

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILE 8672
1973 SCOMM 76: HOUSE SPEC. COMM. EXXON VALDEZ OIL SPILL. . 1991-92

Table 6.--Speaking Rate

Statement Number	Number of Syllables Analyzed	Measured Duration (seconds)	Speaking Rate (syllables per second)	Hours with respect to accident
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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

AVERAGE SPEAKING RATE OF THE EXXON VALDEZ MASTER

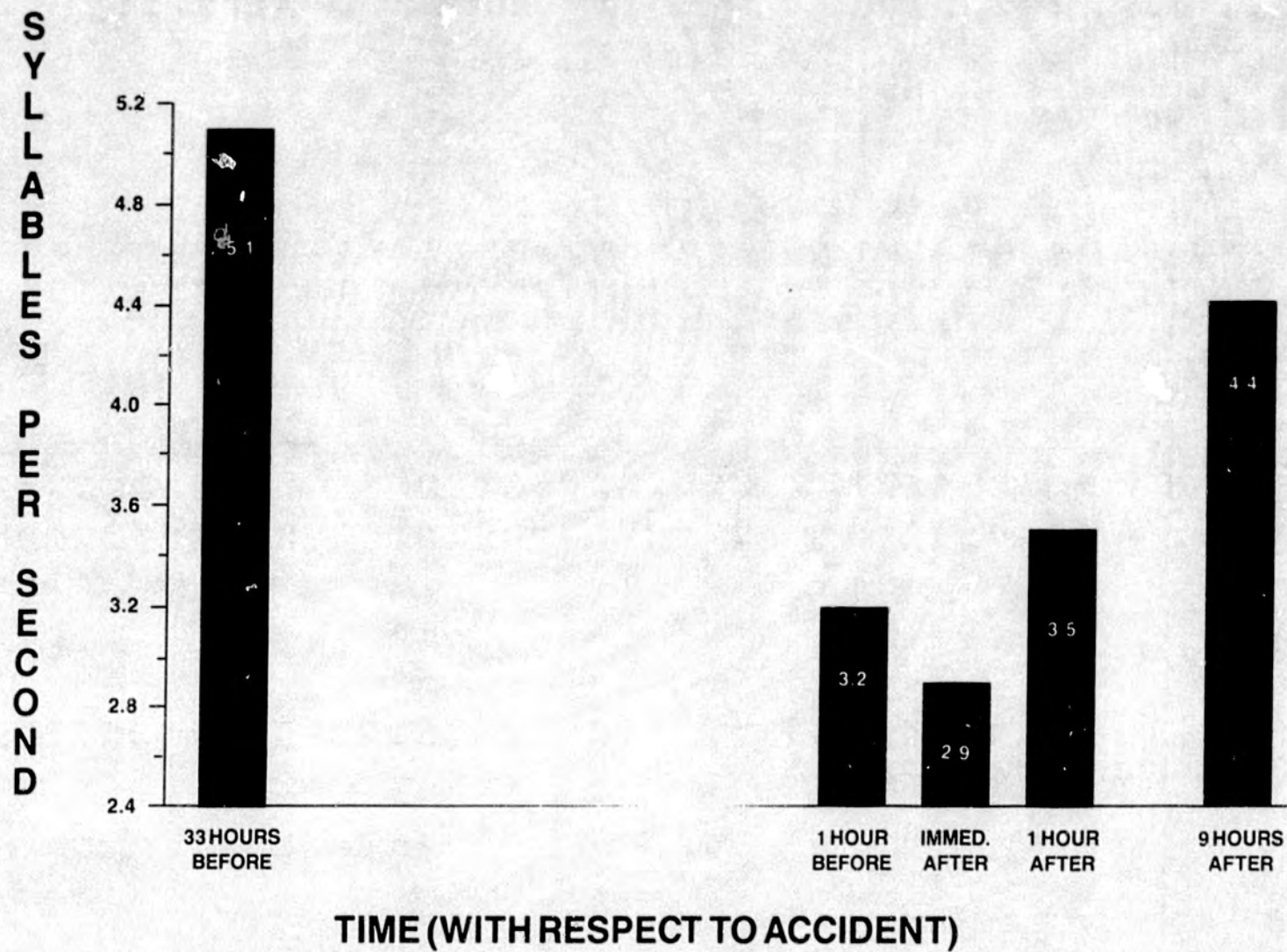


Figure 15.--Graph summarizing speaking rate.

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."

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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.

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

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

⁸¹Ruiz, 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° 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° of right rudder and had not ordered any course to steer.
- (8) About 1.5 minutes after ordering the right 10° rudder, he recognized that the vessel had not turned, so he ordered right 20° rudder.
- (9) He observed the white sector of Busby Island Light from the port bridge wing after ordering the rudder to right 20°.
- (10) About 2 minutes after ordering right 20° 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°.

The course recorder trace confirmed that the vessel was on a course of 180° 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°. 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° rudder, could have turned the wheel to 10°, 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° 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°) 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° 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°, 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 have 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 unlikely 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

⁸²The 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

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.

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, the possible use of alcohol aboard the vessel, and had probably developed considerable tolerance for alcohol. Individuals with such a history are usually 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

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: What 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 relapse into drinking, the signs that might indicate that he had resumed drinking, the kind of assignments he could perform without risking his sobriety. The president of Exxon Shipping Company testified that the master was the most scrutinized employee in the company." If this supervision and monitoring were to 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

⁸⁶Holley, 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.

⁸⁷Johnson, 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, the EXXON VALDEZ was committed to a slow turn toward the traffic. There was a period of about 6 minutes during which the third mate could not see the situation, possibly enabling him to obtain a grasp of the 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 unusually 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 capacity⁸⁸ and memory impairment from sleep loss⁸⁹ 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

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

⁸⁹Webb, 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:

- o 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);
- o 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:

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

⁹⁰The 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.

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 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 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° 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° 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

⁹¹Marine 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.

⁹²Finland 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°, 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

- o 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

- o 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

- o 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

- o 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

- o that toxicological results from Federal employees be made available to investigators of the National Transportation Safety Board.

I-89-11

- o 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 transportation and a third mate's license. He was employed as a third mate in June 1963 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.

APPENDIX C

184

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

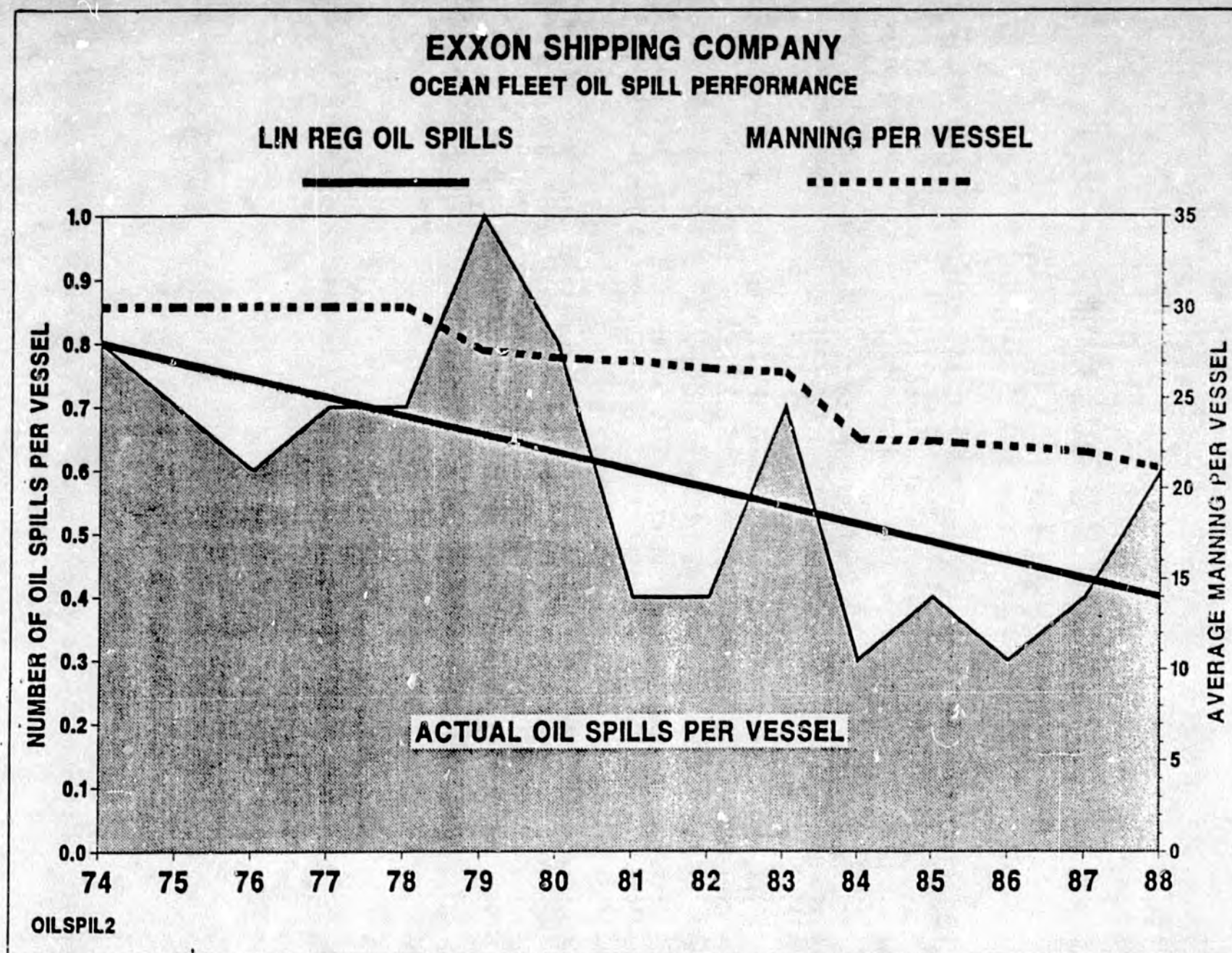
From 1974 through 1988, Exxon's U.S. flag fleet has varied from a total of 17 to 20 ocean tankers. During this 15-year period, 7 older non-automated vessels were retired while 10 new automated vessels were added to the fleet. The older vessels were manned by crews of approximately 30 while the automated 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.

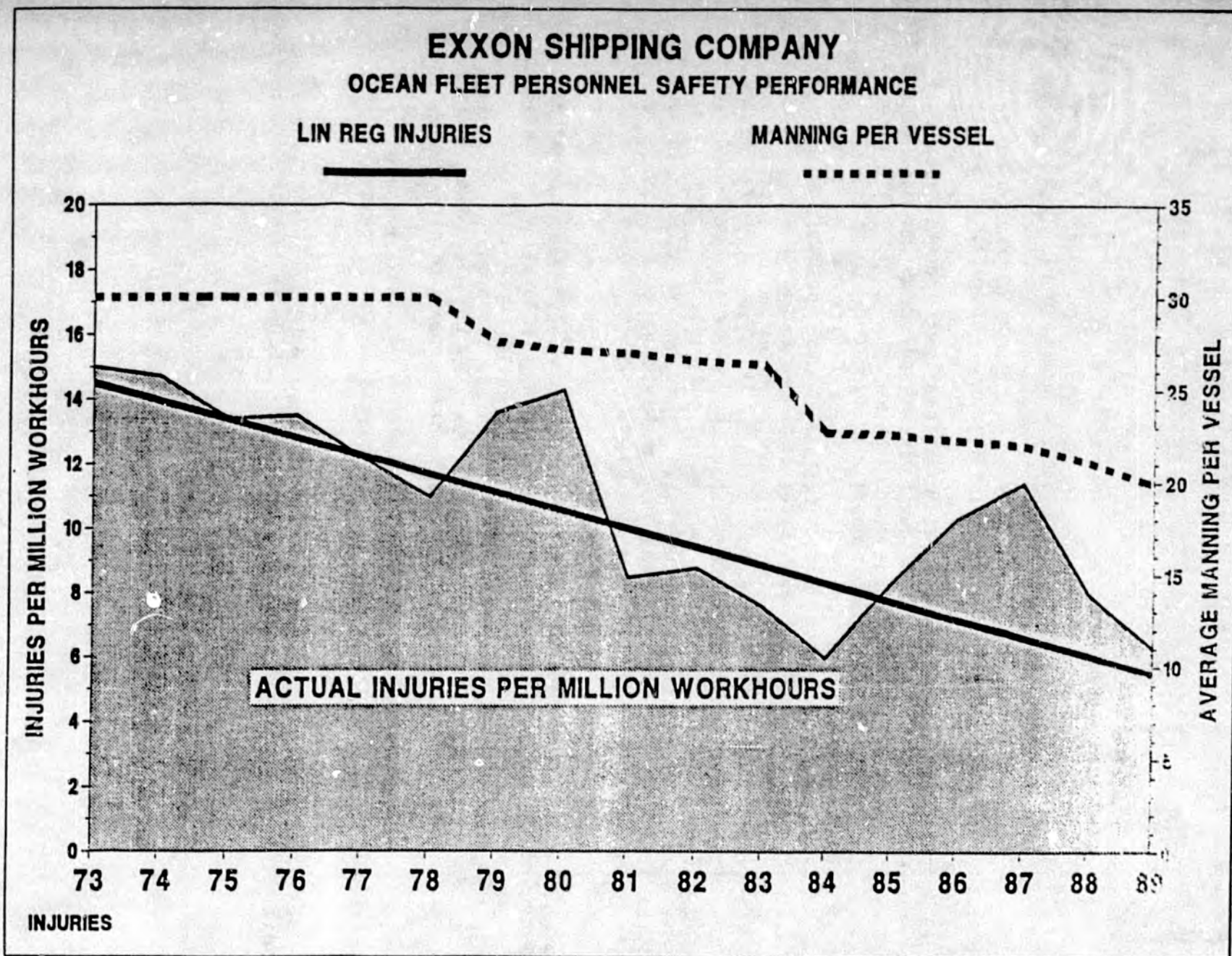
Over this same period, the rates of personnel injuries per million workhours has declined from 14.5 to 5.5 This represents a 62% reduction in the personnel injury ratio.

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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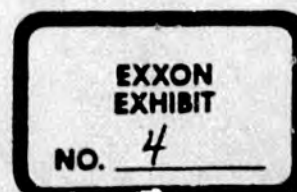




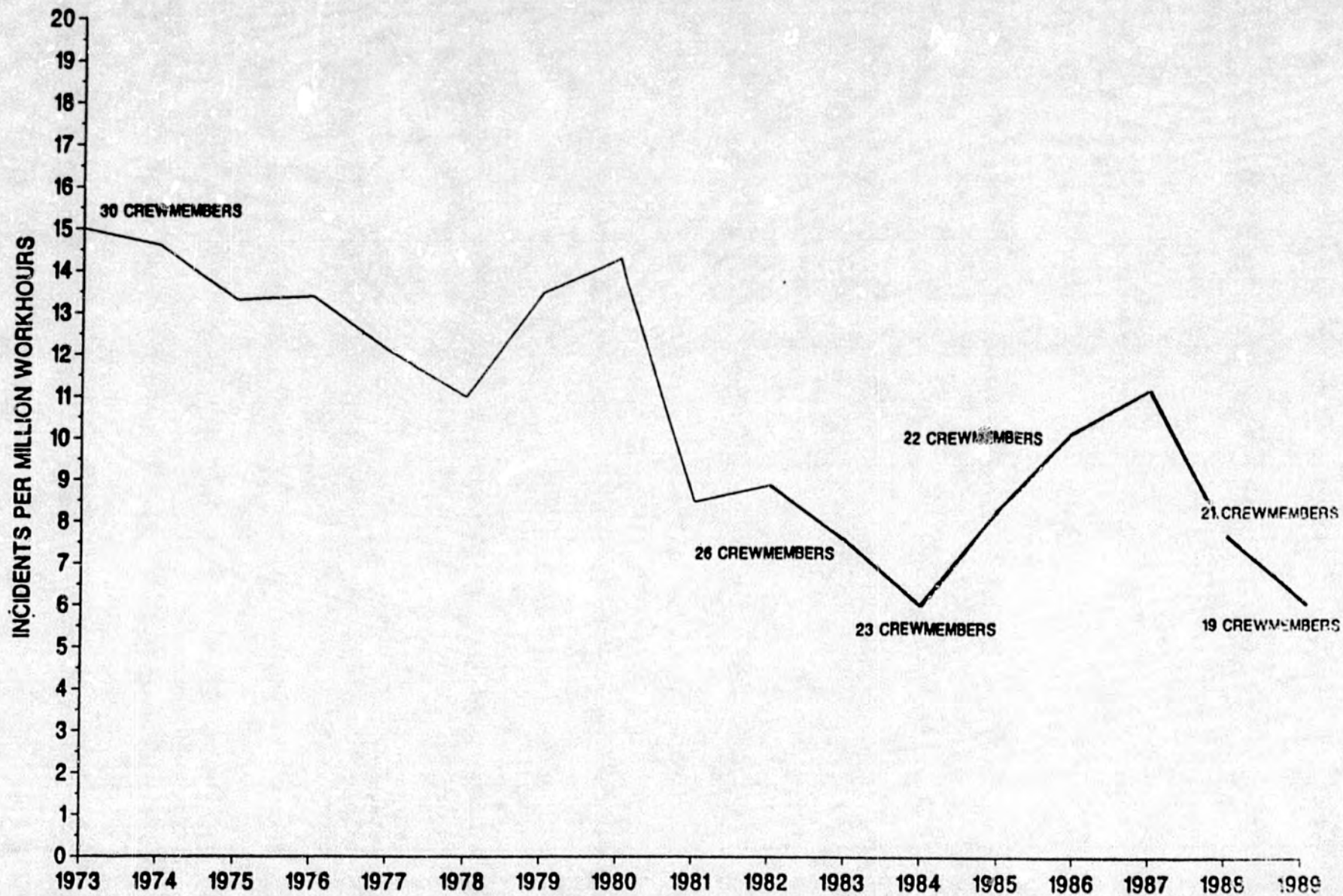
OCEAN FLEET
PERSONNEL SAFETY PERFORMANCE
1973 - 1989 (MAY)

- + 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 Initiative", 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 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 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 Traffic 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 calving [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 calving 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 conjunction 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 to 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.