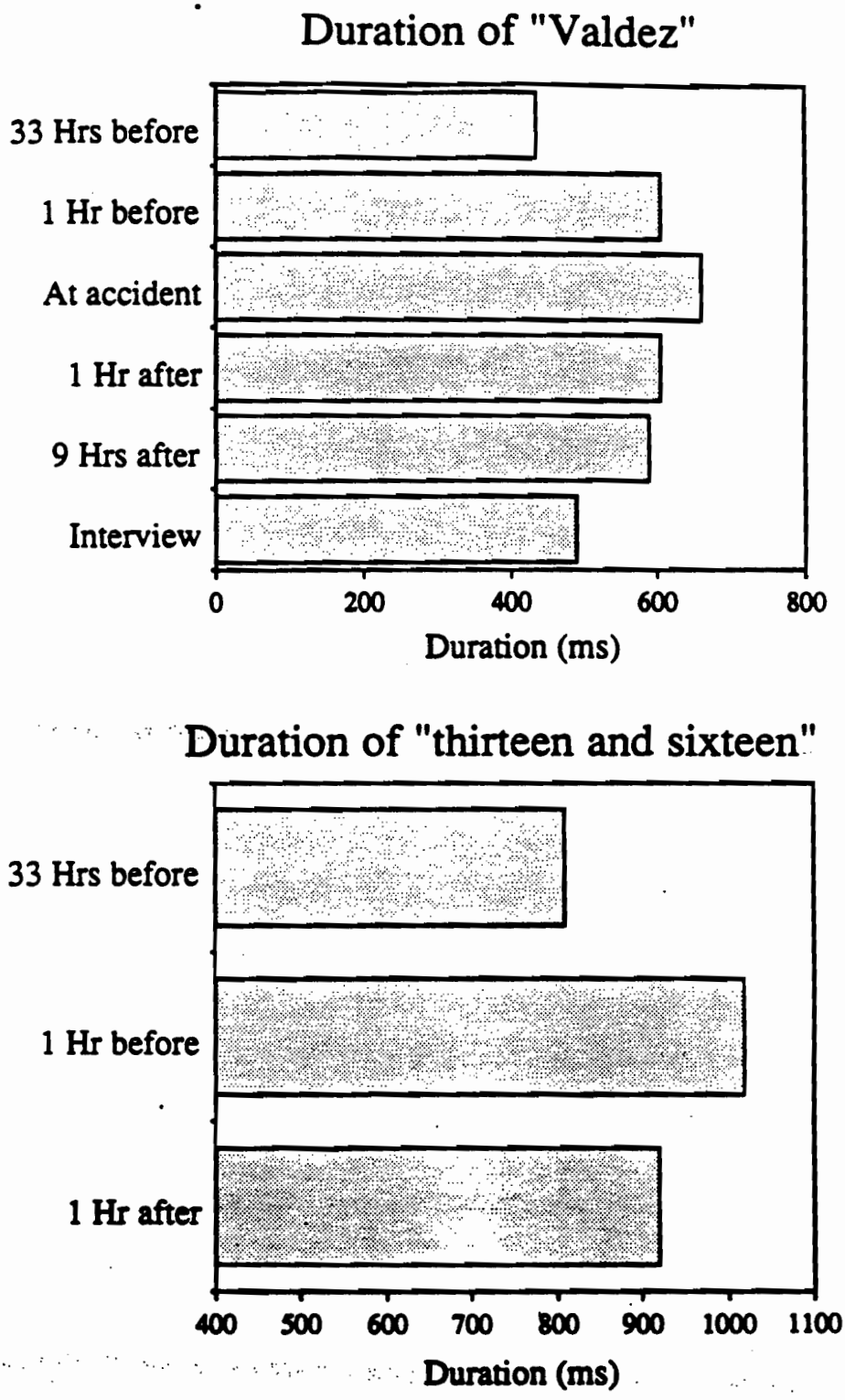


Figure 5. Top panel: Duration of the word *Valdez* from the NTSB tapes (data is the same as that in Figure 4) compared with the same word produced in a similar discourse position in the televised interview. Bottom panel: Duration of the phrase *thirteen and sixteen* from recordings made at three times around the time of the accident.

findings reported by Pisoni, et al. (1986) and Pisoni & Martin (1989) for speech produced while intoxicated.

The top panel of Figure 6 shows voice fundamental frequency (F0) averaged across the phrase *Exxon Valdez* in each of the speech samples, the phrase *thirteen and sixteen* from three of the NTSB recordings, and one sentence from the televised interview. We took F0 measurements from each of the four vowels in *Exxon Valdez* (which occurred at least twice in each of the NTSB recordings). We were not able to measure F0 in all of the vowels in *thirteen and sixteen* because this phrase occurred in utterance final position in the recordings and was produced with quite low amplitude. Each point in Figure 6 for *thirteen and sixteen* is based on measurements from at least two vowels. The last point in each panel shows data averaged across a sentence in the televised interview[9].

The normal pitch detection algorithms were unable to operate on the NTSB speech samples because of the degree of background noise; therefore, we modified an existing vocal jitter algorithm (see Pinto & Titze, 1990 for a recent review). We adapted the existing technique by rectifying and low-pass filtering the signal (to remove high frequency noise) before attempting to find successive pitch periods. The results of the algorithm were visually confirmed and then F0 and jitter measures calculated. We calculated Davis' (1976) pitch perturbation quotient (PPQ) which is the ratio of the "average perterbation measured from the pitch period" and the average pitch period (p. 51, 123).

As the top panel shows, voice fundamental frequency was dramatically lower in the samples recorded around the time of the accident.[10] Also, this panel shows the average F0 range in each speech sample. The different samples cannot be distinguished by their F0 range (except perhaps the items from the recording made nine hours after the accident), but there was a trend for items near the time of the accident to have more F0 jitter (bottom panel of Figure 6). This finding is consistent with Pisoni & Martin's (1989) observation that speakers had higher standard deviation of F0 after alcohol consumption. (Note the discussion above concerning the ways in which SD F0 may be affected.) The lower jitter in the sentence taken from the televised interview (CC) is consistent with Brenner et al.'s (1985) observation that talkers have less F0 jitter when in stressful situations.

Insert Figure 6 about here

In summary, the acoustic-phonetic measurements presented here are all consistent with the findings of previous controlled laboratory studies of the effects of alcohol on speech pro-

[9]The sentence was, "I would say the same for the state of Alaska, they came after me, hammer and tong."

[10]Fundamental frequency as low as that seen here normally occurs only in a mode of vocal cord vibration called creak, or pulse register phonation. In English this mode of vocal cord vibration is usually seen only at the ends of declarative sentences, although this varies somewhat from speaker to speaker.

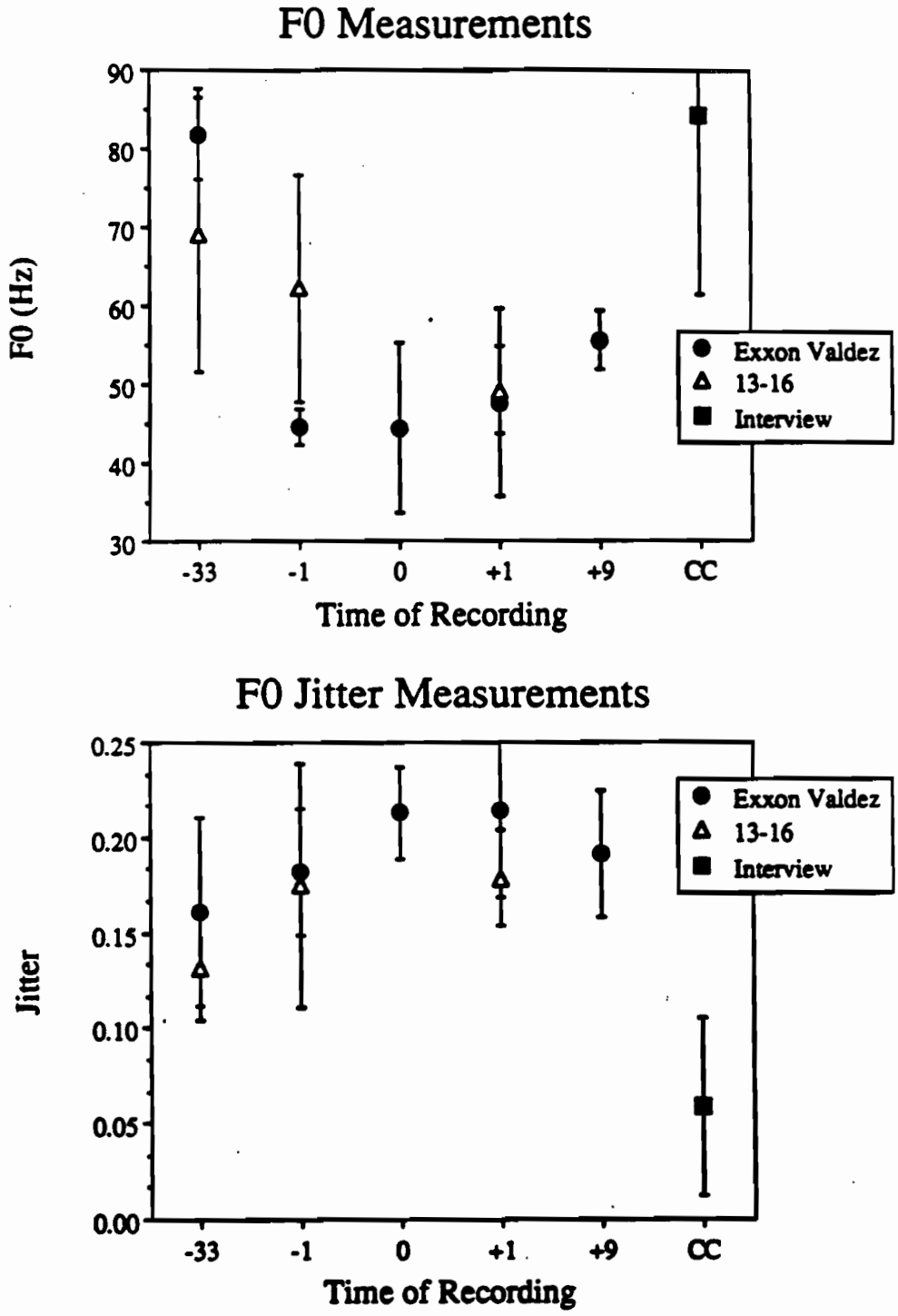


Figure 6. Top panel: Average fundamental frequency (pitch of voice) in *Exxon Valdez thirteen and sixteen* and from one sentence in the televised interview as a function of time of recording. Bottom panel: F0 jitter measurements from the same speech samples.

duction. In listening to the recordings, we observed a number of gross misarticulations and segmental misarticulations around the time of the accident. We also found acoustic evidence in two of the recordings made near the time of the accident (0, +1) for a misarticulation of /s/. Finally, we found that Captain Hazelwood was speaking more slowly, and used a lower fundamental frequency with more fundmental frequency jitter around the time of the accident as compared with his speech 33 hours before the accident and his speech in the televised interview.

Conclusions

We now return to the theme with which this report began. Is it possible to determine, from acoustic analyses of speech, whether an individual is intoxicated? We have presented *a priori* arguments that it is. We also found in a review of previous research on environmental and emotional effects on speech production, that the effects of alcohol are unique among the previous findings. In our present analyses, we have also found a pattern of changes in Captain Hazelwood's speech which is consistent with the pattern of changes observed in previous laboratory studies on the effects of alcohol on speech production (this was as much as we concluded in our preliminary report). Taken together, these findings suggest that the Captain was intoxicated at the time of the accident. There are, however, several methodological and empirical problems that must be taken into consideration with regard to this conclusion.

First, there are gaps in the previous research; both in research concerning the effects of alcohol on speech production and in research on other effects on speech production. For instance, we have reported here measurements of vocal jitter. This is the first time that vocal jitter measurements have been reported in the context of a study of the effects of alcohol on speech. We also noted several gaps in previous research on environmental and emotional effects on speech. For instance, we are not aware of any research which has attempted to explore the effects of fatigue on speech, or any research which explores the ways in which various environmental and/or emotional factors may interact in their effects on speech. In the absence of these types of additional data, we cannot rule out a number of other possible causes for the changes we have observed in Captain Hazelwood's speech.

Second, in addition to a lack of breadth in the existing knowledge, there is a lack of depth There are no normative data on the effects of alcohol on speech production. We don't know how general the effects summarized in Table 1 are. Normative data are also unavailable for the effects summarized in Table 2. This lack of data makes it impossible to make reliable probabilistic statements such as, "Captain Hazelwood had this pattern of changes and 95% of the people who exhibited this pattern were intoxicated while only 10% of fatigued speakers show this pattern." Currently, statements of this type are based on studies which employed very small numbers of talkers.

Third, the recordings which we were working with in the present case limited the type

and quality of the measurements we could make. For instance, it would have been very informative to know whether the Captain was speaking more loudly or softly in the recordings near the time of the accident. This measure was not possible with the NTSB recordings because automatic gain control was used in the transmission equipment and the placement of the microphone in relation to the speaker's lips was (presumably) variable. Furthermore, the variability of the background noise made the calculation of long-term average (LTA) spectra invalid, though Klingholz et al. (1988) found reliable changes in LTA spectra when speakers were intoxicated. Our analysis of fricative spectra was also hampered by the presence of background noise and the frequency response characteristics of the transmission equipment. Finally, the complicated history of the recording made 33 hours before the accident casts some doubt on the measurements taken from that recording. We have outlined the magnitude of error which may have resulted from this situation and have taken measurements from a televised interview to serve as another "control" condition. Still, this extra link in the history of the recording introduces an additional source of error that would not have existed if the original Coast Guard recording had not been erased.

A number of aspects of the data we have reported here suggest that Captain Hazelwood was intoxicated when the Valdez ran aground. Especially suggestive is the pattern that we have observed in measurements of four different speech parameters. The changes in F0, F0 jitter, duration and fricative spectra measurements are all consistent with the hypothesis that Captain Hazelwood was intoxicated at the time of the accident. These four parameters also have an inflection point around the time of the accident. This, coupled with the knowledge that the Captain's blood alcohol level ten hours after the accident was 0.06%, suggests that his blood alcohol level may have been higher at the time of the accident. In addition to these fine-grained acoustic analyses, we also found some additional segmental misarticulations and some gross errors in the recordings made around the time of the accident. From these findings, we conclude that Captain Hazelwood displayed changes in sensory-motor behavior that are similar to those found in earlier laboratory based studies in which the talkers were intoxicated to known BALs. This similarity suggests that the Captain was intoxicated at the time of the accident. However, this conclusion should be qualified in light of the limitations of the present recordings and the limited scientific data on the effects of alcohol and other variables on speech production.

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