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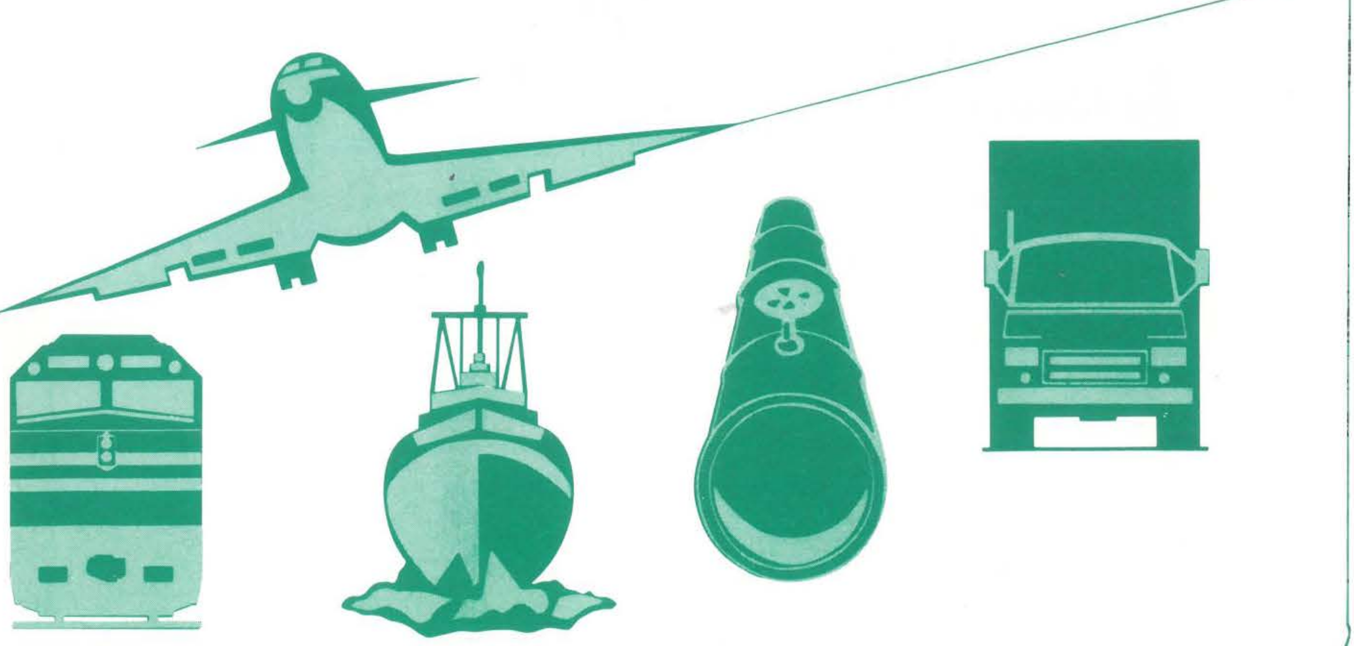
NTSB/MAR-89/06

NATIONAL TRANSPORTATION SAFETY BOARD

MARINE ACCIDENT REPORT

CAPSIZING AND SINKING OF THE MOBILE OFFSHORE DRILLING UNIT ROWAN GORILLA I IN THE NORTH ATLANTIC OCEAN DECEMBER 15, 1988



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16. Abstract

This report explains the sinking of the mobile offshore drilling unit ROWAN GORILLA I on December 15, 1988, in the North Atlantic Ocean. The safety issues discussed are the vessel's design and stability, vessel towing, weather, lifesaving equipment stowage, survival capsule design, survival training, and manning and licensing requirements.

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EXECUTIVE SUMMARY

At 1605 on December 15, 1988, the 297-foot-long U.S. mobile offshore drilling unit ROWAN GORILLA I capsized and sank in the North Atlantic Ocean about 500 nautical miles southeast of Halifax, Nova Scotia, Canada. The ROWAN GORILLA I, a self-elevating type drilling rig, was being towed by the 245-foot-long Bahamian tug SMIT LONDON from Halifax to Great Yarmouth, United Kingdom when the towline broke about 0220 on December 15, during a severe storm. At 1340 on December 15, the 27 persons aboard the ROWAN GORILLA I abandoned the rig using one of the rig's survival capsules. When the rig was abandoned, there were 50-foot-high seas and the wind was blowing at about 60 knots. About 1200 on December 16, when the seas had subsided to about 15 feet in height, the 27 persons were rescued from the survival capsule by the SMIT LONDON crew. The estimated value of the rig was $90 million.

The safety issues discussed in the report are:

- the adequacy of the structural design of the ROWAN GORILLA I for ocean tows;
- the stability of the ROWAN GORILLA I prior to capsizing;
- the appropriateness of towing a self-elevating type drilling rig across the North Atlantic Ocean in December when severe storms are common;
- the adequacy of the tow preparations;
- the appropriateness of the SMIT LONDON master's actions to protect the tow during the severe storm;
- the adequacy of the weather forecasts received by the SMIT LONDON during the tow;
- the lack of remote gauges for the rig's preload tanks;
- the adequacy of Rowan policies regarding the stowage of lifesaving equipment during ocean tows;
- the adequacy of the design of the survival capsules aboard the ROWAN GORILLA I regarding external lighting, radar reflectors, and capacity when survivors are wearing immersion suits.
- the adequacy of survival training provided by Rowan for rig crews; and
- the adequacy of U.S. Coast Guard manning and licensing requirements for mobile offshore drilling units.

Recommendations concerning these issues have been made to the U.S. Coast Guard, Rowan Companies, Inc., the American Bureau of Shipping, Marathon LeTourneau Offshore Company, and the International Association of Drilling Contractors. Also, the Safety Board reiterated recommendations to the Secretary of the U.S. Department of Transportation and the U.S. Coast Guard.

The National Transportation Safety Board determines that the probable cause of the capsizing and sinking of the mobile offshore drilling unit (MODU) ROWAN GORILLA I was the flooding of compartments and tanks as the result of structural failures, non-watertight ventilation openings, loose access hatches, and unsecured cargo. The structural failures were the result of inadequate government and industry analytical methods during the design phase to assess the stresses imposed on the structure of self-elevating MODUs while under ocean tow. Contributing to the accident was the failure of Rowan to employ and the U.S. Coast Guard to require aboard the MODU a person qualified and experienced in moving self-elevating MODUs on an ocean tow.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON D.C. 20594

MARINE ACCIDENT REPORT

CAPSIZING AND SINKING OF THE U.S. MOBILE OFFSHORE DRILLING UNIT ROWAN GORILLA I IN THE NORTH ATLANTIC OCEAN DECEMBER 15, 1988

INVESTIGATION

The Accident

At 1210 local time on December 8, 1988, the 297-foot-long U.S. mobile offshore drilling unit (MODU) ROWAN GORILLA I (see figure 1), a self-elevating type drilling rig, departed Halifax, Nova Scotia, Canada, under the tow of the 245-foot-long Bahamian tug SMIT LONDON (see figure 2) on an approximately 3,250-nautical-mile voyage across the North Atlantic Ocean to Great Yarmouth, United Kingdom. (See figure 3.) The ROWAN GORILLA I was owned by Rowan Companies, Inc. (Rowan) of Houston, Texas, and the SMIT LONDON was operated by Smit Tax International of the The Netherlands. Aboard the rig were the rig superintendent, 25 crewmembers, and a crewmember from the SMIT LONDON who was acting as a liaison between the rig superintendent and the master of the tug. Aboard the tug were its master and 18 crewmembers.

After departing Halifax, the tug master set the tow on a south-southeasterly course. The towline consisted of about 4,100 feet of 9-inch-circumference galvanized steel wire (2.86-inch-diameter), about 180 feet of 21-inch-circumference (6.7-inch-diameter) synthetic rope, and about 200 feet of 8 1/2-inch-circumference (2.7-inch-diameter) galvanized steel wire. The vice president (Rowan vice president) of Rowandrill, Inc., a subsidiary of Rowan, who was responsible for operations of Rowan MODUs in the Gulf of Mexico and Canada, stated that Rowan had discussed two routes across the North Atlantic with Smit Tax International: one route was "to go straight across the North Atlantic," and the other route was "to take a southerly course going by the Azores." The Rowan vice president stated that "the southerly route was taken because it was the least amount of weather exposure." The tug master stated that before the SMIT LONDON left Rotterdam in late November 1988, he was asked by Smit Tax International officials "what my thoughts were about the most favorable route crossing the Atlantic in wintertime," and that he had replied:

> [the tow] should start heading to the south-southeast at first because in December most of the low pressure areas are running either direct over Nova Scotia or a little south of [Nova Scotia] ... So we had to cross that area as quick as possible and then up to a latitude of 40 degrees north and when we had reached that latitude then alter course and start on an easterly heading up until approximately abeam of the Azores ... and from there heading for the English Channel.

Figure 1.--Photograph of ROWAN GORILLA I under tow.
(Courtesy of Marathon LeTourneau Offshore Company)

Figure 2.--Photograph of SMIT LONDON on December 18, 1988.

From December 8 to December 11, the SMIT LONDON log states that the tow was on a south-southeasterly course and travelled a distance of 346 miles during the 72-hour period ending 1200 on December 11 (about 4 knots). The winds varied in speed between 7 and 21 knots and in direction from northwest to northeast. The wave heights varied between 3 and 12 feet. Testimony from the ROWAN GORILLA I crew indicated that during the period December 8 to December 11, the bottoms of the rig's three 503-foot-high legs were positioned 12.9 feet below the bottom of the hull, the normal ocean towing position, and its two thrusters[1] were operating to help control the movement of the rig and to provide an approximate 1 to 1 1/2-knot additional towing speed.

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[1] The thrusters were the propulsion units for the rig. Each thruster consisted of a 9.3-foot-diameter propeller powered by four electric motors.

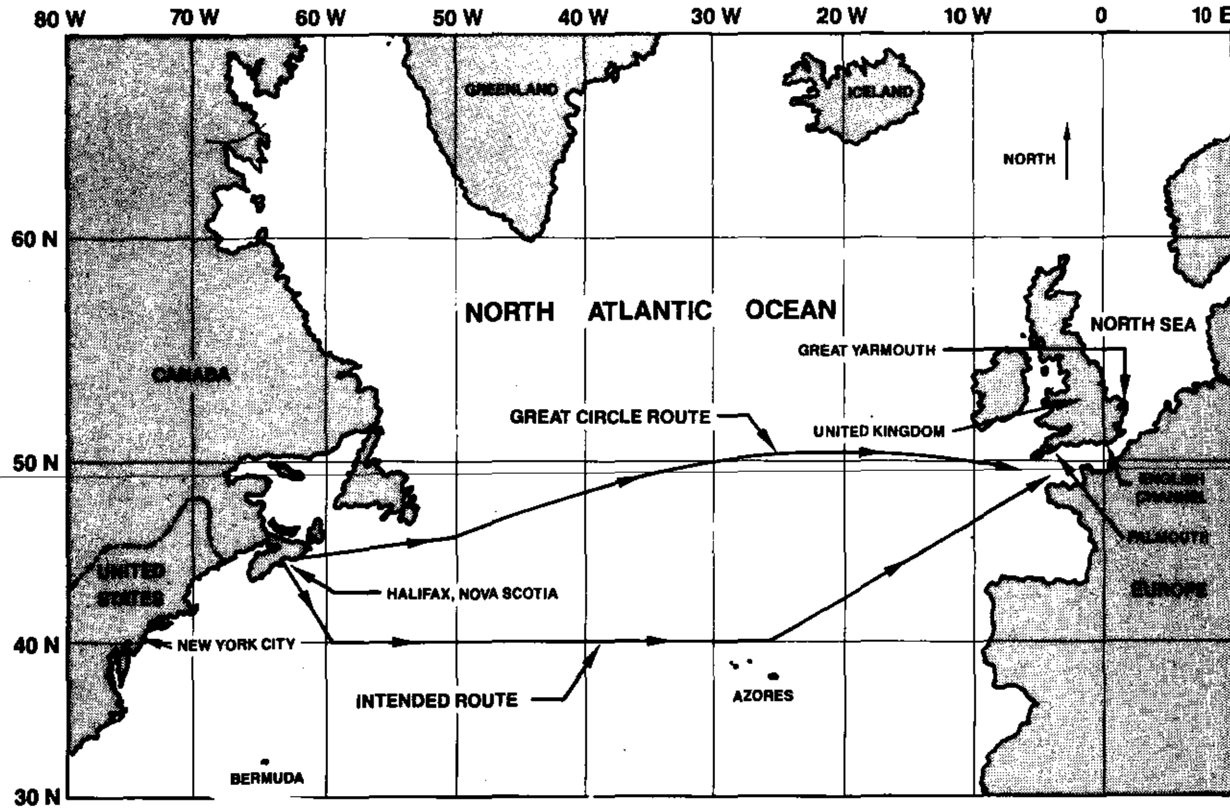

Figure 3.--Intended route of tow from Halifax to Great Yarmouth, December 1988.

About 0630 on December 12, the executive vice president of Rowan received his daily report from the rig at his home in Houston. The report stated that the rig was located at 40° 1′ N latitude, 56° 39′ W longitude, it had traveled 441 miles and had 2,816 miles to go, it was on a east-southeasterly course, it had a roll (port to starboard) period of 7 seconds and was experiencing maximum rolls of 2°, and the winds were from the west-northwest at 20 knots. The SMIT LONDON logs show that during the day on December 12, the winds shifted to the west at speeds ranging from 28 to 40 knots, and the tug master changed to an easterly course. (See figure 4.) From 1200 on December 11 to 1200 on December 12, the waves were between 12 and 40 feet high and the tow covered 144 miles (about 6 knots). The tug master stated that during the evening of December 12, the weather forecasts indicated that the tow was going to encounter a severe storm which was heading to the northeast and that on December 13, when the winds shifted to the north, he changed to a southeasterly course "to get more distance between our position and the forecasted track [of the storm]." On December 13, the

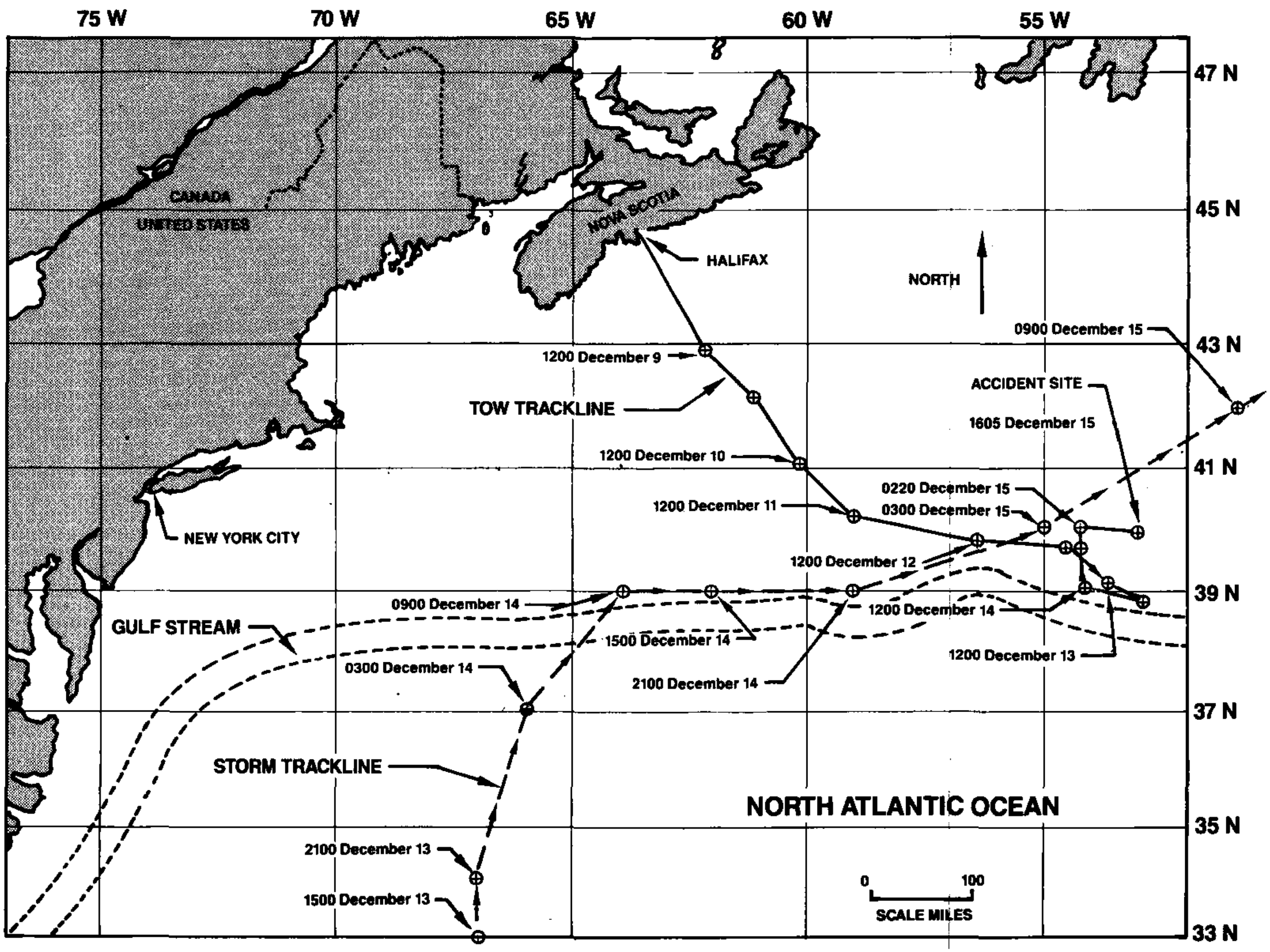

Figure 4.--Tow and storm tracklines, December 1988.

winds varied in speed from 17 to 33 knots and the waves were 8 to 40 feet high. In anticipation of encountering the storm the next day, the tug master placed new protection devices and a second gog wire[2] on the towline.

The December 13 morning report from the rig to the Rowan executive vice president in Houston stated that the rig was located at 39° 29′ N latitude, 54° 5′ W longitude (about 550 miles from Halifax) and it had a roll period of 8 seconds and was experiencing maximum rolls of 2 1/2°. The rig superintendent stated that about 0730 on December 13, fractures in preload tanks[3] 14 and 15 were discovered during the normal inspection of all rig tanks. He stated that a steady spray of water was entering tank 14 and a trickle of water was entering tank 15. The rig superintendent then ordered the eductor system[4] for preload tank 14 activated to prevent any significant accumulation of water in the tank. About 1200, cracks were discovered in a weld on the forward support column for the starboard leg, in a weld on the inboard support column for the starboard leg, and in the structure on the inboard support column for the port leg. During regular communications between the rig and the tug on the evening of December 13, the tug crewmember aboard the rig informed the tug master that the rig had experienced some minor cracks in the crew accommodation areas.

About 2100, the rig superintendent reported to the ROWAN GORILLA I rig manager, who was at his home in Mississippi, that the rig was pitching (fore and aft) 1° to 3 1/2° at a period of 8 seconds, it was rolling 1° to 3 1/2° at a period of 8 seconds, and it had sustained fractures in tanks 14 and 15. There was a 12-inch vertical crack about 20 feet below the main deck in tank 14 and a 4 1/2-inch horizontal crack behind a vertical stiffener about 22 feet 9 inches below the main deck in tank 15. The rig manager then contacted the Rowan vice president in Houston and informed him of the fractures. The vice president in turn contacted the Marathon LeTourneau Company (Marathon), the designers and builders of the ROWAN GORILLA I. Marathon representatives recommended that steel plates be welded over the fractures and this information was passed to the rig superintendent via the rig manager. At 2131 on December 13, the rig legs were placed in the severe storm position 25 feet below the hull. The tug master stated that because the winds were increasing in speed and there was added drag from the rig legs being in the lowered position, he decided at 2315, to turn and tow with the wind and seas on the rig's stern to prevent the rig from dragging the tug backwards and possibly capsizing the tug.

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[2] A 4 1/2-inch-circumference steel wire used to control the movement of the towline.

[3] Preload tanks are filled with water during the positioning of self-elevating rigs to duplicate the maximum rig load prior to the rig jacking to its working level. Preload tanks are normally empty during towing operations.

[4] An educator is a form of suction pump that uses a high-pressure jet of water to create a partial vacuum at an intake opening to draw liquid into the system.

The December 14 morning report to the Rowan executive vice president in Houston stated that the rig was located at 38° 57′ N latitude, 53° 9′ W longitude (about 600 miles from Halifax), was on a westerly course, was rolling 2 1/2° at a period of 7 seconds, and was pitching 3° at a period of 6 seconds. On the morning of December 14, a small crack in preload tank 13 was found but no water was reported entering the tank. The rig superintendent stated that about 0400 on December 14, the seas had calmed sufficiently for the rig crew to go on deck and attempt to repair tank 14; however, before the crew could make any repairs, the seas again began breaking on deck and all repair work had to be suspended. By 1200 on December 14, winds were from the east at 53 to 63 knots, waves were over 40 feet high, and the tow was on a westerly course. During the afternoon of December 14, the winds shifted to the south and the tug master changed to a northerly course. The winds had decreased in speed to 22 to 33 knots, but the waves were still over 40 feet high. The rig superintendent stated that during the early evening on December 14, some of the hatch covers for tanks and compartments on the main deck of the rig began leaking and the crew went on deck to tighten the hatch covers but could not tighten hatch covers on the stern, including the hatch cover for preload tank 14, because of waves breaking over the stern. The tug master stated that about 2200, he was first informed by the rig superintendent of the hull structural cracks in preload tanks 14 and 15.

About 2230, the rig manager received a report from the rig which stated that the rig was located at 39° 27′ N latitude, 53° 54′ W longitude (about 550 miles from Halifax), the winds were from the south at 25 to 30 knots and the seas were 20 feet high. The report also stated that the maximum winds had been 45 knots, the maximum waves were 35 to 40 feet high, the rig was rolling 3 1/2° to 7° at periods from 5 to 8 seconds and pitching 2° to 5° at periods from 6 to 7 seconds, and the rig "seemed to ride better with the seas off the starboard stern." The tug master testified that on the evening of December 14, the winds began to shift counter-clockwise and the barometric pressure decreased significantly indicating to him that the tow was near the center of a low pressure area. The wind speed began increasing and the tug master said that the swells[5] were increasing. He further stated:

> And if the vessel is riding before the seas and the swells, the [vessel] will sheer[6]. [The vessel] will not stay on an exact steady course but there is movement...when [the vessel] goes down the hill [the vessel] will sheer, that means if we sheer the towline is moving on the aft deck and that went so fast that [it was] unbelievable, that movement. So the towing protectors ... got a hell of a beating.

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[5]Long rolling non-crested waves.

[6]Sheer means to deviate from the intended straightline course and to follow a crooked and irregular course.

The tug master further stated:

> ...one gog rope parted, because the movement was so severe ...we didn't dare put too much tension on the spare [gog rope] because if that parts...then it's even worse. So the chafing protectors...got a real beating and they were damaged quite rapidly...we noticed around [2300] that [the stern] protector was so severely beaten that the [towline] wire came through, and in order to save the wire I asked for some power on my towing winch and...to slack some wire, because those towing protectors...are between clamps on the wire.... But to slack some wire, that is very dangerous in those seas because at that stage the tension meter...indicated...peak forces, of over...280 tons. And if I engage my gear of my towing winch and at the same time there will be a pull of 280 tons on that gearbox, my winch will be gone.
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> So I engaged the winch and then I was just waiting between some swells for an opportunity to do it, and we managed and we could slack it for a meter and have a new protector on the stern.
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> * * * * *
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> But even with this new protector on, the wire broke that same night at 0220 [December 15], and it broke about a meter behind the stern.

The rig superintendent stated that after the towline broke, "the wind and seas took over and brought the port side of the rig into the sea." He ordered the thrusters activated and the crewmembers not on duty to don immersion suits, and he notified the rig manager of the situation. He further stated that he used the thrusters to "hold the port aft corner [of the rig] into the seas," and the rig was pitching about 8^{o} at periods from 6 to 7 seconds.

At 0729, the rig superintendent reported to the rig manager in Mississippi that the rig was pitching 5^{o} to 10^{o}, the maximum pitch had been 14^{o} at periods from 4 to 6 seconds and the rig was rolling 1^{o} to 3^{o}. He also told the rig manager that he had turned off the thrusters because the rig rode better without the thrusters, that some containers had gone overboard on the port side, they were taking on water in the port propulsion room, a manhole cover above the pit room[7] was torn off, and they were staying ahead

[7]The pit room was a large after compartment where the tanks used for mixing the mud used during drilling operations were located.

of the flooding by using their pumps. During this conversation, the rig superintendent stated that he would attempt to reconnect the towline when the weather improved. The Rowan vice president testified that the rig superintendent "had used the thrusters to maneuver the rig in different positions and...he reported that it worsened the situation to put the bow into the seas, he said he was taking a lot more pounding, there seemed to be more movement, so he elected at that time not to use thrusters and to let the rig follow its own natural movement...."

In the early hours of December 15, the crew found water in the port propulsion room, and later that morning, several approximately 8-foot by 8-foot by 8-foot containers that had been welded to the main deck broke loose. The crew determined that the water in the port propulsion room had come from the adjacent port air compressor room and that water was entering the air compressor room through a deck vent and conduits for electrical wires which penetrated the main deck. The rig electrician stated that he saw a loose container tear off the hatch to the pit room. The barge engineer stated that there were small cracks in the top plating of both propulsion rooms, and he saw one of the containers break loose and hit the vent for the port drill water tank causing a small fracture. The barge engineer further stated that he believed that the crew had the flooding in the port air compressor room and the after storage compartment under control by using the rig's pumps and the additional submersible pumps that had been provided for the tow; however, the stern trim increased. In addition, the barge engineer stated that during the night, he had performed stability calculations to determine the effect of pumping out drill water tanks 8, 9, 10, and 11 which were located in the after portion of the rig and found that pumping the tanks out would decrease the rig's draft by 3 to 4 inches and reduce the trim. The barge engineer said the tanks were pumped out and "it seemed to help."

The tug log states that on the morning of December 15, the winds were from the west-northwest at speeds ranging from 48 to 71 knots, and the waves were over 40 feet in height. The tug master stated that at daylight about 0800, he observed that the rig was pitching, did not have any unusual trim, and was not slamming.[8] The tug was about 1/2 mile off the rig's port quarter and the rig was drifting easterly at 5 or 6 knots. The rig superintendent stated that about 0900, the rig's aft trim increased from about 2° to 6° and that all the equipment secured on deck, except for the containers, was still in place. The barge engineer stated that about 0900, he had estimated the rig's aft trim as 3° to 5° and that the rig had a slight starboard list.

About 0900, the rig superintendent reported to the rig manager that there was 1 foot of water in the starboard propulsion room and about 3 feet of water in the port air compressor room, the rig was drifting eastward at 6 knots, the winds were from the west-northwest at 60 knots, the seas were 40-feet high, and the rig was rolling 3° at a period of 4 seconds and pitching 10° at a period of 8 seconds. At 0959, the rig reported to Canadian Coast Guard Radio Station, Halifax (Radio Station Halifax) that its position was

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[8] Slamming is the impact stress resulting from a vessel bow hitting the water after coming out of the water during large pitch motions.

40^{o} 5′ N latitude, 53^{o} 22′ W longitude (about 500 miles from Halifax), it was drifting on a easterly course at 6 knots, it had two usable 36-person survival capsules, its liferafts had gone overboard, and the rig's legs were in the storm condition. The tug master stated that about 1000, the tug came abeam of the rig and he observed that the rig was down by the stern, that the pitch motion astern was significantly more than the pitch motion forward, and that the waves were washing across the entire main deck of the rig. The tug master further stated:

> And we did that observation for about one hour and we noticed that sometimes [the rig] didn't even recover completely. Sometimes [the rig] come back to a horizontal position and then [the rig] went down again with the stern. The forward motion with the bow going down at certain stages was completely gone. And when I noticed that, I asked my man [on the rig],...and I didn't ask him direct, but I wanted to convince myself if the people on board did realize what was happening. And out of the conversation of my man, I tried to do it in such a way that even he was not aware I was checking on him, and out of that conversation, my opinion was that they were not aware of the seriousness of the situation. But since I am a tugboat man and of vessels I do know something, but rigs that is a complete different story.
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> But luckily on board our vessel we have a full and detailed report of a loss of a self-elevating rig which happened in 1980, that was the rig DAN PRINCE which was lost near Alaska. So I took that report and studied that report, and then I found out that also the DAN PRINCE started out with minor cracks.
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> * * * * *
>
> The only additional item which I was missing at that time was that the DAN PRINCE had a 6^{o} list and the ROWAN GORILLA I was not listing at this time. But the DAN PRINCE with the 6^{o} list capsized.

The tug master stated that sometime between 1130 and 1200, after discussing the DAN PRINCE report with the tug chief mate and tug chief engineer, he told the rig superintendent that the rig was trimmed astern and of the similar circumstances experienced by the DAN PRINCE. The tug master stated that the rig superintendent then asked, "Do you think this is an emergency situation?" and the tug master replied, "Yes, this is an emergency situation." The tug master further stated that the rig superintendent said, "Please appreciate that we are drilling men, and not seamen" and requested the tug master to advise him concerning the situation. The tug master then advised the rig superintendent to prepare for abandoning the rig.

The rig superintendent stated that up to the time that the tug master advised him to prepare for abandoning the rig, he believed that the rig was in no danger of capsizing, "the sun was out, clear skies," and that when the sea conditions improved they could continue the tow. He further stated that 50-foot-high waves were now breaking on deck and slamming into the accommodations house at the 6- to 10-foot-high level. At 1218, the rig superintendent sent a distress message to the Canadian Coast Guard in Halifax, and at 1317, he reported that the stern trim was caused by flooded aft preload tanks and the trim had increased to about 5^{0} to 6^{0}. Both the rig superintendent and the barge engineer stated that up to the time of the distress message, the crew were able to pump out the rig internal compartments as fast as the water was entering the compartments. The barge engineer stated that the 5^{0} to 6^{0} trim was probably due to the flooding of after preload tanks. He stated that the valves on the rig dewatering system were aligned for dewatering preload tanks 14 and 15, and he did not remember if the crew attempted to dewater any other preload tanks.

The rig superintendent stated that about 1330, he made the decision to abandon the rig when three 60-foot-high waves broke over the stern of the rig, the stern list increased to 12^{0}, and "the rig quit pitching." At 1339, the Canadian Coast Guard in Halifax received a message from the rig superintendent that the crew was abandoning the rig and about 1345, all persons abandoned the rig in the rig's starboard survival capsule. The rig mechanic stated that two engines and all pumps were left running when the rig was abandoned.

After the survival capsule entered the water, the tug master contacted the survivors via their portable radiotelephones, determined that all the survivors were in good condition, and gave them compass headings so that they could maneuver away from the rig. At 1347, the SMIT LONDON reported to Radio Station Halifax that all 27 persons had safely abandoned the rig into the survival capsule and that no attempt should be made to rescue the persons from the survival capsule until the weather improved. At 1520, the first Canadian aircraft arrived on scene and at 1605, the rig capsized and sank. At 1615, the SMIT LONDON master reported that the on-scene weather conditions were 49- to 65-knot winds and 40-foot-high waves. Canadian aircraft remained on scene during the night and about 1200 on December 16, the 27 survivors were safely transferred to the SMIT LONDON when the seas had calmed to 8- to 12-foot-high waves. The SMIT LONDON then proceeded to Halifax with the survivors arriving there at 0746 on December 18.

Injuries to Persons

Injuries	ROWAN GORILLA I	SMIT LONDON	Total
Fatal	0	0	0
Nonfatal	0	0	0
None	26	20	46
Total	26	20	46

Damage to Vessels

The ROWAN GORILLA I capsized and sank in about 16,000 feet of water. Its estimated value was $90 million. The SMIT LONDON lost about 4,000 feet of galvanized steel towing wire which had an estimated value of $50,000.

Crew Information

ROWAN GORILLA I.--The crew of the ROWAN GORILLA I were of various nationalities. The rig superintendent was a U.S. citizen, 24 were Canadian citizens, and 1 was a Dutch citizen. The rig superintendent was the person-in-charge in accordance with Coast Guard regulations (46 Code of Federal Regulations (CFR) 109.107). U.S. Coast Guard regulations (46 CFR 109.301) required that the person-in-charge ensure that each item of lifesaving equipment was maintained in operative condition. The U.S. Coast Guard Certificate of Inspection for the ROWAN GORILLA I required a minimum manning level of three: two able seamen and one ordinary seaman, documented by the U.S. Coast Guard. In addition, three U.S. Coast Guard certificated lifeboatmen, who could be the same persons as the two able seamen and one ordinary seaman, were required aboard the rig at all times. Also, the rig could carry up to 77 industrial personnel. The rig superintendent, the two toolpushers, the barge engineer, and the rig mechanic were all U.S. Coast Guard documented able seamen and certificated lifeboatmen.

The rig superintendent stated that he began his maritime experience as a driller aboard the ROWAN GORILLA I in 1983 and became one of the two ROWAN GORILLA I rig superintendents in 1985. The ROWAN GORILLA I crew normally worked 2 weeks and then were off for 2 weeks. The rig superintendent stated that during his maritime career, he had participated in one field move[9] and one tow from a field[10] to Halifax, and that he was not aboard the rig when it was towed to Halifax in 1983. The Rowan vice president testified that the ROWAN GORILLA I had not experienced severe weather during any moves or tows except for the December 1983 and December 1988 tows.

The rig manager stated that he determined the number and qualifications of the crewmembers who would be aboard during the tow, but he did not know if any of them had maritime experience. The Rowan vice president later stated that a number of the crew had been aboard Rowan rigs during ocean tows. The rig manager stated that there was a crew change on December 7, except for the cook, and that it was normal to have a crew aboard a self-elevating MODU under tow. The Rowan vice president stated that the 26 crewmembers aboard the ROWAN GORILLA I were necessary to monitor rig operations while underway. There were 7 supervisors and 4 members of the catering department leaving 15 crewmembers to be divided into two 12-hour

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[9]The ROWAN GORILLA I operations manual defines a field move as a move that is no longer than 12 hours in duration and where the expected wind speed will not exceed 70 knots.

[10]A field is a geographical area in which a number of oil or gas wells produce from a continuous underground reservoir.

shifts. The vice president stated that two crewmembers were normally assigned to each of the rig's two propulsion rooms at all times while underway.

All Rowan crewmembers aboard the ROWAN GORILLA I had attended a 5-day survival training course, Basic Offshore Training (BOT), which was required by Canadian regulations. The United Kingdom requires similar survival training for rig crews in their sector of the North Sea. The rig superintendent stated that he had attended the BOT in January 1984, and had attended a refresher course in January 1987. He stated that the training included first-aid; firefighting; donning immersion suits; a helicopter emergency simulation during which the participants are strapped in a helicopter seat, lowered into a pool of water, and flipped upside down; and a rescue at sea from a small fishing vessel during which an inflatable liferaft is launched, and then the participants don immersion suits, jump in the water, and climb into the liferaft.

In March 1988, the barge engineer had attended a 5-day rescue course. He stated that the course included instruction in maneuvering a small rescue boat in 18- to 25-foot-high seas and handling the boat during a simulated helicopter rescue of a person from the rescue boat. He stated that he had maneuvered an enclosed survival capsule during his BOT course.

The Rowan vice president stated that although the Marathon operations manual for the ROWAN GORILLA I indicated that Rowan should employ a rig mover[11] for tows, Rowan does not use rig movers because:

> We feel that our rig managers are trained and capable... and rig superintendents are capable of moving rigs and those guys come all the way up through the ranks...a rig mover...is at a disadvantage, when he goes on board a drilling unit, most of the time he's not aware of everyone of those crewmembers and how they're going to respond and how they're going to react to certain situations. In Rowan's case, when the rig superintendent and rig manager move that rig, they know each one of those guys individually and we feel that just offers a more safe working environment.

When the Rowan vice president was asked what training do Rowan rig superintendents receive regarding maritime operations and stability, he replied:

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[11] A rig mover is a person employed by the owner of a rig to be in complete charge of the rig while it is being prepared for a move and is in the process of moving. A rig mover must utilize good seamanship and marine judgment before and after the rig enters the water and at all times when the vessel is afloat. A rig mover should normally have knowledge of meteorology, oceanography, stability, maneuvering and handling, and lifesaving and survival.

> [The rig superintendents get] on-the-job experience as far as the jacking and moving of the rig. Take [the ROWAN GORILLA I rig superintendent] for an example. He was on board the unit when the rig was moved in Nova Scotian waters, so he was aware of the North Atlantic sea conditions that he's going to be working in. He had BOT training; he had fast rescue training; he had Rowan's inhouse safety training; and he also...has his AB card.[12]
>
> * * * * *
>
> Well, as far as formal courses in stability, just using myself for an example, I was a barge engineer for three and a half years on board a Rowan drilling unit, and I started out as a trainee and in that period of trainee, I worked for the barge engineer who showed me the basic calculations and how to figure a rig move and.. I mean, when doing a weight calculation is basically simple math and it's just a learning process. As far as formal training, there's none, but Rowan has a stability procedure that we go by that's sent to all of our rigs for the barge engineer's information.

The Chairman of the Board of Rowan provided the Safety Board with following information:

> Rowan's designated "rig mover" is the rig manager. The rig manager, the rig superintendent and the barge engineer are each capable of conducting a rig move. For field moves, the shore based rig manager is aboard the rig and is the person responsible for the move. For longer ocean tows, the rig manager assures that all preparations for the rig are properly performed, meets with the marine surveyor and towing company to prepare for a move, and is among the last off before departure and the first on at arrival.
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> * * * * *
>
> Safety is the primary reason for utilizing operating supervisors as rig movers. We believe it is a much safer operation to have the same individuals responsible for the safety of the crew and equipment for all rig operations, whether they be moving or drilling. We do not want divided responsibilities, particularly with respect to the management of personnel. We want our crew to know "who is boss" under all circumstances, and we want the "moving boss" to be a Rowan employee.

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[12] U.S. Coast Guard Able Seaman document.

* * * * *

> ...we consider our personnel to be better qualified to move our rigs than a "rig mover." Typically, a Rowan rig manager has been employed by Rowan for more than twenty years. Rowan's philosophy is hire at the entry level and train, train, train.

* * * * *

> In the early period of mobile rig operations, 1970-1974, all Rowan rig managers, rig superintendents and barge engineers attended Marathon LeTourneau's training school. In addition, a LeTourneau representative was on board during all rig move operations...As more rigs were built, fewer Rowan personnel attended the school and more were utilized in training positions aboard existing rigs. ...training [is now] conducted at the rig through instruction and hands-on experience for the trainee.

The rig manager had been employed by Rowan for 13 years. He began his career as a painter and worked his way up until he became rig manager of the ROWAN GORILLA I in 1984. He was the rig superintendent on the ROWAN GORILLA I when it was towed from Belle Chase, Louisiana, to Nova Scotia in 1983.

The Rowan vice president stated that the length of time that a barge engineer is a trainee can range from 3 to 6 months depending on the individual and that the rig superintendent or the barge engineer doing the training determines when the person is qualified. When asked whether Rowan provided survival training similar to that received by the ROWAN GORILLA I crew for all Rowan crews, the Rowan vice president replied:

> In the harsh...or in the North Atlantic operations, say the North Sea, that type of survival training is provided. Here in the Gulf of Mexico, we rely strictly on in-house training...that's taught by our safety department and operations of capsules, operations of evacuations, contingency plans....

* * * * *

> ...there's hands-on training. Every Sunday we have a drill on board our rigs where the guys actually go and get into the capsules, physically start them up. In some cases the capsules are actually lowered, run them around in the water, that type of operation takes place every week.

When the Rowan vice president was asked what training do Rowan rig superintendents receive concerning the use of the maximum motion curves in the ROWAN GORILLA I operations manual which indicated the structural design limits of the rig, he replied:

> ...[the rig superintendent] knew what his single amplitude motion was and he knew the period of that motion and he would actually plot those two coordinates on this graph to determine if he was under the A curve or the B curve and that would determine the actual [position of the rig legs]....
>
> * * * * *
>
> ...if he plots a point that's below curve A,...he's operating out of the design criteria of the rig as stated in the operations manual. ...he should...check the position of his legs and if the legs are in the 12 foot 9 [inch] position, he should go to the 25 foot position. ...If they're in the 25 foot position, then as far as movement of the leg,...there's nothing he can do as far as the changing the position of his legs...he should change the heading of his rig to see if that helps any.
>
> * * * * *
>
> ...I know that from [the ROWAN GORILLA I rig superintendent's] past experience...moving rigs, it's taught...where the legs should be positioned at all times and what time [he] should lower the legs. ...that's something that we go over with our superintendents and that's something that was gone over with [him] before he ever got under tow in Halifax... Just because you've got a graph ..., don't mean that you should wait until the exact minute that you're fixing to plot this out and cross that line, you've got to use some experience or have your knowledge based on experience to be able to interpret these curves.
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> * * * * *
>
> In the case of the Gorilla I getting under tow, I recall a sheet being prepared [by Rowan]...on that sheet of paper, we had the actual wave heights and actual wind conditions that might result in this pitch or roll...so that the rig superintendent would be aware of the type situation that he may be getting into as far as the raising and lowering of the legs.

The Rowan vice president stated Rowan has had a testing program for the use of drugs or alcohol by employees aboard its rigs for a number of years. There is preemployment testing and if any test onboard the rig is positive, the employee is terminated.

SMIT LONDON.--The crew of the SMIT LONDON were also of mixed nationalities. The master, chief officer, second officer, chief engineer, first engineer, second engineer, and the crewmember aboard the ROWAN GORILLA I (tow rider) were Dutch citizens and the rest of the crew were Philippine citizens. The master had over 28 years of experience as an officer on oceangoing tugs operated by Smit Tax International towing all types of vessels throughout the world. He had sailed as master since 1973 and had become the master of the SMIT LONDON on October 20, 1988. He stated that although he had "been across the Atlantic in wintertime with and without tows," he had not towed a self-elevating MODU across the ocean since he was a mate. He also stated that he could only remember once before having a towline break and that was when he was a mate. He could not recall what they were towing when the towline broke, but he did remember that they were able to reconnect the towline and continue the tow.

The SMIT LONDON second officer had 11 years of experience on oceangoing tugs and had boarded the SMIT LONDON for the first time when the tug departed Rotterdam in late November 1988. He stated that he had had 3 years of experience operating rigid-hull inflatable boats in the Persian Gulf, had received survival training while in the Royal Dutch Navy, and had previously rescued "people off burning vessels." The towrider had been sailing for 40 years during which time 35 years had been on oceangoing tugs with Smit Tax International.

Vessel Information

ROWAN GORILLA I Arrangements.--The ROWAN GORILLA I was built by Marathon LeTourneau Company, Vicksburg, Mississippi, in 1983, classed by the American Bureau of Shipping (ABS), and certificated by both the U.S. Coast Guard and the United Kingdom Department of Energy. When the ROWAN GORILLA I was built in 1983, it was the largest self-elevating MODU in the world. Presently, there are four other MODUs which have been built to the gorilla design, three are owned by Rowan and one is owned by Transworld Drilling UK Limited of the United Kingdom.

The ROWAN GORILLA I had a triangular-shaped welded steel barge hull with three square truss-type, 504-foot-long legs with spud can footings[13] at their lower end. (See figure 5.) The forward leg was located along the rig's centerline near the apex of the hull. The other two legs were located on the port and starboard sides near the stern. Its principal characteristics are shown in Table 1:

[13]Spud can footings are placed on the bottom of the rig legs to distribute the load and lessen the amount of leg penetration in soft bottom material.

Table 1.--ROWAN GORILLA I characteristics

Length Overall:	297 feet
Width Overall:	292 feet
Depth of Hull:	30 feet
Full Load Draft:	16.5 feet
Full Load Displacement	19,419 long tons(2,240 lbs.)
Deck Area	42,265 square feet
Longitudinal Distance Between Legs	189 feet
Transverse Distance Between Legs	210 feet
Spud Can Diameter	66 feet

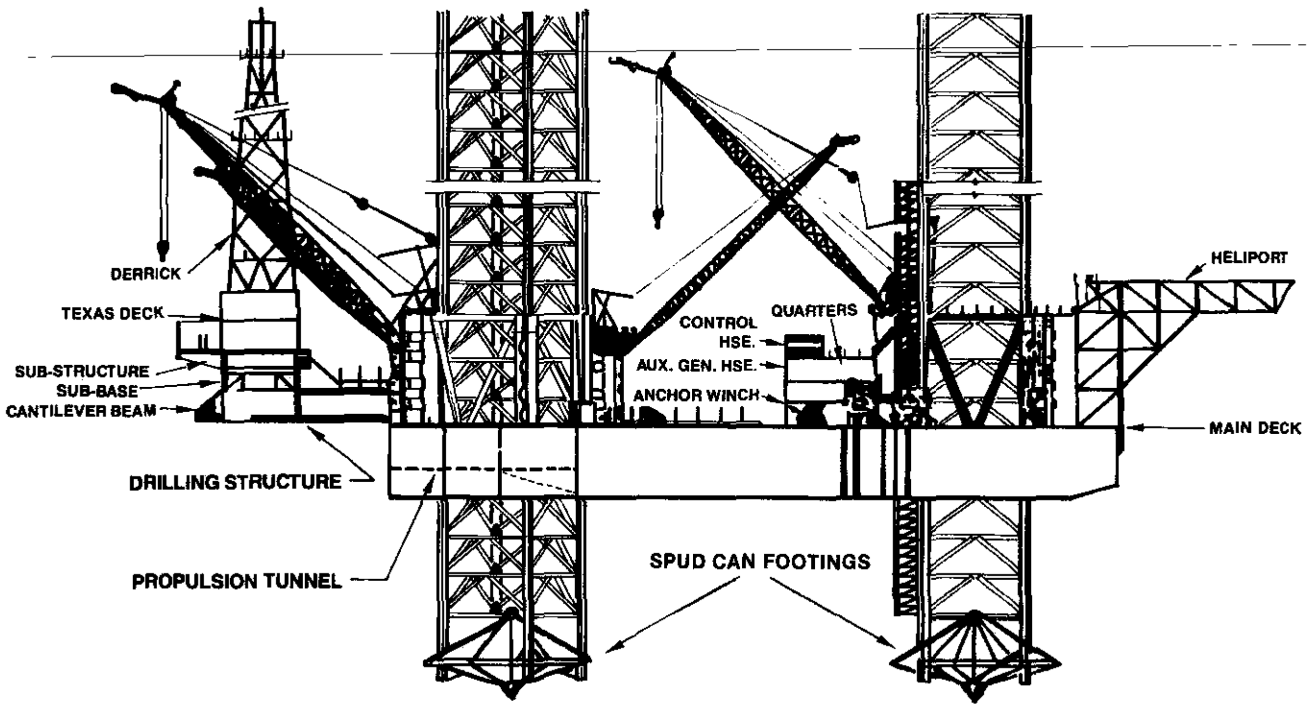

Figure 5.--Outboard profile of ROWAN GORILLA I.

A four-level deckhouse was located along the rig's centerline aft of the forward leg. Living quarters with accommodations for up to 120 persons and office space were located on the first three levels. The fourth or top level was the rig's control room which contained the thruster controls, leg jacking controls, communication equipment, inclinometers, and alarm systems. The communication equipment included two single-side band radios, one VHF-FM radio, and one VHF-FM aircraft radio. The inclinometers, used to measure the MODU's roll and pitch angles, consisted of arched liquid-filled glass tubes where an air bubble moved as the MODU moved in a seaway. A roll and pitch inclinometer with a 5-degree range was installed at eye-level just above the jacking gear console. A roll and pitch inclinometer with a 15-degree range was located behind the jacking gear console on the port bulkhead about 7 feet above the deck. The emergency generator was located on the third level and four sets of launching equipment for the rig's four survival capsules were located outboard of the deckhouse at the second level, two port and two starboard.

The main deck aft of the deckhouse provided a platform for drilling operations and the storage of equipment. (See figure 6.) Two longitudinal cantilever beams on the main deck, each located 26 feet off centerline port and starboard, supported the rig's drilling structure. This structure consisted of a 160-foot-high drilling derrick with a supporting sub-structure and sub-base. While the sub-structure moved fore and aft, the sub-base moved port to starboard permitting multiple drilling positions. For the tow, the drilling structure was located in its stowage position approximately 15 feet aft of the deckhouse.

According to the alternate rig superintendent, who was in charge of the cargo stowage for the tow, 5-inch-diameter drill pipes had been stowed in the center pipe bay and secured with chain in two places for the tow. Just behind the center pipe bay and under the cantilever there were about seven 8-foot by 8-foot by 8-foot steel containers. He stated that "angle iron was placed on the four corners of the containers and welded on three sides to the deck and three sides to the container. It was 3/8-inch thick angle iron." In addition, he stated that the weld testing shack and the welder's shack, each approximately 16 feet by 8 feet by 8 feet high, were also welded down to the main deck between the cantilever beams and alongside the containers.

The Texas deck[14] was stowed over the port side pipe rack and was secured with chains. He also testified that 3 1/2-inch-diameter drill pipes, drill collars,[15] and the flare booms[16] were secured with chains on the starboard pipe rack. The 13 5/8-inch-diameter blowout preventer[17] was welded and bolted to the main deck just forward of the starboard leg. Along the port side of the drilling slot near the stern, the crew had welded and bolted down the 21 1/4-inch diameter blowout preventer.

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[14]The Texas deck is the highest deck above the water except for the helicopter landing pad.

[15]Collars are pipe fittings with threads on the inside for joining two pieces of threaded pipe of the same size.

[16]Flare booms are an arrangement of pipes and burners used to dispose of combustible gas during drilling operations.

[17]A series of valves placed on the ocean floor to control well pressure during drilling operations.

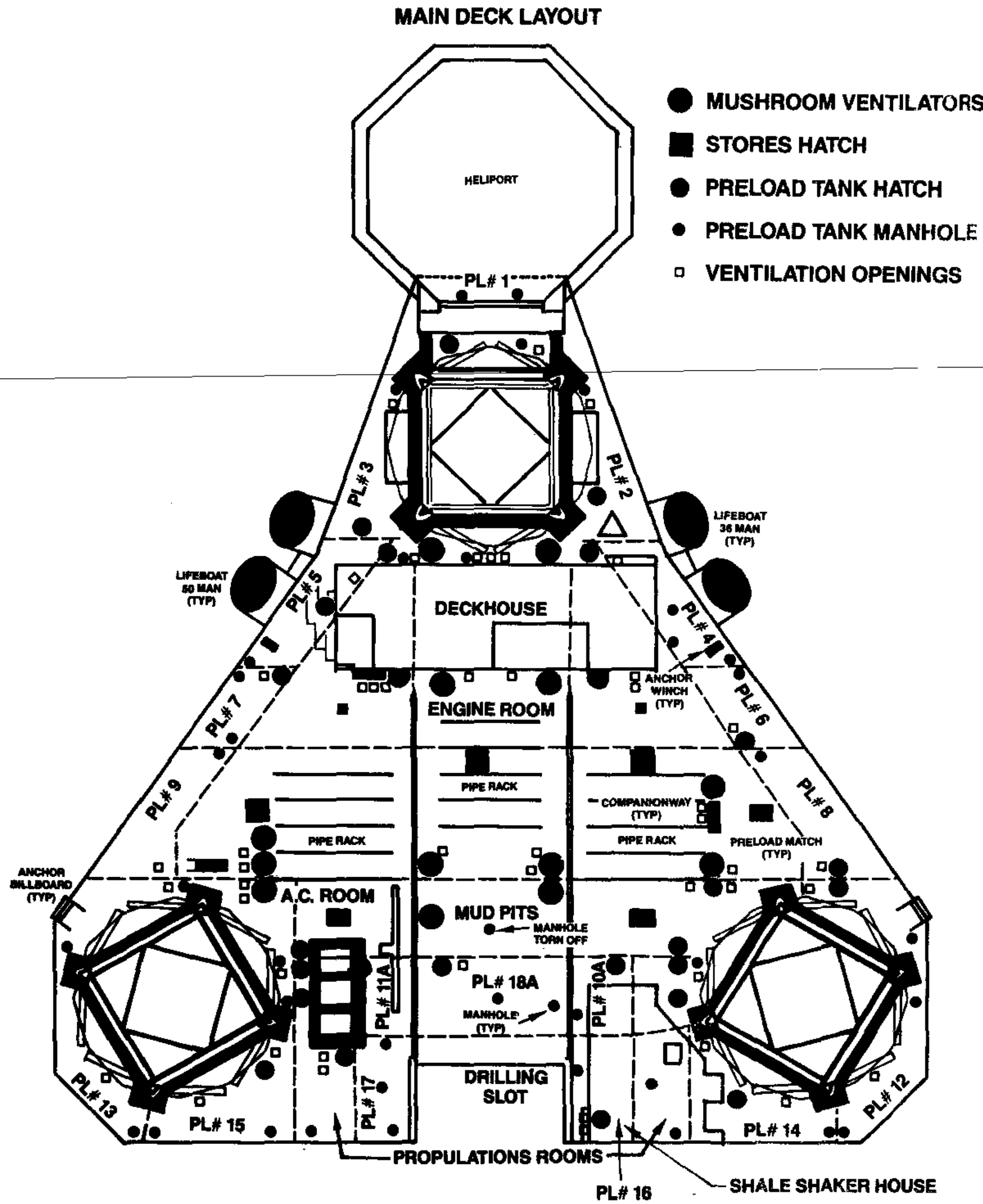

Figure 6.--Plan view of ROWAN GORILLA I main deck showing machinery deck and preload tanks.

Small pipes were secured on the port side of the drilling structure while the diverter[18] was secured on the starboard side. The alternate rig superintendent also stated that a small working platform and the anchor buoys were secured with chains on the port side of the drilling structure above the pipes and steel. Finally, he testified that the crane shacks and two survival capsules were secured with chains on top of the deckhouse. He said that a Noble, Denton Company surveyor was present throughout the securing and preparation of the rig for the tow.

The shale shaker house, which contained the equipment required to remove rock cuttings from the drilling fluid during drilling operations, was located on the after end of the starboard main deck inboard of the starboard leg. The shale shaker house was approximately 50 feet by 50 feet and 20 feet high. It was constructed of corrugated steel with a 1-foot-high opening around the top of the structure just below the overhead.

The machinery deck, located one deck below the main deck, contained the propulsion rooms for the thrusters, the mud pit room, the air compressor room, and various store rooms. Except for the propulsion rooms, these spaces were fitted with 48-inch-diameter mushroom ventilators which extended approximately 42 inches above the main deck. The propulsion room ventilators extended about 15 feet above the main deck. The store rooms were accessed through 6-foot by 6-foot hatches in the main deck. The pumps and controls for transferring liquids were also located on this deck. Dewatering aboard the rig was accomplished by means of a combination bilge and eductor system. The system serviced the preload tanks, voids, propulsion rooms, fuel tanks, drill water tanks, and other tanks. Suction and discharge could be obtained through the same piping by use of either an eductor or bilge pump. According to the rig mechanic, normally one of the rig's fire pumps was used for the bilge and eductor system while under tow. Below the machinery deck, the hull was subdivided into tanks for the storage of fuel oil, fresh water, drill water, and for preloading the rig.

The liquid level in each tank was measured by taking manual measurements through 2-inch-diameter sounding tubes located throughout the main and machinery decks. The sounding tubes for the preload tanks were located on the main deck adjacent to the access hatches for the particular tank. Each preload tank was accessible through a 36-inch-diameter raised trunk which extended approximately 24 inches above the main deck. Each trunk had a hinged watertight steel cover fitted with four dogs and a flexible gasket. In addition, each preload tank, depending on its size, had one or more 18-inch-diameter flush-mounted, watertight manhole covers which were bolted to the main deck. The preload tanks were also fitted with vents which terminated about 30 inches above the main deck. These vents consisted of steel cylinders with plate covers over the vent openings to minimize the ingress of water due to boarding seas.

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[18] A system to control well blowouts encountered at relatively shallow depths by diverting the flow away from the rig.

a. Stresses due to static loadings only, where the static loads include operational gravity loadings and weight of the unit afloat or resting on the sea in calm water.

b. Stresses due to combined loadings, where the applicable static loads are combined with relevant environmental loadings, including acceleration and heeling forces.

Section 4 of the ABS rules contained the specific structural design requirements for self-elevating units. Included in this section were the following requirements:

> [The legs must be able to] withstand a bending moment caused by a 6 degree single amplitude roll or pitch at the natural period of the unit plus 120% of the gravity moment caused by the angle of inclination of the legs.
>
> * * * * *
>
> [The legs must be able to withstand] acceleration and gravity bending moments resulting from the motions in the most severe anticipated environmental transit conditions, together with wind moments corresponding to a velocity of no less than 100 knots. The motions may be determined by acceptable calculation methods or model test methods. Alternatively, legs are to withstand a bending moment caused by minimum criteria of 15 degree single amplitude roll or pitch at a 10 second period, plus 120% of the gravity moment caused by the angle of inclination of the legs.
>
> * * * * *
>
> Jackhouse structures or frames are to have adequate strength to properly transmit the loads between the legs and the hull.

The ABS rules did not require Marathon to consider any dynamic loads due to the motion of the rig in a seaway, except for the accelertion forces on the legs, in designing the hull structure of the ROWAN GORILLA I. According to the Marathon vice president of engineering, neither dynamic response calculations nor wave load calculations on the rig's stern have ever been performed for the gorilla design.. He testified that model tests, performed at Rice and Michigan universities, were used for the purpose of analyzing towing resistance and the motion of the rig with and without a slow-roll device. He also stated that, based on engineering judgement, Marathon concluded that the worst structural loading occurred while the MODU was in the elevated mode, and that a dynamic structural analysis of the MODU afloat could not be done because there was no available method for accurately and reliably predicting the motions of a triangular shaped hull, particularly when the influence of lowering the legs was included as a factor. A representative of Marathon stated that although there are commercially-available computer software which predicts motions of ship-shape MODUs, these are not always reliable. Further, computer results do not correlate with the results of model tests and without an accurate prediction of motions, the input loading information for a dynamic analysis cannot be determined.

During the investigation, the Safety Board determined that there are commercially-available computer software programs which can be used for the dynamic structural analysis of triangular-shaped rigs including the influence of lowering the legs. Several classification societies have such programs. However, to obtain accurate and reliable predictions, the computer software should be calibrated using model tests to predict the rig's motions in a seaway.

Based on structural calculations submitted to ABS by Marathon, on August 24, 1984, ABS approved the structural design of the ROWAN GORILLA I for the following transit conditions:

- Transit (70 knot wind) - A 6 degree single amplitude roll or pitch at the natural period of the unit (11.9 seconds) with a total length of leg of 504 feet [and the bottom of the leg] 1.5 feet below [the bottom of the hull].

- Transit (100 knot wind) - A 15 degree single amplitude roll or pitch with 10 second cycle period of the unit with a total length of leg of 504 feet [and the bottom of the leg] 12.9 feet below [the bottom of the hull].

Both ABS and the U.S. Coast Guard required that an operations manual be developed for use by the rig crew. The ROWAN GORILLA I operations manual contained information which enabled the crew to determine the intact stability of the rig under any condition of loading. The manual also contained a section describing the rig's limits of service for all afloat transit conditions. In addition, the manual contained design limits of legs afloat graph (see figure 7) on which period of motion in seconds versus single amplitude motion in degrees curves were plotted. The graph stated that if the rig motions were above the curve for the applicable type of transit, the rig was considered safe. According to the Marathon vice president, the graph was "based on the maximum allowable motions, the leg strength of the unit in the towing position [assuming] the 15 degree 10 second limit as defined by the [ABS]."

The Marathon vice president further stated that the ROWAN GORILLA I legs were not designed to be lowered beyond the 25-foot level while in transit. The legs are specifically reinforced at the 12.9- and 25-foot levels. Lowering the legs beyond the 25-foot level would be "jeopardizing the

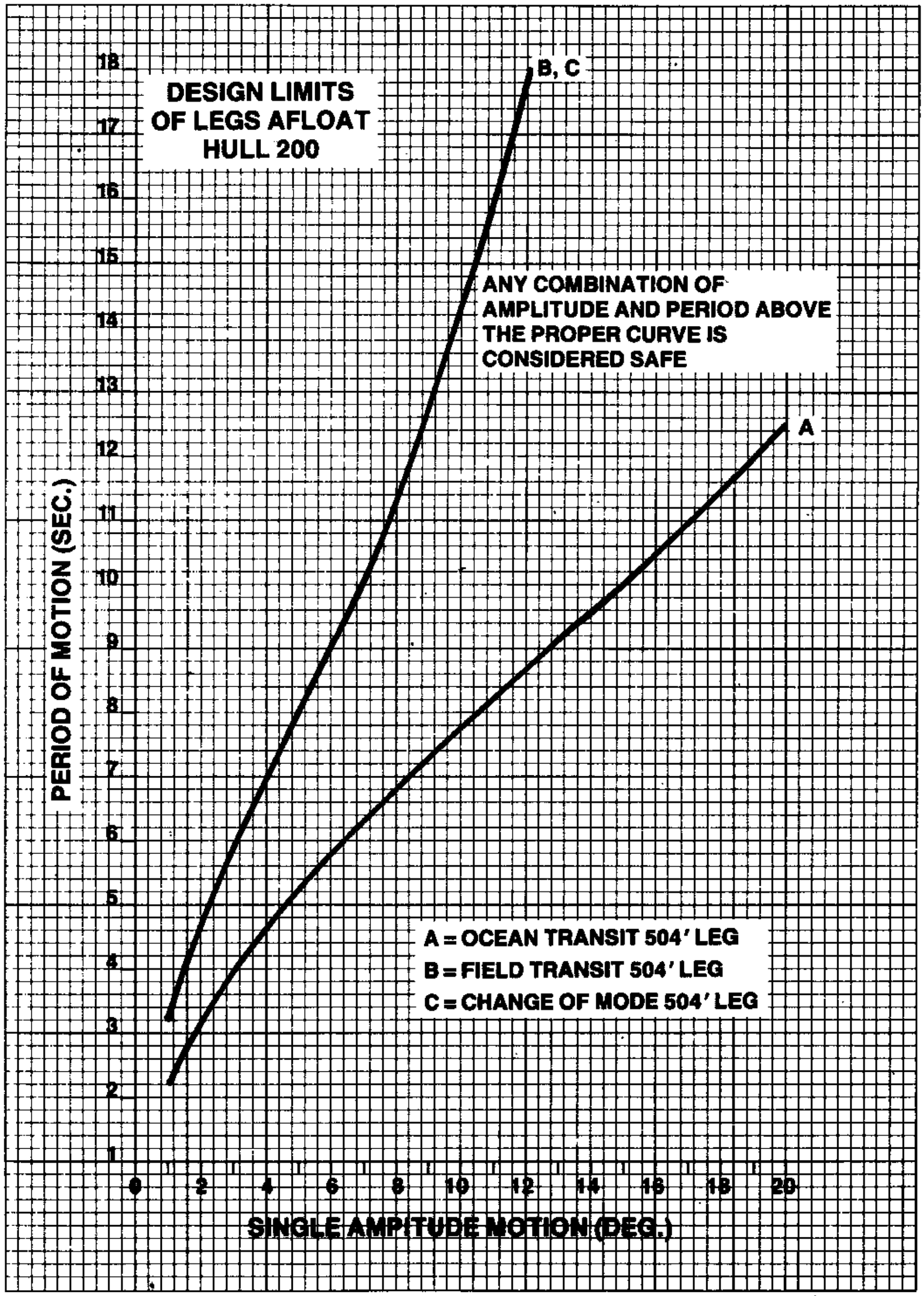

Figure 7.--Design limits of legs afloat graph.

integrity of the leg...if you continue to lower the leg and dampen the motion, then you're going to take more green water over the deck." The Rowan vice president stated that the rig superintendent was responsible for ensuring that the rig did not exceed the design limits of the legs afloat graph. He further stated that if the rig motions were exceeding the design limits with the legs at the 25-foot level, the only option for the rig superintendent would be to attempt to change heading to reduce the motions and that the rig superintendent should never lower the legs below the 25-foot level.

ROWAN GORILLA I Structural Failures.--During the rig's first ocean tow in December 1983, the ROWAN GORILLA I sustained structural damage. The rig was being towed from Louisiana to Nova Scotia by two tugs, and at 0330 on December 23, the tow encountered 15-foot-high waves and 50-knot winds. About 0530, the tow wire to one of the tugs broke and the rig started taking waves over its stern. Shortly thereafter, the crew discovered cracks in both propulsion rooms, in preload tanks 14, 16, and 10A. The next day, the crew also found cracks in preload tank 17 and in the hull around both thruster tunnels. The ROWAN GORILLA I's log indicated that the rig's most severe motions occurred on December 23 when it rolled 9° and pitched 6°. Rowan records do not show the period of roll or pitch.

The tow wire was reconnected and the ROWAN GORILLA I arrived in Saint Margaret's Bay, Nova Scotia on December 26, 1983. Marathon repaired the structural damage by welding the cracks and adding reinforcing plates along the tunnel structure for the thrusters. The repairs were examined and design of the succeeding four gorilla rigs was modified. The Marathon vice president stated that there had been no further hull cracking problems until the December 1988 incident on the ROWAN GORILLA I, and based on the location of the cracks, there was no correlation between the 1983 and 1988 cracks. The Rowan vice president stated:

> And another thing that I'd like to point out, when I went on the rig in 1983, those cracks went all the way through the propulsion room floor...all the way down that tunnel, which is part of the propulsion room floor.... In [1988], those cracks were never there...those cracks didn't transfer down to that tunnel. We know that the modification that was made to the tunnel in that area did work.

On November 8, 1988, the ABS conducted an annual hull survey, a periodical survey of the hull, the equivalent of a drydock survey and an annual loadline survey. The ABS found all deck plating, hull plating, leg structural members, leg support structures, and all deck structures to be in satisfactory condition. All ventilators, hatchways, manholes, scuttles and their respective covers, fastenings, and supports were examined and found in satisfactory condition. All preload tanks were opened, internally examined, and found in satisfactory condition. On November 11, 1988, the U.S. Coast Guard conducted a mid-period inspection and an equivalent drydock inspection and found all hull structure to be in satisfactory condition.

Noble, Denton and Associates, an offshore surveying and consulting firm, approved the preparations for the tow. This approval was based on a preliminary survey report conducted on October 14, 1988, and on final recommendations given by an on-site surveyor on December 8, 1988. Included in the recommendations given by Noble, Denton and Associates were the following:

- Watertight hatches, companionways and other openings in the main deck to be secured closed and watertight in the afloat condition. They should be opened only in fine weather temporarily as required for necessary operations and secured again as expeditiously as possible.

- Decks to be cleared of all small equipment, gas bottles, welding equipment, spare plate, etc. These should be stowed in bottleracks and baskets if available and stowed in sheltered areas below the drilling structure, or below decks and secured against motion.

- Welding bench and steel material on the port side of the bow leg to be moved to a better protected area.

- Flare booms on the starboard side main deck pipe racks to be fitted with additional seafastenings.

- Pipe collars are to be laid down in racks, neatly stowed ..., and well secured against movement...

- The drilling structure is to be used for storage. This is an area unaffected by breaking seas and affords better stowage than the open main deck areas for small items particularly.

- Crane booms to be laid down and secured against sideways movement in boom rests for the voyage so that the boom may move longitudinally in the rest if necessary.

- It is recommended that the advice of a long range forecasting service should be used for the duration of the towage.

After the accident, the rig superintendent testified that between December 13 and 15, 1988, the crew discovered the following hull cracks aboard the ROWAN GORILLA I:

1. Preload Tank No.15 - Two 7-inch-long horizontal cracks. These cracks were located approximately 23.5 feet below the main deck, near the connection of a 7/16-inch-thick longitudinal bulkhead and a 36-inch-wide by 7/16-inch-thick web frame.

2. Preload Tank No.14 - One 12-inch-long vertical crack. This crack was located along the port aft corner of the tank where the transom bulkhead connects to a longitudinal bulkhead about 22 feet below the main deck. The transom bulkhead plating was 5/8-inch thick while the longitudinal bulkhead plating was 7/16-inch thick. The two bulkheads were connected with 5/16-inch double continuous fillet welds.

3. Preload Tank No.13 - One small crack which yielded a negligible amount of water. This crack was located near the inboard aft corner of the tank along the connection of the transom bulkhead and a 45-inch-wide by 1/2-inch-thick web frame. The plating in this area was 5/8-inch thick.

4. Aft Starboard Leg - Two small cracks on welds. These cracks were located on the outer welds which connected the forward inboard gear unit boundary plate to the main deck. The gear unit bottom plating consisted of a 1-inch-thick deck insert while the main deck consisted of 1/2-inch-thick plate. The two steel plates were connected with 5/16-inch continuous outer and inner fillet welds.

5. Aft Port Leg - One 6-inch horizontal crack. This crack was located along the weld area which connected the gear unit housing to the gear unit boundary plate. The weld consisted of a 9/16-inch-thick double continuous fillet weld.

6. Preload Tank No.16 - One small crack. This crack was found along the overhead (main deck) of the tank near the crack on the inboard gear unit boundary plate of the aft starboard leg. The main deck plating in this area was also 1/2-inch thick.

7. Port and Starboard Propulsion Rooms. A small crack in the overhead (main deck) in relatively the same place in both propulsion rooms.

<u>The December 1988 Tow</u>.--The Chairman of the Board of Rowan stated that since 1983, Rowan had operated offshore eastern Canada and at one time, had three rigs in the area. However, with the collapse of world oil prices in 1986, the development of oil and gas discoveries in this area did not appear to meet their customers' criteria for additional investments. Thus, drilling activity was greatly reduced, and the ROWAN GORILLA I completed its final drilling assignment in the area in September 1988. He stated that it became apparent that there would be no possibility of additional drilling contracts in the area until at least January 1990, and that date was highly speculative. Meanwhile, demand in the North Sea for self-elevating MODUs had increased with eight Rowan rigs working in the North Sea. He also stated that during the fall of 1988, Rowan was bidding for several contracts, three of which required operations to commence by February 1989. In addition, he stated that because there was no potential work in offshore eastern Canada for at least 15 months and the financial burden for the ROWAN GORILLA I to remain idle in Halifax harbor versus operating was in excess of $1 million per month, the decision was made to depart Halifax in December.

The Chairman of the Board of Rowan stated that the moving of the ROWAN GORILLA I across the North Atlantic aboard a heavy lift ship was not considered because Rowan "anticipated difficulty, in the event of unfavorable weather conditions upon arrival, in unloading the GORILLA I" and because the ROWAN GORILLA II spud cans "were continuously in the water" during a tow aboard a heavy lift ship from Singapore to the North Sea. The Rowan vice president stated that Rowan did not consider moving the ROWAN GORILLA I aboard a heavy lift ship because in 1983, he had observed extensive damage to a self-elevating rig that had been moved across the North Atlantic Ocean to Halifax aboard a heavy lift ship. The Rowan vice president also stated that Rowan did not consider reducing the height of the legs for the tow because the rig was designed to be towed with its legs raised, it would cost about $1.5 million and take about 1 week to remove 100 feet of the three legs, it would cost about $2.25 million and take about 2 weeks to replace the 100 feet, and it would require an additional vessel to transport the legs.

<u>ROWAN GORILLA I Survival Equipment</u>.--The ROWAN GORILLA I was equipped with two 50-person and two 36-person totally enclosed survival capsules manufactured by Survival Systems International (see figure 8), one 14-foot-long rigid-hull inflatable boat (Zodiac) manufactured by Zodiac Hurricane Marine, Inc., four 25-person Beaufort inflatable liferafts, 100 adult lifejackets; 120 immersion suits, 8 ring buoys, and an emergency position indicating radio beacon (EPIRB) as required by its U.S. Coast Guard Certificate of Inspection. According to the manufacturer of the survival capsules, each capsule was designed to operate for at least 24 hours. When the rig left Halifax on December 8, 1988, the two 36-person capsules were in their U.S. Coast Guard approved launching equipment, the two 50-person capsules were bolted to the top of the deckhouse next to the control room,

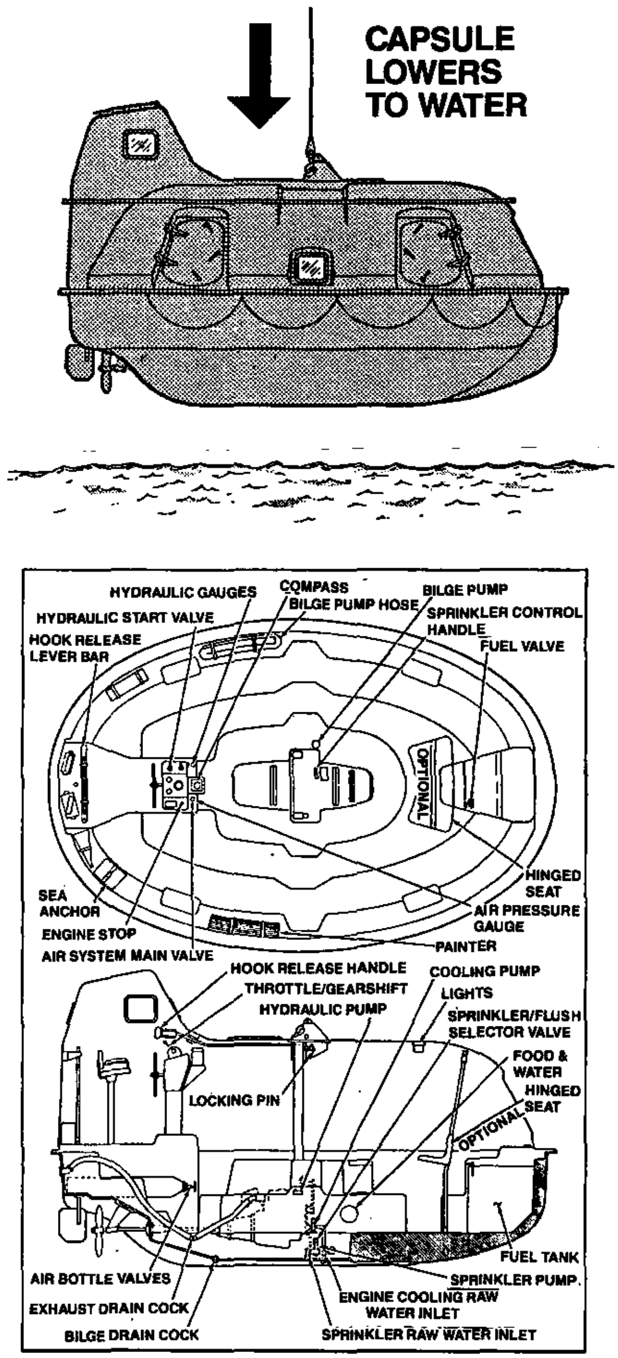

Figure 8.--Drawings of the type of survival capsule used aboard the ROWAN GORILLA I. (Courtesy of Survival Systems International)

and the four liferafts had been removed from their U.S. Coast Guard approved launching equipment near the edge of the main deck and stored near the center of the main deck.

The organization chart and the fire and abandon platform (station) bill for the ROWAN GORILLA I contained different position titles for the same person, and the fire and abandon platform bill had incorrect position titles and did not identify by name the certificated lifeboatmen required by the U.S. Coast Guard Certificate of Inspection for the ROWAN GORILLA I. The fire and abandon platform bill stated that the toolpusher was in charge of two survival capsules and the night towerpusher was in charge of the other two survival capsules; actually, the rig superintendent was in charge of two survival capsules and the night toolpusher was in charge of the other two survival capsules.

SMIT LONDON Arrangements.--The SMIT LONDON was an ocean-going salvage tug, built of welded steel in Hardinxveld, The Netherlands in 1975, and classed by Lloyd's Register of Shipping. Its principal characteristics are shown in table 4:

Table 4.--SMIT LONDON characteristics

Length Overall:	245 feet
Width Overall:	50 feet
Depth of Hull:	24.9 feet
Full Load Draft:	22.4 feet
Bollard Pull:	180 tons

The tug's main propulsion machinery consisted of two nine-cylinder unidirectional diesel engines which delivered about 17,000 horsepower to two controllable pitch propellers. In addition, the tug was outfitted with a 650 horsepower bow thruster and two electrically-driven towing winches each consisting of one storage drum and two friction drums. Each winch carried about 4,265 feet of special high grade steel, 9-inch-circumference wire rope. The winches, located amidships in the towing winch room, could be monitored by closed circuit television and controlled from the towing control room or from the bridge. Two electrical winches, located aft on the main deck, carried steel gog wires which were rigged to the tow wire to restrict athwartships movement of the tow wire.

According to the SMIT LONDON master, the towline used to tow the ROWAN GORILLA I was connected to the rig's chain bridle. The master stated that the towline was fitted with synthetic "Vulkalon" chafing gear, which was specifically designed to protect the towline from rubbing on the tug, that the 180 feet of synthetic rope provided the flexibility needed to prevent the towline from parting when subjected to sudden dynamic loads, and that the 200 feet 8 1/2-inch wire rope was intended to serve as the weak link and should part before any part of the towline. The 9-inch wire rope had a breaking strength of 361 long tons, the synthetic stretcher had a breaking strength of 721 long tons, and the 8 1/2-inch wire rope had a breaking strength of 310 long tons.

Meteorological Information

The Rowan vice president stated that although Rowan had under contract a private company to provide Rowan with weather forecasts, Rowan relied upon the SMIT LONDON to obtain weather information during the tow because the rig's facsimile machines did not operate while under tow. The ROWAN GORILLA I rig manager stated that Rowan did not interpret the surveying company's recommendation that a long range forecasting service should be used during the tow as meaning that Rowan should employ a long range forecasting service. The rig manager stated that it was the SMIT LONDON's responsibility to obtain weather information for the tow.

The SMIT LONDON received the U.S. National Weather Service (NWS) high seas forecasts for the North Atlantic Ocean. When the tow departed Halifax at 1210 on December 8, the latest NWS forecast indicated that there would be no severe weather along the intended trackline until at least 1500 on December 9, and that winds would be less than 25 knots and the seas would be less than 8 feet. (See appendix C.) However, at 1900 on December 8, the NWS reported a gale (winds between 39 and 46 knots) moving through the area of the North Atlantic Ocean where the tow was expected to be about December 12, and on December 10, the NWS reported a storm (winds between 48 and 55 knots) moving through the same area. Also, on December 10, the NWS forecast a gale to be in this area by 0300 on December 12.

The 0100 NWS forecast on December 13, stated that a storm was developing off the east coast of Florida, that by 0900 on December 14, the storm would be near latitude 29^{o} N, longitude 78^{o} W (about 500 miles to the west of the intended position of the tow), and that 30- to 45-knot winds and 10- to 20-foot-high waves could be expected within 500 miles of the center of the storm. Figure 4 shows the actual trackline of the storm. The NWS forecasts at 0700, 1300, and 1900 on December 13 and the 0100 NWS forecast on December 14 provided similar information regarding the developing storm. The 1900 NWS forecast on December 13 predicted the storm to be located about 120 nautical miles northwest of the actual storm location at 0300 on December 15. The 0700 NWS forecast on December 14 stated that at 0300 on December 14, the storm was located about 600 miles to the west of the tow's location and was moving to the northeast at 25 knots. The 1300 NWS forecast on December 14 placed the storm's position at 0900 near the position forecast at 0100 on December 13 and that the storm was still moving to the northeast at 25 knots. The 1900 NWS forecast on December 14 and the 0100 NWS forecast on December 15 both predicted that the storm was moving to the northeast and reported the storm's actual trackline to be easterly. The 0700 NWS forecast reported that at 0300 on December 15, the now "dangerous storm" had turned toward the northeast and was within 50 miles of the ROWAN GORILLA I's position.

At 0000 on .December 15, a commercial vessel about 120 miles to the southeast of the tow's position reported 46-knot winds from the southwest and 23-foot-high waves. At 0900 on December 15, the same vessel reported 50-knot winds from the west and 49-foot waves every 12 seconds, and at 1500, the vessel reported 45-knot winds from the west-northwest and 49-foot waves every 10 seconds. Based on available meteorological and oceanographic information, the Safety Board estimated that about 0900 on December 14, there were 60-knot winds and 45-foot-high waves from the east near the tow, and about 0900 on December 15, there were 60-knot winds and 45-foot-high waves from the west-northwest near the tow. The air temperature was about 60° F and the sea temperature was about 68° F at the tow's location.

Using the U.S. Navy Marine Climatic Atlas of the World,[19] the Safety Board estimated the percent frequency at which a tow would encounter a storm with wind speeds over 34 knots and wave heights over 20 feet along two assumed routes across the North Atlantic Ocean from Halifax to Great Yarmouth during various months of the year. Route C assumed a great circle route[20] (see figure 3) and Route D assumed the intended trackline of the SMIT LONDON master. The results indicate that there is about a 40 percent decrease in both the percent frequency of encountering wind speeds over 34 knots and wave heights over 20 feet if Route D is used instead of Route C during December, that the greatest percent frequency of encountering wind speeds over 34 knots on either route occurs in December, and the percent frequency of encountering wave heights over 20 feet on Route D during December is two to six times greater than for the period April through October. Also, the percent frequency of winds greater than 48 knots during December along the tow's trackline from Halifax to the accident location is about 1 percent. The results also show that the percent frequency of encountering wind speeds over 34 knots along Route D does not decrease significantly until March.

Marathon provided the Safety Board with information on the frequency at which a tow would encounter a storm with wind speeds over 34 knots and wave heights over 12 feet along Routes C and D assumed by the Safety Board and a third Route E along latitude 32° N. Marathon used the Pilot Charts of the North Atlantic Ocean for October, November, and December 1988 published by the U.S. Defense Mapping Agency. The results indicate that there is about a 35 percent decrease in both the percent frequency of encountering wind speeds over 34 knots and wave heights over 12 feet if Route D is used instead of Route C during December, and there is about a 65 percent decrease if Route E is used.

From December 1, 1988, until February 26, 1989, a scientific/meteorological experiment called ERICA (Experiment on Rapidly Intensifying Cyclones over the Atlantic) was in progress for an area of the North Atlantic Ocean which included the accident location. ERICA was a joint field program to study winter storms over the North Atlantic Ocean supported by the U.S. Office of Naval Research. The program was designed to obtain a new understanding on the rapid intensification of winter storms at sea. ERICA included a triangular region of the North Atlantic Ocean from southeastern Newfoundland, Canada to Cape Hatteras, North Carolina to latitude 40° N, longitude 50° W. This region was chosen because during a typical winter, several moderate to strong storms occur in this region.

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[19] "U.S. Navy Marine Climatic Atlas of the World, Volume 1; North Atlantic Ocean," NAVAIR 50-1C-528, December 1974.

[20] A great circle route is the shortest route between two ports.

A meteorologist associated with the ERICA project stated that a long range forecast prepared by the local Environment Canada Weather Office for the Halifax area on December 11 had predicted the major storm encountered by the tow on December 14 and 15. He further stated that during the December 14/15 storm and two other storms that were studied by the ERICA project during December, the following was observed:

- o rapid changes in wind direction while the wind speed remained well above 40 knots, and often above 50 knots.
- o chaotic seas near the centers of the storms with whitecaps being blown off the waves which were moving in one direction by winds from another direction.
- o occasional interference between wave systems from two directions with mammoth foamy water turrets the result.

Survival Aspects

While the ROWAN GORILLA I was being prepared for the tow from Halifax to Great Yarmouth, the new rig area manager in England ordered all rig survival capsules and liferafts removed from their launching equipment and secured for the tow from Halifax to Great Yarmouth. Thus, the Rowan alternate rig superintendent, under instructions from Rowan shoreside managers, removed the rig's four survival capsules and four inflatable liferafts from their U.S. Coast Guard approved launching equipment. Rowan managers stated that the reason for removing the survival capsules and liferafts from their approved launching equipment was to protect the survival equipment during the tow. However, Canadian Coast Guard inspectors boarded the ROWAN GORILLA I a few days before the rig departed Halifax, and told the alternate rig superintendent that the survival capsules should not have been removed without U.S. Coast Guard permission. Consequently, the two 36-person survival capsules were replaced in their launching equipment, one port and one starboard, before the rig departed Halifax. However, the other two survival capsules and the liferafts were not replaced, and the U.S. Coast Guard was never contacted by Rowan managers regarding the removal of the survival capsules and liferafts from their approved launching equipment. The Rowan vice president stated that he was not aware of any Rowan policies regarding the storage of U.S. Coast Guard required lifesaving equipment during ocean tows, and the ROWAN GORILLA I operations manual does not address the storage of lifesaving equipment.

After the ROWAN GORILLA I informed Canadian Coast Guard Radio Station Halifax at 0242 on December 15, that its towline had broken but there was no emergency, the radio station established an hourly communications schedule with the rig and monitored all radio communications from the rig, and Halifax Rescue Coordination Center informed the U.S. Coast Guard Rescue Coordination Center in New York and the United Kingdom Rescue Coordination Center in Falmouth, England of the situation. In anticipation of a possible emergency situation, the Halifax Rescue Coordination Center at 0853 requested the U.S. Coast Guard Rescue Coordination Center in New York to interrogate the U.S. Coast Guard AMVER[21] system to determine which vessels were in the immediate area of the rig. The AMVER information was received by the Halifax Rescue Coordination Center at 1100, and at 1228, the ROWAN GORILLA I broadcasted a distress message.

At 1230, the Canadian stand-by long-range P-140 search and rescue aircraft was ordered launched, and at 1250, the Canadian Coast Guard vessel SIR WILLIAM ALEXANDER got underway from Halifax. Also, at 1230, the U.S. Coast Guard New York Rescue Coordination Center directed the U.S. containership SEALAND PERFORMANCE to the scene.

The SMIT LONDON crewmember aboard the rig stated that about 1330, he and the rig superintendent jointly decided to abandon the rig and that no Rowan management personnel ashore were consulted. The rig superintendent then ordered all crewmembers to muster with their immersion suits in the deckhouse and told the crew that they would be abandoning the rig in the starboard survival capsule. The SMIT LONDON crewmember aboard the rig stated that the starboard capsule was used because "of the wind direction," and the port capsule was still in good condition when the rig was abandoned. After the crew mustered in the deckhouse, the senior barge engineer went to the hospital, retrieved the seasickness pills stored there, and distributed the pills to all crewmembers. The barge engineer stated that he and three other crewmembers then went to the starboard capsule and determined that the capsule was ready for launching, and the capsule fuel tank was full. The barge engineer stated that the fuel had been changed about 2 months previously. After the rig superintendent informed the Canadian Coast Guard and the tug captain that the crew was abandoning the rig, the crew, with immersion suits on, immediately proceeded to the starboard capsule. The rig superintendent stated:

> All I can say about the actual escape from the rig was the fact that it went just like the drills that we hold weekly...
>
> * * * * *
>
> We got to the boat, everyone got in, there was no confusion. It was just like a drill. Everybody got in, they moved around, evenly spaced themselves in the capsule, strapped in; everybody had their survival suits on.

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[21]The U.S. Coast Guard Automated Mutual Assistance Vessel Rescue System (AMVER) is an international voluntary system operated by the U.S. Coast Guard through which the U.S. Coast Guard keeps track of the position of all vessels participating in the system to aid in search and rescue missions.

He further stated that after they got into the survival capsule, one of the crew began reciting a check-off list that they had learned during the Canadian mandatory survival training:

> The first one being to get away from the danger. In this case, get away from the rig. So we'd done that. And he said, he named off the second item which was to check for injuries. He said, well, we've done that. and he just went down the list and checked those off by the book. He remembered each one by its letter of significance.

The rig mechanic stated that, "I believe that [the survival training] saved my life." The rig electrician stated that the survival training made his decision to abandon the rig "a lot easier. ...You know what you have to do, ...and you don't think twice about it."

The rig superintendent said that he put the senior barge engineer in charge of operating the capsule because the barge engineer had just completed a course in rescue craft operations. The barge engineer stated that during the course he was shown "the difference between riding a small boat into the seas and riding with the seas and this was just invaluable information." The access door and overhead hatch were then closed and the capsule lowered to the water. After the capsule was released from the launching cable, the barge engineer contacted the tug master using one of the portable VHF radios they had brought aboard and obtained a course to steer in order to maneuver the capsule away from the rig. The rig superintendent stated:

> The capsule went underwater two, maybe three times where waves washed over it. ... When you're inside of it in 50-foot, 60-foot seas, you had the sensation of being in 4-foot seas. You can't see far enough out the portholes to determine what the sea state is...

The barge engineer stated that the capsule engine ran for about 40 minutes and then stopped. He tried to restart the engine but was unsuccessful. He believed that the engine stopped because of a lack of fuel. He said when the engine stopped, the capsule engine water temperature gauge indicated a temperature between 210^{o} and 220^{o} F and the oil pressure gauge was in the normal range. The rig superintendent stated that the engine stopping did not cause the survivors any anxiety because the capsule had maneuvered a sufficient distance from the rig so that if the rig capsized, the rig would not hit the capsule.

The rig superintendent stated that by the time the survival capsule engine had stop running, four or five crewmembers were already seasick. He said that each crewmember then took another pill for seasickness and a sip of water. During their stay in the survival capsule, only six crewmembers, including the two female crewmembers and the SMIT LONDON crewmember, did not get seasick. The rig superintendent stated:

> It was after dark, maybe the spirits were getting a little bit low, and there was just a little like spontaneous singing that started. And I think that helped a bunch. That was something we were taught in survival school that...you should...tell jokes, sing. People were still in good enough presence of mind to cut each down in a family-type way, ...in a joshing way.
>
> If someone...threw up with a lot of volume or a lot of sound it was commented on. "Pass the bucket" was a familiar phrase. There was a small galvanized bucket and pail in there. If you didn't have the pail that was okay. The floor was full anyway.
>
> Something a lot of people have asked me about was the smell and the smell was not overwhelming, I don't know why. You just blocked it or, why, but it wasn't.

The tug master stated that after the capsule entered the water, he maneuvered the SMIT LONDON to within about 500 feet of the capsule and stationed three crewmembers on the bridge as lookouts for the capsule. He said that the capsule engine stopped when the capsule was about 5 miles from the rig and that after the engine stopped, the capsule and rig continued to drift apart.

At 1320, Halifax Rescue Coordination Center was able to divert a Canadian C-130, which was en route to Bermuda, to the scene. At 1520, the C-130 was the first aircraft to arrive at the accident location which was about 500 miles southeast of Halifax. The P-140 arrived at 1640. Meanwhile, several other commercial vessels as well as the HMCS OTTAWA were directed to the scene. Canadian aircraft stayed with the survival capsule throughout the night until the survivors were rescued by the SMIT LONDON.

The tug master stated that when it began to get dark:

> ...I noticed...that there was no light outside of the capsule. ...which would make it...very, very difficult to keep track of it at night time, even risking colliding with it, if you attempt to do that. ...So I called the rescue plane...and asked them whether they were able to locate the capsule during the dark hours. And the pilot...told me that that was no problem for them.... And then, when it indeed became dark,...we lost the capsule out of sight.... And then during the dark hours the rescue plane dropped...very bright white lights...on the sea surface...four of those markers around the capsule...and in that respect, they kept track of [the capsule].

The rig superintendent stated that the rig's EPIRB was activated for about 1 hour at the request of the Canadian Coast Guard so that a search and rescue satellite could get a fix on their position. He said that they had "unless absolutely necessary" until seas were below 10 feet in height "to ensure safety of survivors."

At daylight, about 0800 on December 16, the tug master again spotted the capsule, and about 0900 on December 16, the SMIT LONDON master and Halifax Rescue Coordination Center agreed that rescue by the helicopter on board the OTTAWA, which had arrived in the area at daylight on December 16, was the safest method to evacuate the survivors from the capsule. However, about 1000, the sea conditions had improved and the tug master informed the Canadian Coast Guard that he was sending the tug's 12-foot Zodiac over to the capsule with batteries for their radio and food for the survivors, and, if possible, they would rescue the survivors.

The rig superintendent stated that about 1000 on the morning of December 16:

> We were told that the...OTTAWA was on the way and they had a helicopter and they'd be launching that and that's how we would be recovered. It just seems like within moments of receiving that word that the helicopter experienced technical difficulties and they could not launch at that time. Spirits went down....
>
> And the [tug] captain then told me over the radio that he'd be sending the Zodiac with another radio. Our battery was getting quite weak. The last part of the night we didn't even talk back to the planes, except on one occasion. ...I'm not sure in so many words that the captain told me that if people wanted to get out of the capsule into the raft,...no way he could stop... Immediately as soon as hearing that word, the general feeling in the capsule was we were leaving the capsule and I had to stop that celebration. I hadn't determined at that time that we'd be leaving. That kind of quieted people down for a minute and after thinking about it for a minute I could recall all the times that the weather can close in on you out there. So we determined,... three people could get into the Zodiac.
>
> * * * * *
>
> ...as soon as the [Zodiac] pulled alongside, we opened the door on the port side which was the lee side of the capsule.... The guys in the Zodiac threw us a rope ... and we sent three of the guys...to the boat.
>
> * * * * *
>
> After that point it just continued three people at a time until the last trip when there was four.... Attempted one time to close the capsule door. Somebody mentioned

> that they wanted to try and recover the capsule, but that was not a major concern to us at the time.

The SMIT LONDON second mate, who was in charge of the Zodiac during the rescue of the ROWAN GORILLA I crew from their survival capsule, said that the SMIT LONDON port crane was used to launch the Zodiac into the 15-foot-high seas, and that the relative motion between the Zodiac and the survival capsule was "Not more than half a meter [one to two feet]." The SMIT LONDON second engineer, who was maneuvering the Zodiac during the rescue, stated that the Zodiac was equipped with a 20-horsepower outboard engine, and they had no difficulty rescuing the rig crew. He said:

> ...it was quite easy, because the Zodiac was a bit lower than the capsule. As soon as [the rig crew] opened the doors,...they ...roll[ed]...into the Zodiac. ...we used a pilot ladder [to transfer the rig crew to the SMIT LONDON] and just maneuvered the Zodiac against the pilot ladder and then tried to keep it steady. And then the second mate, he assisted the people to climb the ladder."

At 1215 after the survivors were safely aboard the SMIT LONDON, Halifax Rescue Coordination Center ordered the WILLIAM ALEXANDER to attempt to recover the survival capsule. The WILLIAM ALEXANDER arrived on scene at 0200 and departed at 0746 on December 17 without sighting the survival capsule. Canadian aircraft searched for the survival capsule on December 18 and 19; however, the survival capsule used by the rig crew was never recovered.

Tests and Research

According to the stability calculations performed by the ROWAN GORILLA I crew, the rig, with the legs located 12.9 feet below the bottom of the hull, was loaded as shown in table 5 when it departed Halifax on December 8, 1988.

Table 5.--ROWAN GORILLA I loading on December 8, 1988

Displacement:	18,853 long tons
Longitudinal Center of Gravity (forward of the centerline of the aft legs):	65.6 feet
Transverse Center of Gravity:	0.1 foot to port
Vertical Center of Gravity (above bottom of hull):	85.5 feet

According to the data used for the stability calculations, all preload tanks were empty except for a few inches of water in each tank. To determine the stability characteristics of the ROWAN GORILLA I at the time of capsizing, the Safety Board and the U.S. Coast Guard corrected the departure loading to account for the normal consumption of fuel and water, the lowering of the legs to 25 feet below the hull, the additional weight of the broken towline, and the dumping of the drill water tanks reported in witness testimony. Marathon was then requested to perform damage stability calculations assuming the following flooding:

1. Preload tank 14 to the waterline.

2. Preload tanks 14 and 15 to the waterline.

3. Preload tanks 14 and 15, and both propulsion rooms to the waterline.

4. Preload tanks 14 and 15 and both propulsion rooms to the waterline, and the mud pit and air compressor rooms half full.

5. Preload tanks 14 and 15 and both propulsion rooms to the waterline, the mud pit and air compressor rooms half full, and the shale shaker house full.

Results of the damage stability calculations indicate that the rig's stability decreased as more compartments were flooded; however, for all five flooding cases the rig's righting moment was greater than the wind overturning moment. For the most severe flooding condition calculated, condition 5 above, the righting moment was still about twice the overturning moment due to the 60-knot wind and the maximum after trim was about 2^{o} to 3^{o}. With preload tanks 14 and 15 flooded, the rig's righting moment was several times greater than the overturning moment from a 60-knot wind, and the rig had almost no stern trim.

Other Information

<u>Survival Capsule Design</u>.--The 1983 amendments to SOLAS 1974 became effective internationally on July 1, 1986. The 1983 amendments contain construction standards for enclosed lifeboats, similar to the survival capsules aboard the ROWAN GORILLA I, which include requirements for a light on the top of the cover visible for at least 2 miles, for an efficient radar reflector, and the capability of operating with a full load for 24 hours at 6 knots. However, the construction standards for enclosed lifeboats only apply to vessels built after July 1, 1986, and the 1983 amendments do not consider persons wearing immersion suits in determining the capacity of enclosed lifeboats.

As of the date of this report, the U.S. Coast Guard has not implemented the 1983 amendments to SOLAS 1974 into U.S. Coast Guard regulations and has no published regulations for the construction of enclosed lifeboats similar to the survival capsules found on the ROWAN GORILLA I except that "Lifeboats with rigid shelter may be approved, provided that it may be readily opened from both inside and outside, and does not impede rapid embarkation and disembarkation or the launching and handling of the lifeboat." (46 CFR 160.035-3) Because all vessels subject to SOLAS 1974 are required to comply with the 1983 amendments, the U.S. Coast Guard has published interim guidelines for compliance with the 1983 amendments for U.S. vessels making international voyages and U.S. manufacturers of lifesaving equipment used on vessels engaged in international voyages. Present U.S. Coast Guard regulations do not consider persons wearing immersion suits in determining the capacity of enclosed lifeboats.

U.S. Coast Guard Manning and Crew Qualifications.--U.S. Coast Guard regulations (46 CFR 12.05) include the following minimum requirements for issuance of mobile offshore unit able seaman documents:

1. Proof of citizenship;
2. Pass a physical examination;
3. Speak and understand the English language;
4. Have 12 months service on vessels operating on the oceans;
5. Present certification from the person-in-charge of the rig that they have been trained in all the operations connected with the launching of lifeboats and liferafts, are acquainted with the practical handling of lifeboats, and are capable of taking command of a lifeboat;
6. Pass an examination showing knowledge of seamanship including knowledge of nautical terms, distress signals, firefighting, and operation of lifeboats found on rigs.

A merchant mariner's document endorsed as able seaman is considered a certificate of efficiency as lifeboatman without further endorsement.

On May 17, 1989, the Coast Guard published a supplemental notice of proposed rulemaking (SNPRM) for the licensing of officers and operators of mobile offshore drilling units. The preamble to the SNPRM contained proposed manning scales. Under the proposed manning scale, the ROWAN GORILLA I would be required to have one offshore installation manager with a bottom bearing unit underway endorsement, two able seamen, and one ordinary seaman while under tow. Under the SNPRM, an applicant for an offshore installation manager license with a bottom bearing unit underway endorsement must:

1. Provide certification that he/she has witnessed 10 rig moves either as an observer in training or as a rig mover under supervision;
2. Provide certification that he/she has successfully directed, while under the supervision of an experienced rig mover, 5 rig moves on bottom bearing units including 1 move within 1 year preceding the date of application;
3. Have a lifeboatman certificate;

4. Complete a Coast Guard approved stability course;

5. Complete a Coast Guard approved immersion suit and survival craft training course;

6. Pass an examination which includes demonstrating knowledge of meteorology and oceanography; stability; ballasting; construction and damage control; maneuvering and handling, which includes heavy weather operations and towing operations; and lifesaving and survival.

Rig Mover.--A home study course[22] issued by the Petroleum Extension Service of The University of Texas at Austin in cooperation with the International Association of Drilling Contractors states:

> Jackup drilling units have suffered the greatest number and percentage of losses of all types of mobile offshore rigs. Forty-five jackup casualties were recorded from 1955 to 1975. This is two-thirds of all drilling unit losses, even though jackups represent less than half of the total mobile units. And more than half of the jackup losses took place while the rigs were under tow or being moved on or off a drilling location. Because of this high incident rate, qualified move supervisors are now in charge of moving operations.
>
> The move supervisor, sometimes called the captain, has the responsibility of operating the jacking system in a manner consistent with good mechanical judgment. He must utilize good seamanship and marine judgment before and after the vessel enters the water and at all times when the vessel is afloat. He is responsible for, and must insure, the weight on board is distributed so the vessel will float with the proper heel and trim at a level not to exceed the draft marks and/or the load line. He must insure that the legs or mat are raised high enough to obtain the proper clearance above bottom for the operation involved, taking into account the weather and state of the sea. He must insure that the vessel's marine equipment, i.e., deck machinery, power plants, ballast pumps, bilge pumps, etc., is operative, and that the hull is properly secured, meaning that hull openings, hatches, watertight doors, vents, etc., are closed and

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[22]"Rotary Drilling, Jacking Systems and Rig Moving Procedures, Unit V, Lesson 4" Petroleum Extension Service, The University of Texas at Austin, 1976.

sealed before the hull is lowered into the water. The move supervisor must insure that all lines of communication are open and ready for use; this will include radios, telephones, or other communication means. The move supervisor must be able to "read the seas" at all times be ready to take into account the effects of weather before lowering the vessel into the water. He must maintain weather service contacts and plan the actual moving according to these forecasts, but the actual condition of wind and waves will determine when to lower the hull or move the unit. The move supervisor will see that suitable tugs are available and will direct their operation when the vessel is under tow.

<u>Severe Weather Planning During Rig Moves</u>.--In a paper[23] presented by the technical vice president of Santa Fe Drilling Company at the Second International Conference on Offshore Safety from March 19 to 21, 1986, the author states:

> Ocean moves are defined, for the purpose of this paper, as distances greater than 2000 miles. [The ROWAN GORILLA I was going to be towed over 3000 miles.] With today's large self-propelled transport vessels that carry rigs at speeds of more than 15 miles per hour, an ocean move could conceivably take as little as six days. On the other end of the scale is the wet-tow concept of a tug pulling a floating rig, where typical speeds are 4 miles per hour. Because the distance between locations for ocean moves can be more than halfway around the world, the time could be as much as six months. Therefore, ocean moves can vary from 6 days to 6 months. [The ROWAN GORILLA I tow was expected to take about a month.] Long distances and times are involved and the possibility for encountering severe weather increases.
>
> The industry has, historically, recognized the increased risks of ocean moves and has acted accordingly. At times, sections of leg have been removed from the rig to increase safety. At other times, portions of the derrick or mast have been lowered. Still further severe weather planning should be done to increase safety by considering the following.
>
> 1. Make a comprehensive weather-route study. If a rig must be moved at a specified time of the year, then a complete investigation of the alternative routes should be made. A

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[23] Pekarek, Joseph L., "Sever Weather Planning During Rig Moves," Second International Conference on Offshore Safety, Miami, Florida, 1986, pp.49-54.

study of this type should define the route most likely to have the least severe weather conditions. In addition, the study should provide a complete listing of all sheltered areas along the route. Sheltered locations may be necessary if conditions get too severe.

2. Make a comprehensive time-route study. If it is not critical as to when a rig must make an ocean move, then why not plan the move during the part of the year when the least severe weather can be expected. A time-route study should give just this type of data. A combined weather-route study and a time-route study could and should provide results that are good and safe as safe can be.

3. When economics and technical factors permit, self-propelled dry-tow vessels should be used. Vessels of this type can transport a rig at a faster rate through the water than the ocean-going tugs. The faster rate has two distinct advantages. The total transit time is shortened and thus there is less probability of encountering severe weather conditions; and the greater speed has the advantage of being able to deviate course and miss a storm completely.

DAN PRINCE.--On October 22, 1980, the 207-foot-long triangular-shaped Liberian self-elevating MODU DAN PRINCE capsized and sank while under the tow of the 224-foot-long, 16,000-horsepower Dutch tug SMIT NEW YORK in the Gulf of Alaska.[24] The tow had departed Dutch Harbor, Alaska, on October 10, 1980, for Abidjan, Ivory Coast via the Cape of Good Hope. The DAN PRINCE operator was Dan-Tex International, Houston, Texas, and the SMIT NEW YORK owner was Smit Internationale. The DAN PRINCE had three 418-foot-long legs and a crew of 18 aboard at the time of the sinking. Wilkens Weather Technologies, Inc. of Houston, Texas recommended the westerly passage via South Africa and

[24] Republic of Liberia--"Decision of the Commissioner of Maritime Affairs, R.L. and Report of the Preliminary Investigation In the Matter of the Loss of the Jack-Up Drilling Rig DAN PRINCE (O.N. 6178) Which Sank in Alaskan Waters on 22 October 1980," 18 May 1981, Monrovia, Liberia.

provided daily forecasts for the tow route. The Liberian report of this accident states:

* * * * *

> From departure through 15 October 1980, DAN PRINCE experienced strong winds and increasing seas which caused some cracks and leaks of a controllable nature. On the 14th, Wilkens Weather advised that a storm system would begin to affect the tow route by the night of 15 October. By 2245 [Universal Time] 15 October 1980, Wilkens Weather reported that the approaching low pressure system would result in a significant upward revision of wind and sea projections sent earlier in the day. The roughest weather was still anticipated along the route on Thursday 16 October. Gusts of 50-55 knots were anticipated with 40 foot seas.
>
> At 1635 [local time] 15 October 1980, DAN PRINCE dipped her bow into the sea which caused a combination of fateful events. The port side of the heliport was damaged and was hanging loose. Some of the stowed drill pipes shifted forward against the living quarters' bulkhead. At 1820 [local time] 15 October the bow again plunged heavily into the sea; the entire heliport broke away, struck the main deck and severed the towing bridle, and fell into the sea. The tow was not resumed until 18 October.
>
> On the morning of the 16th it was noted that the No. 1 Pre-Load Tank, under the heliport, was flooded. ... On 16 October DAN PRINCE faced 50 knot winds and 45-50 foot seas. The roll and pitch of DAN PRINCE was observed up to 20^{o} in 10 second periods. Pitching of up to 22^{o} was noted a few times. During the period 16-19 October, the bow anchor broke loose from its temporary position on the Main Deck. Other equipment also broke loose to cause considerable damage. The stress caused by roll and pitch resulted in at least six structural failures....

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> Faced with the expectation of 75 knot winds and 60 foot seas, 12 members of the riding crew were transferred to [the U.S. Coast Guard Cutter] BOUTWELL on the morning of 20th October. By afternoon the remaining men on board also left DAN PRINCE for BOUTWELL, after dark, fully expecting to return when the weather abated. However, on the 21st, DAN PRINCE was seen to be down by the stern with a list to starboard. In early hours of 22 October, she capsized and sank.

* * * * *

The following are conclusions of the Investigating Officer as a result of this Investigation:

* * * * *

Stowage preparations on DAN PRINCE were not adequate to withstand the sea and wind conditions encountered during the period 15-22 October 1980.

It was imprudent to tack weld the anchor to the Main Deck of DAN PRINCE.

It was imprudent to install a temporary metal paint stowage locker on the weather deck of DAN PRINCE.

It was inadvisable to stow quantities of drill pipe on the weather deck of DAN PRINCE for the extended ocean tow from Dutch Harbor.

The impact of the falling Heliport, the shifting anchor, paint locker and drill pipe sections, and cracks that developed were major causes of the loss of the watertight integrity of DAN PRINCE.

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Available pumps were adequate to restrict the level of sea water flow into DAN PRINCE until 20 October 1980. After 20 October 1980, unsupervised pumping operations were not adequate to control the flow of sea water into DAN PRINCE.

The starboard list of DAN PRINCE was caused by massive flow of sea water into the hull structure.

DAN PRINCE capsized and sank as a result of massive flow of sea water into the hull.

* * * * *

ANALYSIS

The Capsizing and Sinking

For the ROWAN GORILLA I to capsize on December 15, 1988, either the rig did not have sufficient intact stability for the environmental conditions or its stability was reduced by flooding below a level capable of withstanding the overturning forces of the wind and seas. However, once the rig capsized, it would only be a matter of minutes before it sank as the result of flooding of internal compartments through ventilation openings on the main deck. To determine the cause of capsizing, the Safety Board requested that Marathon, the designers and builders of the ROWAN GORILLA I, perform stability calculations representing the vessel and environmental conditions at the time of the capsizing. In addition, the Safety Board examined several sources of flooding before capsizing including hull structural failures, flooding through ventilation openings on the main deck, and flooding as the result of damage on the rig's main deck from loose cargo.

Stability

With its legs in the severe storm condition 25 feet below the hull, as they were at the time of capsizing, the intact ROWAN GORILLA I was designed to have sufficient stability to withstand the overturning forces imposed by a sustained wind of 100 knots during severe storm conditions provided that the rig was loaded properly. In addition, the rig was designed to withstand the overturning forces imposed by a sustained wind of 50 knots with any one compartment or tank, located within 5 feet of the exterior hull, flooded. Based on meteorological information from the rig, the tug, other vessels in the area, the NWS and other meteorological sources, the Safety Board estimated that the maximum sustained wind speed at the time of capsizing to be about 60 knots. Thus, the wind speed at the time of capsize was well below the design maximum speed of 100 knots for the intact rig, but in excess of design maximum speed of 50 knots for the rig with one compartment flooded. However, the stability calculations performed by Marathon after the accident indicate that as loaded on December 15, 1988, and with both preload tanks 14 and 15 flooded, the ROWAN GORILLA I's righting moment was several times greater than the overturning moment from a 60-knot wind, and the rig would have almost no stern trim. Therefore, the Safety Board believes that the ROWAN GORILLA I, as loaded on December 15, 1988, had sufficient stability to withstand the overturning moment of the wind even with preload tanks 14 and 15 flooded.

Flooding

The Safety Board next considered how much flooding would be required to reduce the rig's stability below a level at which a 60-knot wind could capsize the ROWAN GORILLA I. The rig crew testified that in addition to the water entering preload tanks 14 and 15 through hull cracks, water was entering both propulsion rooms through cracks on the main deck, water was entering the air compressor room through an opening in the main deck, and the mud pit room was flooding through an opening on the main deck whose hatch cover had been torn off by the loose container. In addition, the Safety Board assumed that water was being trapped in the shale shaker house on the rig's stern because the house was open near the top for ventilation but otherwise constructed of corrugated steel plating. The stability calculations performed by Marathon showed that with water in all the above tanks and compartments, the ROWAN GORILLA I's righting moment would still be about twice the overturning moment due to the 60-knot wind and the stern trim would be about 2^{0} to 3^{0}. Thus, the Safety Board does not believe that the ROWAN GORILLA I would have capsized from water in preload tanks 14 and 15, the propulsion rooms, the air compressor room, the mud pit room and the shale shaker house.

About 0900 on December 15, the rig superintendent stated that the stern trim had increased from about 2^{0} to 6^{0} although all the equipment on deck, except for the containers which had broken loose earlier, was still in place. The Safety Board estimated that it would take a 5^{0} to 6^{0} stern trim for the after edge of the main deck of the ROWAN GORILLA I to be under water in still water. Therefore, with a 6^{0} stern trim, the rig's after deck was now almost constantly under water. The barge engineer stated that although the crew were dewatering preload tanks 14 and 15, the stern trim continued to increase indicating to him that other after tanks must be flooding. Since both the rig superintendent and the barge engineer stated that up to the time the crew abandoned the rig, the crew was able to pump out the internal compartments as fast as the water entered the compartments, the Safety Board believes that additional after preload tanks had to be flooding to cause the 6^{0} stern trim.

Because the ventilation openings for the after preload tanks were only about 30 inches above the main deck which was about 10 feet above the mean water level with a 2^{0} stern trim, and about 50-foot-high waves were breaking over the rig's stern, it is probable that the after preload tanks were taking on water through their ventilation openings. It is also possible that hull structural failures had occurred in additional after preload tanks resulting in their flooding. Another possible cause of flooding of after preload tanks was flooding through their 30-inch-high access hatches. The crew reported that on December 14, they had found some access hatch covers loose and had attempted to tighten all hatch covers, but could not reach those hatch covers near the stern because of the waves breaking on deck. Because the rig sank in about 16,000 feet of water and there are no plans to salvage the rig, the Safety Board was not able to examine the hull of the ROWAN GORILLA I after the sinking to determine what caused the flooding of after preload tanks. The Safety Board believes that the flooding of after preload tanks was probably due to a combination of hull structural failures, loose access hatch covers, and ventilation openings.

Once the after trim reached 6^{0}, the after main deck would be constantly under water and the ROWAN GORILLA I would rapidly loose stability. In addition, other empty tanks and compartments would begin taking on water through ventilation openings as the after main deck sank deeper into the water. When the stern trim reached 12^{0} just before the crew abandoned the rig, probably the entire main deck aft of the deckhouse was under water and all internal compartments and tanks in this area were taking on water through their main deck ventilation openings. Thus, as tanks and compartments flooded, the ROWAN GORILLA I slowly lost stability, the overturning forces of the wind and waves exceeded the righting ability of the rig, and it capsized.

The Safety Board considered several factors which may have affected the flooding of the ROWAN GORILLA I internal compartments and preload tanks. These factors included: (1) the decision to tow the ROWAN GORILLA I across the North Atlantic Ocean in December; (2) the adequacy of the tow preparations; (3) the adequacy of the weather forecasts; (4) the decision of the SMIT LONDON master to tow the ROWAN GORILLA I with the wind and the waves on the rig's stern; and (5) the ROWAN GORILLA I design.

The December 1988 Tow.--The decision by Rowan to tow the ROWAN GORILLA I across the North Atlantic in December was based on economic reasons. The Chairman of the Board of Rowan stated that the decision was made to depart Halifax in December 1988 because the ROWAN GORILLA I had completed its last contract in September 1988, there was no potential work in offshore eastern Canada for at least 15 months, there were potential contracts in other parts of the world beginning in February 1989, and the cost of the ROWAN GORILLA I remaining idle versus operating was in excess of $1 million per month.

Rowan and the tug master chose a southerly route along latitude 40° north versus a great circle route across the North Atlantic to minimize the exposure of the tow to severe weather. Historic meteorological information compiled by the U.S. Navy showed that although the greatest probability of encountering wind speeds over 34 knots along the intended trackline of the SMIT LONDON master occurs in December, the probability of winds greater than 48 knots along this trackline between Halifax and the accident site was only about 1 percent. In addition, the probability of encountering wind speeds over 34 knots along the intended trackline does not decrease significantly until March. The information also showed that there was about a 40 percent decrease in probability of encountering wind speeds over 34 knots by taking the intended route versus a great circle route. A more southerly route along latitude 32° north would further reduce the probability of encountering wind speeds over 34 knots by 35 percent but would take the tow through the same area where it encountered the severe storm on December 15 and would expose the tow for a longer time to the potential of severe weather. The Chairman of the Board of Rowan stated that the moving of the ROWAN GORILLA I aboard a heavy lift ship was not considered because Rowan anticipated difficulty unloading the rig in the North Sea where unfavorable weather conditions are prevalent in January and February. The Rowan vice president also stated that the reason a heavy lift ship was not considered was that he had observed in 1983 extensive damage to a rig which arrived in Halifax aboard a heavy lift ship. The Rowan vice president also stated that it would not be practical to remove portions of the legs for the tow because of the cost, time involved, and the requirement for an additional vessel to transport the legs. Since neither ABS nor the U.S. Coast Guard had placed any restrictions on the ROWAN GORILLA I regarding the time of year or the waters where the rig could be towed and the rig was designed for a maximum wind speed of 100 knots, the Safety Board believes that Rowan's decision to tow the ROWAN GORILLA I across the North Atlantic Ocean in December on the southerly route along latitude 40° north was reasonable.

<u>Tow Preparations</u>.--Rowan retained the services of a recognized surveying and consulting company to supervise and approve the preparations for the tow. The October 14, 1988 survey report prepared for the ROWAN GORILLA I tow recommended that the advice of a long range forecasting service should be used for the tow. However, the rig manager stated that Rowan did not interpret this statement as meaning that Rowan should employ a long range forecasting service, but that the weather information obtained by the tug would be sufficient. The Rowan vice president stated that Rowan does not use their contracted private weather service during towing because they do not have the proper radio equipment for receiving the information. The Safety Board believes that Rowan should have employed a long range

forecasting service before the tow departed Halifax. Meteorologists from local government forecast offices or private companies can augment information contained in official marine forecasts. Meteorologists, with some skill, can provide weather outlooks out to 4 to 5 days. Information such as this would have been useful in determining an appropriate time to begin a tow across the North Atlantic Ocean from Halifax and would have provided updated weather predictions during the tow. The weather information could have been relayed to the rig via the tug during the tow.

As a result of its investigation of the capsizing and sinking of the self-elevating MODU OCEAN EXPRESS,[25] the Safety Board issued Safety Recommendation M-79-51 to the International Association of Drilling Contractors (IADC):

> Recommend that its members use private meteorological services which provide the special information needed when engaged in weather-sensitive operations.

On May 9, 1979, IADC replied:

> The International Association of Drilling Contractors has received your NTSB Safety Recommendation M-79-51, issued on April 17, 1979. We have reproduced this Recommendation and have sent it to our Offshore Committee. I am certain that this topic will be discussed at the Committee's next-scheduled meeting which will be held in mid-June.

On June 1, 1989, IADC again replied:

> The use of private weather services has long been routine during weather-sensitive offshore operations such as the moving of mobile offshore drilling units. In the case of long range moves, it is not uncommon for the unit's owner to consult more than one private weather service....
>
> * * * * *
>
> I am attaching a copy of the Proceedings for the Second International Conference on Offshore Safety which [IADC] co-sponsored with the Rosenstiel School of Marine and Atmospheric Science of the University of Miami in 1986. [IADC's] primary purpose in approaching the Rosenstiel School to co-sponsor this conference was to focus attention on the importance of accurate offshore weather forecasting to our industry.

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[25] Marine Accident Report--"Capsizing and Sinking of the Self-Elevating Mobile Offshore Drilling Unit OCEAN EXPRESS Near Port O'Connor, Texas, April 15, 1976," (NTSB/MAR-79/05).

On July 27, 1989, the Safety Board classified Safety Recommendation M-79-51 as "Closed--Acceptable Action." The Safety Board believes that had Rowan requested their contracted weather service to provide them with a 4- to 5-day outlook before the tow departed Halifax, the weather service may have noted the potential for the development of a severe storm about December 15 in the area of the capsizing. Rowan could have also requested the local Canadian government weather service to provide Rowan with a 5-day outlook. Thus, the tow could have been delayed until the potential for encountering a severe storm had passed.

There were numerous items stored on the main deck of the ROWAN GORILLA I during the tow including seven containers. Despite 50-foot-high waves breaking on deck, the only deck cargo reported broken loose were several of the containers. Based on the testimony of the ROWAN GORILLA I crew, the SMIT LONDON crewmember aboard the rig, the Rowan personnel responsible for preparing the rig for the tow in Halifax, and the survey report prepared for the tow by the surveying company, the Safety Board believes that all deck cargo was secured in accordance with good marine practice. The containers that broke loose had been placed in a protected location near the center of the main deck and were secured by angle irons placed on the four corners of the containers and welded on three sides to the deck and three sides to the container. The Safety Board believes that the force of the waves breaking over the stern on December 15, was greater than normal securing procedures could be expected to withstand. However, both the ROWAN GORILLA I and the DAN PRINCE accidents show the potential hazard of carrying deck cargo on self-elevating MODUs during ocean tows. Deck cargo also broke loose on the DAN PRINCE causing damage on its main deck that resulted in flooding of internal compartments and tanks. The Safety Board believes that the amount of deck cargo stowed on the main deck of self-elevating MODUs during ocean tows should be minimized.

According to the stability calculations performed by the ROWAN GORILLA I barge engineers on December 8, 1988, the rig departed Halifax with all the preload tanks nearly empty except for 2 or 3 inches of water and the main deck about 14 feet above the mean water level. The vents for the preload tanks were located about 30 inches above the main deck and were designed to minimize water from entering the tanks through the vents. The purpose of these vents was to prevent over pressurization or implosion during filling or discharge. However, the rig preload tanks were located around the periphery of the hull where boarding seas during a storm could easily reach the opening to their vents. The Safety Board believes that because the preload tanks were not being used during the voyage and they were all nearly empty, their vents should have been made watertight for the tow to prevent entry of any water into the tanks.

Weather Forecasts.--The NWS forecast (valid for 32 hours from the time of its issuance) in effect before the departure of the ROWAN GORILLA I from Halifax indicated no significant storms that would impact the intended trackline of the rig. The track of the storm that passed near the ROWAN GORILLA I on December 15, was correctly forecast by the NWS, and the SMIT

LONDON master received this information aboard the tug. Wind speeds forecast for this particular storm by the NWS were substantially correct; however, actual wave heights were probably 10 to 15 feet higher than those forecast. The storm was first noted in the 0100 forecast on December 13 and was carried in subsequent forecasts up through the time of the capsizing.

The Decision to Tow with the Wind and Waves on the Stern.--About 2300 on December 13, the SMIT LONDON master had to decide whether to continue towing into the wind and waves as the predicted storm approached or turn and tow with the wind and waves on the stern of the ROWAN GORILLA I. The tug master stated that he decided to turn and tow with the wind and seas on the rig stern to prevent the rig from dragging the tug backwards and possibly capsizing the tug. The tug master's decision was based on over 28 years of experience as an officer on oceangoing tugs towing all types of vessels. His experience included towing vessels across the North Atlantic in wintertime although he had not towed a self-elevating MODU across the ocean for over 15 years. At 2131, the ROWAN GORILLA I legs had been lowered to their severe storm condition increasing the underwater drag resistance of the rig. In addition, as the storm approached, the force of the wind on the above water portions of the rig would increase as the wind speed increased, and there would be increased resistance on both the rig and tug hulls caused by the higher waves. The Safety Board believes that had the tug master continued to tow into the wind and waves, the tug would have been dragged backwards by the force of the wind and waves on the rig with a high probability of the tug capsizing. However, the rig stern preload tanks, which had experienced hull cracks on the morning of December 13, were now exposed to the full force of waves breaking on the stern.

When the tug master made his decision to turn and tow with the wind and waves on the stern of the ROWAN GORILLA I, he was not aware of the hull fractures in preload tanks 14 and 15. The SMIT LONDON crewmember aboard the rig had informed the tug master on the evening of December 13 that the rig had experienced some minor cracks in the crew accommodation areas. However, it was not until about 24 hours later that the rig superintendent informed the tug master of the hull fractures in preload tanks 14 and 15 and the other rig damage caused by the loose container. Therefore, at the time of his decision, the tug master was not aware that turning and towing with the wind and waves on the rig stern could result in further damage or flooding of after preload tanks on the rig.

In October 1980, the triangular self-elevating MODU DAN PRINCE was being towed into the wind and waves during a severe storm by the tug SMIT NEW YORK in the Gulf of Alaska when the rig capsized and sank. According to the Liberian report of the accident, at 1635 on October 15, the DAN PRINCE "dipped her bow into the sea" which caused extensive damage to the heliport on the bow which broke away and struck the main deck of the rig. The towline was severed and the preload tank under the heliport flooded. On October 16, the weather conditions were 50-knot winds and 45- to 50-foot-high waves and additional flooding of internal compartments and tanks from structural damage was discovered. On October 20, the crew were rescued by the U.S. Coast Guard. On October 21, the rig had a stern trim with a list to starboard before capsizing and sinking. The Liberian report found that the DAN PRINCE capsized and sank as a result of "massive flow of seawater into the hull" as the result of the falling heliport, shifting deck cargo, and structural cracks in the hull caused by high stress levels resulting from rolling and pitching about 20° ever 10 seconds. The Safety Board believes that the SMIT LONDON master exercised good judgment in turning to protect his tug from the possibility of being capsized by the rig. The Safety Board also believes that the DAN PRINCE accident shows that towing into severe wind and waves can have similar results to turning and towing with the wind and waves on the stern.

In addition, the Safety Board believes that after the tug master turned at 2315 on December 13, and began towing with the wind and waves on the rig's stern, the tug master made every effort to protect the tow. For about 24 hours, the tug master was able to keep control of the rig; however, on the early morning of December 15, the center of the severe storm passed close to the position of the tow and the tug master was unable to control the movement of the tug in the 40-foot-high waves. When one of the towline protector wore through because of the motions of the tug, the tug master, with great skill, moved another towline protector into place to protect the towline. However, the tug motions continued and the second towline protector also wore through. Once the second towline protector wore through, it was only a matter of time before the towline parted.

After the towline parted, the rig superintendent used the rig thrusters to maneuver the rig so that the wind and waves were on the port aft corner of the rig. Later that morning, the rig superintendent turned off the thrusters because he believed that the rig rode better without the thrusters. Thus, after the towline broke, the rig superintendent permitted the about 50-foot-high waves to break over the rig's stern despite the known flooding in preload tanks 14 and 15. At 0729 on December 15, the rig superintendent reported to the rig manager that if he put the bow into the waves the rig took "a lot more pounding." However, the stern waves were slowly causing more flooding in after preload tanks as the rig slowly trimmed aft as described earlier. Nevertheless, it was not until about 1130 on December 15, when the tug master contacted the rig superintendent, that the rig superintendent realized that the rig was slowly sinking by the stern although the rig superintendent stated that about 0900 on December 15, the stern trim increased from 2° to 6°. The Safety Board believes that had the rig superintendent realized earlier that stern preload tanks, in addition to preload tanks 14 and 15, were flooding due to the stern waves and turned the rig using its thrusters so that the waves were not breaking over the stern, the rig superintendent could have minimized the amount of flooding.

Rig Design.--The ROWAN GORILLA I was not equipped with a remote method of determining the amount of liquid in its preload tanks. The only method available to the crew of the rig was to go out on the main deck and measure the amount of liquid in each tank through either its tank sounding tube or access opening. The rig superintendent stated that from about noon on December 14 to the time they abandoned the rig, the crew were not able to safely go on deck because of the waves breaking on deck. The Safety Board believes that had the ROWAN GORILLA I been equipped with remote gauges for its preload tanks, the crew would have been able to determine that preload tanks in addition to 14 and 15 were flooding and they may have been able to repair or plug the leaks, drain those tanks and thereby reduce the loss of freeboard and the amount of boarding seas.

Before the first hull fractures were discovered about 0730 on December 13, the rig had experienced maximum rolling of 2 $1/2^{\circ}$ every 8 seconds which was well within the design limits of the legs afloat curve (see figure 7), and a maximum wind speed of 40 knots which was well below the 100 knot design limit. During the day on December 13, the rig experienced maximum rolling of 1° to 3 $1/2^{\circ}$ every 8 seconds and maximum pitching of 1° to 3 $1/2^{\circ}$ every 8 seconds and maximum winds of 33 knots which were still well within design limits. No changes regarding the fractures in tanks 14 and 15 were reported by the crew, but about 1200 on December 13, the crew discovered cracks in welds on the support columns for the starboard leg and a crack in the structure on the inboard support column for the port leg. In anticipation of encountering a severe storm the next day, the rig superintendent at 2131 on December 13, lowered the rig legs from 12.9 feet below the hull to the severe storm position 25 feet below the hull to reduce rig motions, and at 2315 on December 13, the tug master turned the tow so that the wind and waves were on the stern of the rig.

The December 14 morning report from the rig stated that the rig was rolling 2 $1/2^{\circ}$ every 7 seconds and pitching 3° every 6 seconds. These motions were still well within design limits. However, about 2230 on December 14, the rig manager received a report from the rig that the maximum winds were 45 knots, the maximum waves were 20 feet high, and the rig was rolling 3 $1/2^{\circ}$ to 7° every 5 to 8 seconds and pitching 2° to 5° every 6 to 7 seconds. The rolling motion was now getting close to the design limits; however, the rig superintendent could do nothing to reduce the motions. The legs were not structurally designed to be lowered beyond the 25-foot level, and according to the tug master, a heading change under the severe weather conditions to reduce the motions would not have been possible. However, after the towline broke, the rig superintendent attempted to maneuver the rig to reduce the motions but he stated that the rig was pitching about 8° every 6 to 7 seconds which was close to the design limits. At 0729, the rig superintendent reported that the maximum pitch motion had been 14° every 4 to 6 seconds, which is well outside design limits, and that he had turned off the thrusters because the rig rode better without the thrusters. The Safety Board believes that because the rig motions on the evening of December 14 and on December 15 were at or above the structural design limits of the ROWAN GORILLA I, it is probable that the rig's hull experienced further hull fractures during this time. Since the crew were not able to go on deck because of the waves breaking on deck and there were no remote gauges for the periphery preload tanks, the fractures went undetected.

The hull fractures in preload tanks 14 and 15 which were discovered on the morning of December 13, before the rig experienced severe weather conditions and before the rig had the wind and waves on its stern, raise questions regarding the structural design of the rig. The ROWAN GORILLA I had sustained similar fractures in 1983 during an ocean tow when the rig experienced 50-knot winds and 9° rolls. (Rowan records do not indicate the period of roll.) Marathon determined that the 1983 fractures were the believes that a dynamic structural analysis of the gorilla design can and should be conducted to determine the environmental limits of the design. In addition, the Safety Board believes that the U.S. Coast Guard, in conjunction with the ABS, needs to revise the structural design criteria for self-elevating MODUs under tow to account for dynamic loads in a seaway.

MODU Manning and Crew Qualifications

The Safety Board examined how the marine crew qualifications and manning of the ROWAN GORILLA I may have affected this accident. Present U.S. Coast Guard regulations required that the minimum manning level for the ROWAN GORILLA I under tow to be two able seamen and one ordinary seaman documented by the U.S. Coast Guard. In addition, the owner must designate an individual to be the person in charge of the unit. To receive a U.S. Coast Guard Able Seaman document, an individual must pass an examination showing knowledge of nautical terms, distress signals, firefighting, and the operation of lifeboats found on rigs; there are no knowledge requirements for ordinary seaman or the person in charge. The ROWAN GORILLA I rig superintendent was the person in charge and an able seamen; there were also four other able seaman aboard at the time of the accident. Thus, the minimum U.S. Coast Guard manning and marine crew qualifications were met.

Aboard the ROWAN GORILLA I for the ocean tow were 26 Rowan employees plus a crewmember from the SMIT LONDON, who was acting as a liaison between the rig superintendent and the tug master. According to Rowan managers, the 26 crewmembers were necessary to monitor rig operations while underway. The Rowan vice president stated that while under tow, the rig thrusters helped control the movement of the rig and provided an approximate 1- to 1 1/2-knot additional towing speed. Since the rig normally made only about 4 knots while under tow, the additional 1 to 1 1/2 knots provided by the rig was significant. If the rig was not manned while under way, the time for the approximate month-long, 3,250-nautical-mile tow at 4 knots would be increased by several weeks. Thus, the rig would be exposed to potential severe weather for a longer period of time, and it would be difficult for the tug to control the rig. Therefore, the Safety Board believes that the crew was necessary for the tow across the ocean.

According to the Petroleum Extension Service of the University of Texas, qualified rig movers "are now in charge of moving" self-elevating MODUs because of the high accident rate of self-elevating MODUs under tow or being moved from 1955 to 1975. A home study course by the Petroleum Extension Service states that a rig mover must utilize good seamanship and marine judgment before and after the rig enters the water, is responsible for ensuring the rig's watertight closures are secured, and is responsible for maintaining contact with a weather service and planning the tow according to the weather forecasts. The ROWAN GORILLA I operations manual, which was developed for the rig by Marathon, indicates that a rig mover should be employed by the owner to be in complete charge of the rig while it is being prepared for a move and is in the process of moving. The Coast Guard SNPRM for the licensing and manning of MODUs, which was published on May 17, 1989, will require an offshore installation manager with a bottom bearing unit underway endorsement aboard self-elevating MODUs like the ROWAN GORILLA I while under tow. The SNPRM will require an offshore installation manager to pass an examination which includes demonstrating knowledge of meteorology and oceanography; stability; ballasting; construction and damage control; maneuvering and handling, which includes heavy weather operations and towing operations; and lifesaving and survival. In addition, the SNPRM will require an applicant for the license to certify that he/she has witnessed 10 rig moves and directed under the supervision of an experienced rig mover 5 rig moves. However, Rowan did not employ a rig mover aboard the ROWAN GORILLA I for the tow from Halifax to Great Yarmouth, but designated their shoreside rig manager as the rig mover.

Both the Rowan Chairman of the Board and the Rowan vice president stated that their rig managers and rig superintendents are trained and capable of moving rigs, and they believe it is safer to have a Rowan employee be in charge of all rig operations, whether moving or drilling. The Chairman of the Board of Rowan stated, "we consider our personnel to be better qualified to move our rigs than a 'rig mover.' Typically, a Rowan rig manager has been employed by Rowan for more than twenty years." Although the ROWAN GORILLA I rig manager may have been qualified to serve as a rig mover, he was not aboard the ROWAN GORILLA I for the intended month-long tow to the North Sea. A rig mover has responsibilities before, during, and after a tow. In addition to preparing the rig for the tow as done by the ROWAN GORILLA I rig manager, a rig mover is also responsible for the safety of the rig underway including maintaining adequate stability, maintaining the watertightness of the hull, and planning the tow according to weather forecasts and actual wind and wave conditions. The Safety Board does not believe that a shoreside manager can serve as a rig mover during a month-long tow across the North Atlantic Ocean.

Based on the statements by the Chairman of the Board and vice president of Rowan, the ROWAN GORILLA I rig superintendent should also have been qualified as a rig mover. The Rowan vice president stated that Rowan rig superintendents get on-the-job experience in moving rigs and that the ROWAN GORILLA I rig superintendent had experience under North Atlantic sea conditions while the rig was operating off the east coast of Nova Scotia. In addition, he stated that the rig superintendent had taken the mandatory Canadian survival training, had a U.S. Coast Guard Able Seaman document, had on-the-job training in stability, had been taught how to use the maximum motion curves in the ROWAN GORILLA I operations manual which indicate the structural design limits of the rig, and had been given written guidance on what to do regarding rig motions in anticipation of a storm.

Although the rig superintendent had been aboard the ROWAN GORILLA I while the rig was operating off the east coast of Nova Scotia for about 5 years, the December 1988 tow was his first ocean tow. The Safety Board does not believe that one short field move and one tow in good weather during the 5 years off the coast of Nova Scotia provided the rig superintendent with sufficient experience in ocean towing to supervise the December 1988 tow. The Rowan vice president stated that a rig superintendent had to have some experience with rig motions to interpret the maximum motion curves; the ROWAN GORILLA I rig superintendent had no experience with large amplitude rig motions. Also, when the SMIT LONDON master informed the rig superintendent about 1130 on December 15, that the rig was listing astern and the similar circumstances experienced by the DAN PRINCE, the tug master stated that the rig superintendent asked, "Do you think this is an emergency situation?" and requested that the tug master advise him concerning the situation because "Please appreciate that we are drilling men, and not seamen." The Safety Board believes that a qualified rig mover aboard the ROWAN GORILLA I would have realized that when the rig motions exceeded design limits on the morning of December 15 and the rig's stern trim increased from 2^{o} to 6^{o}, that the rig was probably in a dangerous condition and would not have had to rely on the advice of the tug master, who stated that he was not familiar with rigs, regarding the condition of the ROWAN GORILLA I. The Safety Board believes that the circumstances of this accident and the historical accident record of self-elevating MODUs indicates a need for trained rig movers aboard self-elevating rigs under tow.

The Safety Board has been concerned with the lack of U.S. Coast Guard regulations for MODU personnel qualification and manning standards since the self-elevating rig OCEAN EXPRESS[26] capsized and sank with the loss of 13 lives in 1976. Vessels engaged in offshore oil exploration, collectively designated MODU's, are divided into three major categories: Self-elevating rigs--vessels which utilize bottom bearing legs to raise their hull above the surface of the sea; column stabilized rigs--vessels supported by columns on submerged buoyant lower hulls; and drill ships, or drill barges--vessels with conventional hulls. Self-elevating rigs and drill barges have to be towed from location to location, drill ships are self-propelled vessels, and column stabilized rigs can be either self-propelled or non-selfpropelled. All these vessels are considered vessels in navigation, except self-elevating rigs when fully elevated above the surface and, thus, are subject to the Coast Guard manning and crew qualification laws and regulations. In addition to the ROWAN GORILLA I and the OCEAN EXPRESS, the Safety Board has investigated two other major marine accidents involving MODUs while in navigation. On February 15, 1982, the column-stabilized OCEAN RANGER[27] capsized and sank with the loss of 84 lives, and on October 25, 1983, the drillship GLOMAR JAVA SEA[28] capsized and sank with the loss of 81 lives. The capsizing and sinking of the OCEAN EXPRESS, the OCEAN RANGER, and the GLOMAR JAVA SEA all involved matters putatively under the cognizance of mariners and not industrial personnel.

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[26]Marine Accident Report--"Capsizing and Sinking of the Self-elevating Mobile Offshore Drilling Unit OCEAN EXPRESS near Port O'Connor, Texas, April 15, 1976" (NTSB-MAR-79-5)

[27]Marine Accident Report--"Capsizing and Sinking of the U.S. Mobile Offshore Drilling Unit OCEAN RANGER off the East Coast of Canada, 166 Nautical Miles East of St. John's, Newfoundland, February 15, 1982" (NTSB-MAR-83-2)

[28]Marine Accident Report--"Capsizing and Sinking of the United States Drillship GLOMAR JAVA SEA in the South China Sea, 65 nautical miles south-southwest of Hainan Island, People's Republic of China October 25, 1983" (NTSB-MAR-84-8)

In 1978, the Coast Guard published regulations for the inspection and certification of mobile offshore drilling units. However, the regulations did not include personnel qualifications or manning standards for MODUs, except to specify the number and qualifications of lifeboatmen required to man primary lifesaving equipment and to require that the owner must designate an individual to be the master or person-in-charge of a MODU. As a result of its investigation of the capsizing and sinking of the OCEAN EXPRESS, the Safety Board issued the following Safety Recommendation M-79-43 on April 17, 1979, recommending that the Coast Guard:

> Expedite the promulgation of regulations for personnel qualifications and manning standards for self-elevating mobile offshore drilling units, and require that industrial personnel who perform seafaring duties obtain appropriate training and licenses.

As a result of its investigation of the capsizing and sinking of the OCEAN RANGER, the Safety Board on February 28, 1983, issued the following Safety Recommendations M-83-8, M-83-9, and M-83-10 to the Coast Guard. Safety Recommendation M-83-8 superseded Safety Recommendation M-79-43 by calling for similar regulations for all types of MODUs.

> **M-83-8**
>
> Expedite the promulgation of regulations regarding personnel qualifications and manning standards for mobile offshore drilling units.

In a letter dated July 20, 1983, the Coast Guard stated:

> The Coast Guard concurs with this recommendation. The licensing qualifications and examination requirements for masters, mates, chief engineers, and assistant engineers on mobile offshore units, which include mobile offshore drilling units, are part of a major regulatory revision project of 46 CFR Part 10. The Notice of Proposed Rulemaking is undergoing the final clearance process and is expected to be published shortly.

> **M-83-9**
>
> Require that the master and the person-in-charge of a mobile offshore drilling unit be licensed and that their licenses be endorsed as qualified in mobile offshore drilling operations, including knowledge of U.S. Coast Guard regulations, stability characteristics of mobile offshore drilling units, the operation of ballast systems on mobile offshore drilling units, and the use of lifesaving equipment peculiar to mobile offshore drilling units.

In its July 20, 1983 letter, the Coast Guard stated:

> The Coast Guard concurs with this recommendation. The Coast Guard is initiating a regulatory project to revise 46 CFR Subchapter 1-A. As part of this project, 46 CFR 107.111 will be revised to indicate that the master of mobile offshore units (which includes mobile offshore drilling units) shall be the person-in-charge. All mobile offshore units will be required to have a licensed master, either as a master of mobile offshore units or a conventional master's license. Included in the 46 CFR Part 10 revision is a list of examination topics for a license as a master of mobile offshore units. This list includes all of the subjects mentioned in this recommendation. ...

M-83-10

> Require that the person-in-charge of a mobile offshore drilling unit also be a certificated lifeboatman.

In its July 20, 1983 letter, the Coast Guard stated:

> The Coast Guard concurs with this recommendation. The 46 CFR 10 revision requires that licensed deck officers hold a merchant mariner's document. The deck license examinations for service on mobile offshore units will cover those topics included in the lifeboatman examination. Masters and mates with the industrial mobile offshore unit license will therefore qualify for the endorsement "any unlicensed rating in the deck department including able seaman" on their merchant mariners's document. This endorsement includes the lifeboatman certification.

Based on the Coast Guard response to Safety Recommendations M-83-9 and M-83-10, the Safety Board on October 26, 1984 classified these two Safety Recommendations as "Open--Acceptable Action." However, as a result of its investigation of the capsizing and sinking of the GLOMAR JAVA SEA on October 25, 1983, the Safety Board classified Safety Recommendation M-83-8 as "Open--Unacceptable Action" on November 14, 1984, and issued the following Safety Recommendation M-84-48 to the Secretary of the U.S. Department of Transportation:

> Direct the Commandant of the U.S. Coast Guard to address immediately the early promulgation of personnel qualification and manning regulations for mobile offshore drilling units.

On October 16, 1987, the Coast Guard published interim final rules for the licensing and manning of MODUs with an effective date of April 1, 1989. As a result, the Safety Board on June 2, 1988, classified M-84-48 as "Closed--Acceptable Action." However, on February 28, 1989, the Coast Guard suspended the effective date of these interim rules indefinitely because comments on the Interim Final Rule indicated substantive revisions to the rule were necessary, and on May 17, 1989, issued a SNPRM.

On June 6, 1989, the Safety Board sent a letter to the Secretary of the U.S. Department of Transportation expressing its disappointment that it took the Coast Guard 10 years to publish an Interim Final Rule to implement these urgently needed regulations, and then to learn that the Coast Guard had suspended the rules indefinitely. As a result of the Coast Guard action, the Safety Board placed Recommendation M-84-48 in an "Open" status. The Safety Board believes that the lack of a qualified rig mover aboard the ROWAN GORILLA I again shows the need for MODU personnel qualification and manning standards and reiterates Safety Recommendations M-83-8, -9, and -10 to the U.S. Coast Guard and M-84-48 to the Secretary of the U.S. Department of Transportation. Because, as of the date of this report, the U.S. Coast Guard has not implemented personnel qualification and manning regulations for MODUs, Safety Recommendation M-84-48 has been classified "Open--Unacceptable Action."

The May 17, 1989 SNPRM will require an applicant for the offshore installation manager license with a bottom bearing unit underway endorsement to provide certification that he/she has witnessed 10 rig moves and directed 5 rig moves under the supervision of an experienced rig mover. However, the proposed regulations do not state what type of moves. The Safety Board does not believe that the experience gained from short field moves in protective waters is sufficient for supervising a long ocean tow where severe weather can be expected, and that the applicants for the offshore installation manager license with a bottom bearing unit underway endorsement should have had experience observing and directing both field and ocean moves.

Crew Survival

Despite severe wind and waves conditions, all persons aboard the ROWAN GORILLA I safely evacuated the rig before it capsized and sank and were safely rescued the next day. The Safety Board examined a number of factors which affected their survival including: (1) Rowan procedures and policies for the stowage of survival capsules and inflatable liferafts during ocean tows; (2) crew survival training; (3) the Canadian and SMIT LONDON search and rescue response; and (4) the design of survival capsules.

<u>Rowan Survival Equipment Procedures and Policies</u>.--The Safety Board is concerned that present Rowan procedures and policies regarding the stowage of survival capsules and inflatable liferafts during ocean tows does not give sufficient emphasis to the protection of personnel. The U.S. Coast Guard Certificate of Inspection for the ROWAN GORILLA I required that the rig be equipped with four survival capsules with a total capacity for 172 persons. Two of the capsules were required to be stowed on the port side and two on the starboard side. Additionally, the certificate of inspection required

that the rig carry four inflatable liferafts with a total capacity for 100 persons. U.S. Coast Guard regulations required that the survival capsules and the liferafts be stowed in their U.S. Coast Guard approved launching equipment at all times and that the rig superintendent ensure that each item of lifesaving equipment was maintained in operative condition. However, contrary to these U.S. Coast Guard requirements, the Rowan alternate rig superintendent, under instructions from Rowan shoreside managers, removed the rig's four survival capsules and four inflatable liferafts from their U.S. Coast Guard approved launching equipment while preparing the rig for its tow across the North Atlantic Ocean. Rowan managers stated that the reason for removing the survival capsules and liferafts from their approved launching equipment was to protect the survival equipment from being washed overboard during the tow. The Rowan vice president was not aware of any Rowan policies regarding the stowage of U.S. Coast Guard required lifesaving equipment during ocean tows, and the ROWAN GORILLA I operations manual did not address the stowage of lifesaving equipment during ocean tows.

Fortuitously, Canadian Coast Guard inspectors boarded the ROWAN GORILLA I before the rig left Halifax and told the alternate rig superintendent that the survival capsules should not have been removed without U.S. Coast Guard approval. As a result, the two 36-person survival capsules were replaced in their launching equipment. Because there were only 27 persons on board the rig, the two 36-person survival capsules were probably sufficient for safety. However, Rowan managers never contacted the U.S. Coast Guard for permission to remove any of the survival capsules or liferafts from their launching equipment and none of the liferafts was replaced in approved launching equipment.

The Safety Board believes that the location of the ROWAN GORILLA I launching equipment for liferafts was inappropriate for an ocean tow. If the rig's liferafts had remained in their launching equipment on top of the rails near the edge of the main deck for the ocean tow, the hydrostatic releases for the liferafts would probably been activated and the liferafts would have been washed overboard during the severe storms encountered during the tow. The Safety Board believes that for the ocean tow, Rowan should have provided alternate U.S. Coast Guard approved liferaft launching equipment in locations on the ROWAN GORILLA I that would be protected from waves during severe weather. In addition, the Safety Board believes that Rowan should have provided explicit instructions in the rig's operations manual regarding the proper stowage of lifesaving equipment during ocean tows. Had the ROWAN GORILLA I proceeded to sea without any of its survival capsules or liferafts in their approved launching equipment, the Safety Board believes that there may have been serious injuries and loss of life when the rig capsized and sank on December 15, 1988, because the crew would not have been able to launch the survival capsules and liferafts. Although the crew's immersion suits would have provided them with thermal protection, they may not have been able to swim away from the rig before the rig capsized on top of them. If any of the crew were able to escape the sinking rig, they would probably have become separated in the high seas and darkness, and may not have been found by rescue aircraft or the SMIT LONDON. The Safety Board believes that the U.S. Coast Guard should examine the location of liferaft launching equipment on all U.S. self-elevating MODUs to ensure that the liferafts are protected from being washed overboard during storms while the rig is being towed. It may be necessary to require alternate liferaft launching equipment for ocean tows.

The Safety Board is also concerned that the U.S. MODU industry does not put sufficient emphasis on maintaining lifesaving equipment operational. During its investigation of the capsizing and sinking of the ODECO owned OCEAN RANGER[29] off the east coast of Canada in 1982, the Safety Board found that two of the four U.S. Coast Guard required covered lifeboats did not meet U.S. Coast Guard standards. One of the two U.S. Coast Guard approved covered lifeboats was operational and the other was lashed on deck. In addition, the OCEAN RANGER did not have the davit-launched liferafts required by the U.S. Coast Guard. The Safety Board could not determine if ODECO's failure to comply with U.S. Coast Guard lifesaving equipment requirements contributed to the loss of life on the OCEAN RANGER; however, the lack of compliance decreased the usable lifeboat and liferaft capacity. The Safety Board believes that there is a need for the International Association of Drilling Contractors (IADC) to put more emphasis on maintaining required lifesaving equipment operational at all times.

Survival Training.--The ROWAN GORILLA I rig superintendent testified that the evacuation of the rig via the survival capsule "went just like the drills that we hold weekly." He stated that all crewmembers had donned their immersion suits, entered the capsule in an orderly manner, and secured their seat belts. All the rig crewmembers had attended the Canadian mandatory survival training course and the rig superintendent stated that he had put the senior barge engineer in charge of operating the capsule because the barge engineer had just completed a course in rescue craft operations. Once the survival capsule was underway, the crew relied on their survival training to minimize the physiological (hunger, dehydration), physical (sea sickness), and psychological stresses during their approximately 23-hour stay in the capsule. The rig mechanic stated that the survival training had saved his life, and the senior barge engineer stated that his training in rescue craft operations was "invaluable." Thus, the Safety Board believes that the ROWAN GORILLA I weekly abandon platform drills and the Canadian mandatory training contributed substantially to the orderly and safe rescue of all persons aboard the rig under the severe sea conditions.

The Rowan vice president stated that Rowan does not provide survival training similar to that provided in Canadian waters or the North Sea for MODU crews in the Gulf of Mexico, but relies on in-house training taught by their safety department and weekly abandon platform drills for MODU crews in the Gulf of Mexico. Furthermore, the U.S. Coast Guard does not require survival training for the crews of MODUs. The May 17, 1989 U.S. Coast Guard SNPRM for the licensing of officers and operators of MODUs would require the person in charge of the MODU to have completed U.S. Coast Guard approved immersion suit and survival craft training; however, this requirement would not apply to the other U.S. Coast Guard required crew or the industrial personnel aboard a MODU. The Safety Board believes that this accident shows

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[29] Marine Accident Report: NTSB-MAR-83-2.

the need for formal survival training for MODU crews who normally do not have a maritime background and that the U.S. Coast Guard should require that all MODU crewmembers attend a survival training course which includes donning of immersion suits, boarding liferafts from the water, and dealing with the stresses associated with abandoning a MODU under adverse conditions.

The incorrect position titles and the absence of names identifying the certificated lifeboatmen on the ROWAN GORILLA I fire and abandon platform bill did not affect the evacuation on December 15 because only one survival capsule was used and the rig superintendent took charge. However, if two survival capsules had been used, the Safety Board believes that there may have been confusion as to who was in charge of the second survival capsule and Rowan should revise any rig fire and abandon platform bills that have incorrect titles. Because MODU position titles do not identify the required U.S. Coast Guard Certificated lifeboatmen who should take charge of survival craft during an emergency, the Safety Board issued Safety Recommendation M-83-11 to the U.S. Coast Guard as a result of its investigation of the capsizing and sinking of the OCEAN RANGER:[30]

> Require that the station bill on mobile offshore drilling units identify by name the certificated lifeboatmen required by the U.S. Coast Guard Certificate of Inspection.

In a letter dated April 13, 1987, the U.S. Coast Guard stated:

> The Coast Guard concurs with the intent of this recommendation. The Coast Guard published Navigation and Inspection Circular No. 7-82 which revised station bill requirements to identify billets with emergency stations. Although the Board recommended identification by name, we believe our alternate action satisfies the intent of this recommendation. Therefore, no further action on this recommendation is anticipated.

On August 1, 1987, the Safety Board classified Safety Recommendation M-83-11 as "Closed--Unacceptable Action." The Safety Board believes that this accident again shows the confusion that can exist with MODU station bills if the U.S. Coast Guard certificated lifeboatmen are not identified and urges the U.S. Coast Guard to reconsider its position.

<u>The Search and Rescue Response</u>.--The Safety Board believes that when Canadian Coast Guard Radio Station Halifax was notified at 0242 on December 15, that the ROWAN GORILLA I towline had broken but there was no emergency, the Canadian Rescue Coordination Center in Halifax took appropriate action. An hourly communications schedule was established between the rig and Canadian Coast Guard Radio Station Halifax, the Rowan rig manager was informed of the situation, the U.S. Coast Guard Rescue Coordination Center in New York and the United Kingdom Rescue Coordination Center in Falmouth were

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[30] Marine Accident Report: NTSB-MAR-83-2.

notified, and the New York Rescue Coordination Center was requested to interrogate the AMVER system to determine which vessels were in the area in case of an emergency. In addition, when the ROWAN GORILLA I declared an emergency situation at 1218 on December 15, Canadian search and rescue resources were mobilized quickly. Within 2 minutes of the distress message, the Canadian stand-by aircraft was ordered launched and within 22 minutes, a Canadian Coast Guard vessel was ordered to get underway. Also within 2 minutes of the distress message, the New York Rescue Coordination Center directed the U.S. Containership SEALAND PERFORMANCE, which was in the area of the tow, to the scene. The first Canadian aircraft arrived on scene within about 3 hours of the distress message. Canadian aircraft then stayed with the ROWAN GORILLA I survival capsule throughout the night. The aircraft dropped flares to mark the capsule's position so that the SMIT LONDON could stay nearby, and maintained radio communication with the capsule which provided comfort to the survivors.

The Safety Board believes that the request by the Halifax Rescue Coordination Center about 0400 on December 14, to the SMIT LONDON master to delay rescue until the sea conditions improved was prudent. The Safety Board has investigated two other accidents where survival capsules have capsized in high wave conditions after the crew has been safely evacuated from the MODU. After the crew of the self-elevating MODU OCEAN EXPRESS[31] abandoned the rig in two survival capsules, one capsule capsized in 20- to 24-foot-high waves killing 13 persons. After the crew of the self-elevating MODU PENROD 61[32] abandoned the rig in two survival capsules, one capsule capsized in 24-foot-high waves with 19 persons on board. The SMIT LONDON master, however, had to consider the condition of the ROWAN GORILLA I survivors, who had been in the capsule for almost an entire day, and the possibility that weather conditions or darkness could prevent rescue that day if the rescue attempt was delayed. The survivors needed food, the batteries for their radios were running low, and the OTTAWA helicopter experienced mechanical problems, delaying its launch. The tug crew had had experience operating a Zodiac in 12- to 15-foot-high seas and rescuing persons from vessels in emergency situations. Therefore, the Safety Board believes that the decision by the tug master to rescue the survivors using the tug's Zodiac, when the seas had calmed to about 15-foot-high swells, expedited the safe rescue of the survivors and minimized the chance of any injuries to the survivors.

<u>Survival Capsule Design</u>.--The tug master stated that he was not able to locate the position of the rig's survival capsule in the dark because it did not have an external light, and therefore, the SMIT LONDON had to stay some distance away to avoid colliding with the capsule. The officer in charge of the Halifax Rescue Coordination Center stated that because the survival capsule did not have an external light and it was made of fiberglass (a poor radar reflector), the Canadian aircraft pilots found the survival capsule very difficult to see at night and that they often lost contact with the

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[31]Marine Accident Report: NTSB/MAR-79/05.

[32]Marine Accident Report--"Collapse of the U.S. Mobile Offshore Drilling Unit PENROD 61, Gulf of Mexico, October 27, 1985," (NTSB/MAR-86-10).

capsule on radar. The 1983 amendments to SOLAS 1974 require a light on the top of survival capsules visible for at least 2 miles and for an efficient radar reflector. However, these requirements only apply to vessels built after July 1, 1986 on international voyages and the U.S. Coast Guard has not implemented these requirements for U.S. vessels. The Safety Board believes that the circumstances of this accident show the need for lights and radar reflectors for all survival capsules on U.S. vessels and the need for the U.S. Coast Guard to implement the 1983 amendments to SOLAS 1974. As a result of its investigation of the explosions and fires aboard the U.S. Tankship OMI YUKON[33] on October 28, 1986, the Safety Board issued Safety Recommendation M-87-32 to the U.S. Coast Guard:

> Implement for all U.S. vessels the second set of amendments to the 1974 Safety of Life at Seas Convention regarding improved lifesaving equipment which became effective internationally on July 1, 1986.

On October 6, 1988, the U.S. Coast Guard replied:

> A regulatory project now in progress will propose incorporation of the 1983 SOLAS Amendments into the Code of Federal Regulations, and will propose to extend appropriate new SOLAS requirement to U.S. ships not otherwise required to comply with SOLAS. ... Publication of a Notice of Proposed Rulemaking is now anticipated by the end of 1988.

On February 28, 1989, the Safety Board classified Safety Recommendation M-87-32 as "Open--Unacceptable Action," noting that the Notice of Proposed Rulemaking was not expected to be published until the summer of 1989. On April 21, 1989, the U.S. Coast Guard published a notice of proposed rulemaking to implement the lifesaving equipment carriage requirements of the 1983 amendments to SOLAS 1974 and stated that lifesaving equipment standards including lights on survival capsules would be the subject of a separate notice. Because the U.S. Coast Guard has not implemented the lifesaving equipment standards contained in the 1983 amendments to SOLAS 1974 as of the date of this report, the Safety Board reiterates Safety Recommendation M-87-32.

The rig superintendent and other survivors testified that the 36-person survival capsule was very crowded with 27 persons wearing immersion suits although 36 persons with lifejackets had sufficient room in the capsule during drills. Neither U.S. Coast Guard or SOLAS 1974 standards consider immersion suits in determining the capacity of survival craft. The Safety Board believes that both the U.S. Coast Guard and the International Maritime Organization should consider persons wearing immersion suits in the sizing of survival craft on vessels where immersion suits are required.

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[33] Marine Accident Report--"Explosions and Fires Aboard the U.S. Tankship OMI YUKON in the Pacific Ocean about 1,000 miles west of Honolulu, Hawaii, October 28, 1986" (NTSB-MAR-87-6).

The ROWAN GORILLA I survival capsule engine stopped after only about 40 minutes of operation although the capsule was designed for 24 hours of operation; the rig crew had determined that its fuel tank was full just before launching, and the fuel had been replaced about 2 months earlier. Since the survival capsule has never been recovered, the Safety Board cannot determine why the survival capsule engine stopped after only 40 minutes.

CONCLUSIONS

Findings

1. The ROWAN GORILLA I as loaded on December 15, 1988 had sufficient stability to withstand the overturning forces of the wind and waves with preload tanks 14 and 15 flooded, and water in both propulsion rooms, the air compressor room, the mud pit room, and the shale shaker house.

2. The 6° stern trim experienced by the ROWAN GORILLA I about 0900 on December 15 was caused by the flooding of additional after preload tanks resulting from a combination of further structural failures, loose access hatch covers, and ventilation openings.

3. The capsizing of the ROWAN GORILLA I was the result of the progressive flooding of preload tanks and internal compartments as the rig sank by the stern.

4. Because the ROWAN GORILLA I was designed by Marathon, classed by ABS, and certificated by the U.S. Coast Guard for towing during any time of the year in any waters provided the wind speed did not exceed 100 knots, the decision by Rowan to tow the rig in December across the North Atlantic on a southerly route, where the frequency of severe weather was 40 percent less than a great circle route and the probability of encountering winds greater than 48 knots was 1 percent, was reasonable.

5. If Rowan had employed a weather service to provide a long-range forecast before the tow departed Halifax, the weather service may have noted the potential for the development of a severe storm about December 15 in the area of the capsizing, and the departure of the tow could have been delayed until the potential for encountering severe storm activity had decreased.

6. The stowage of cargo on the main deck of the ROWAN GORILLA I contributed to the flooding of the rig.

7. To prevent flooding from boarding seas, vents on preload tanks should be made watertight during ocean tows.

8. The NWS forecasts for the period December 8 through 16 were substantially correct.

9. The SMIT LONDON master had accurate weather information from the NWS for making decisions regarding the safest trackline for the tow.

10. The decision of the SMIT LONDON master to turn and tow with the wind and waves on the rig's stern was made to protect both the tug and the rig and the tug master exhibited good seamanship in attempting to prevent the towline from breaking under the severe sea conditions.

11. If the rig superintendent had made an attempt to keep the waves from breaking over the rig's stern after the towline broke, he may have prevented the flooding of some after preload tanks and avoided increasing the amount of trim aft.

12. If the ROWAN GORILLA I had been equipped with remote gauges for its preload tanks, its crew would have been able to detect the flooding which was causing the stern trim and may have been able to take corrective action.

13. Because the hull structural fractures in preload tanks 14 and 15 occurred at less than half the design wind speed and when rig motions were well within design limits, the ABS structural criteria for self-elevating MODUs under tow is not adequate and does not accurately reflect rig motions expected to be encountered during ocean tows.

14. If Rowan had employed a rig mover experienced in ocean towing and the motions of self-elevating mobile offshore drilling units (MODU), the ROWAN GORILLA I rig superintendent would not have had to rely on the advice of the SMIT LONDON master, who was not familiar with MODUs, regarding the survivability of the rig after the towline broke.

15. Promulgation by the U.S. Coast Guard of personnel qualification and manning standards for mobile offshore drilling units is long overdue.

16. The location of the inflatable liferaft launching equipment on the ROWAN GORILLA I was inadequate for ocean tows because liferafts in the launching equipment would have been easily washed overboard during storms.

17. Rowan procedures and policies were not adequate to ensure that U.S. Coast Guard required survival capsules and inflatable liferafts were operational for the tow from Halifax to Great Yarmouth.

18. If Canadian Coast Guard inspectors had not told Rowan that the ROWAN GORILLA I survival capsules should not be removed from their launching equipment without U.S. Coast Guard approval, the rig would probably have left Halifax without any operational survival capsules or inflatable liferafts, and there probably would have been serious injuries and loss of life when the rig capsized and sank.

19. The Canadian mandatory survival training, which all ROWAN GORILLA I crewmembers had received, contributed substantially to the orderly and safe rescue of all persons aboard the rig.

20. The ROWAN GORILLA I fire and abandon platform bill was inadequate because it did not correctly identify the person in charge of each survival capsule.

21. U.S. Coast Guard standards for station bills on MODUs are inadequate because they do not require identification by name of the U.S. Coast Guard certificated lifeboatmen who should be in charge of survival craft during emergencies.

22. The Canadian search and rescue response was timely, efficient, and contributed to the safe rescue of the survivors.

23. The SMIT LONDON rescue of the rig survivors without injury in 15-foot-high swells can be attributed to good judgment and seamanship of the master and the crew.

24. The lack of an external light and a radar reflector on the ROWAN GORILLA I survival capsules made detection of the capsule either visually or by radar very difficult at night and added to the danger of collision between the SMIT LONDON and other vessels.

25. Despite the Coast Guard's stated intention, it has failed to implement the improved lifesaving equipment standards contained in the 1983 amendments to SOLAS 1974, which became effective internationally on July 1, 1986.

26. Both the U.S. Coast Guard and the International Maritime Organization need to revise their capacity standards for survival craft to account for the wearing of immersion suits.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the capsizing and sinking of the mobile offshore drilling unit (MODU) ROWAN GORILLA I was the flooding of compartments and tanks as the result of structural failures, non-watertight ventilation openings, loose access hatches, and unsecured cargo. The structural failures were the result of inadequate government and industry analytical methods during the design phase to assess the stresses imposed on the structure of self-elevating MODUs while under ocean tow. Contributing to the accident was the failure of Rowan to employ and the U.S. Coast Guard to require aboard the MODU a person qualified and experienced in moving self-elevating MODUs on an ocean tow.

RECOMMENDATIONS

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

--to the U.S. Coast Guard:

Require remote gauging devices for all tanks on self-elevating mobile offshore drilling units. (Class II, Priority Action) (M-89-88)

In conjunction with the American Bureau of Shipping, revise the structural design criteria for self-elevating mobile offshore drilling units under ocean tow to include a dynamic analysis which accurately reflects rig motions expected to be encountered. (Class II, Priority Action) (M-89-89)

Require applicants for the offshore installation manager license with a bottom bearing unit underway endorsement to provide certification of experience observing and directing both field and ocean moves. (Class II, Priority Action) (M-89-90)

Conduct a one-time inspection of the location of the launching equipment for inflatable liferafts on self-elevating mobile offshore drilling units (MODU) and, where necesssary, require that alternate launching equipment locations be provided to protect the liferafts from being washed overboard by waves when the MODU is being towed. (Class II, Priority Action) (M-89-91)

Require both the marine and industrial crews of mobile offshore drilling units (MODU) to attend a survival training course which includes donning of immersion suits, boarding of liferafts from the water, and dealing with the stresses associated with abandoning a MODU under adverse conditions. (Class II, Priority Action) (M-89-92)

Require that the station bill on mobile offshore drilling units identify by name the certificated lifeboatmen required by the U.S. Coast Guard Certificate of Inspection. (Class II, Priority Action) (M-89-93)

Require that all new and existing enclosed lifeboats or survival capsules be equipped with a light on the top visible for at least 2 miles and an efficient radar reflector. (Class II, Priority Action) (M-89-94)

Revise the capacity standards for survival craft required on board vessels required to carry immersion suits for all crewmembers to account for the wearing of immersion suits by all persons while in the survival craft. (Class II, Priority Action) (M-89-95)

Urge the International Maritime Organization to amend the capacity standards for survival craft to account for the wearing of immersion suits. (Class II, Priority Action) (M-89-96)

--to Rowan Companies, Inc.:

Employ a weather service to provide long-range forecasts whenever towing self-elevating mobile offshore drilling units across the ocean. (Class II, Priority Action) (M-89-97)

When towing self-elevating mobile offshore drilling units on routes where severe weather can be expected, make the ventilation openings for empty tanks watertight. (Class II, Priority Action) (M-89-98)

Provide remote gauges for all tanks on self-elevating mobile offshore drilling units. (Class II, Priority Action) (M-89-99)

During ocean tows, employ rig movers with experience in ocean towing and the motions of self-elevating mobile offshore drilling units under severe sea conditions. (Class II, Priority Action) (M-89-100)

Provide alternate launching equipment in a protected location for the inflatable liferafts on self-elevating mobile offshore drilling units (MODU) to protect the liferafts from being washed overboard by waves when the MODU is being towed. (Class II, Priority Action) (M-89-101)

Provide explicit instructions in mobile offshore drilling unit operations manuals regarding the proper stowage of lifesaving equipment during ocean transits. (Class II, Priority Action) (M-89-102)

Revise mobile offshore drilling unit (MODU) fire and abandon platform bills to correctly state the position titles of the persons aboard the MODU and to identify by name the certificated lifeboatmen required by the U.S. Coast Guard Certificate of Inspection. (Class II, Priority Action) (M-89-103)

Provide enclosed lifeboats and survival capsules with a light on the top visible for at least 2 miles and an efficient radar reflector. (Class II, Priority Action) (M-89-104)

--to the American Bureau of Shipping:

In conjunction with the U.S. Coast Guard, revise the structural design criteria for self-elevating mobile offshore drilling units under ocean tow to include a dynamic analysis which accurately reflects rig motions expected to be encountered. (Class II, Priority Action) (M-89-105)

--to Marathon LeTourneau Offshore Company:

Conduct a dynamic structural analysis of the ROWAN GORILLA I design to determine the environmental limits of the design, and revise the operating manuals of the existing mobile offshore drilling units built to this design accordingly. (Class II, Priority Action) (M-89-106)

--to the International Association of Drilling Contractors:

Publicize the circumstances of this accident to members through industry publications. (Class II, Priority Action) (M-89-107)

Emphasize to members the need for maintaining required lifesaving equipment operational at all times. (Class II, Priority Action) (M-89-108)

Recommend that members minimize the amount of deck cargo carried on self-elevating mobile offshore drilling units during ocean tows. (Class II, Priority Action) (M-89-109)

Recommend that members make ventilation openings for empty tanks watertight when towing self-elevating mobile offshore drilling units on routes where severe weather can be expected. (Class II, Priority Action) (M-89-110)

Also, the Safety Board reiterated the following safety recommendations:

--to the Secretary of the U.S. Department of Transportation:

<u>M-84-48</u>

Direct the Commandant of the U.S. Coast Guard to address immediately the early promulgation of personnel qualification and manning regulations for mobile offshore drilling units.

--to the U.S. Coast Guard:

M-83-8

Expedite the promulgation of regulations regarding personnel qualifications and manning standards for mobile offshore drilling units.

M-83-9

Require that the master and the person-in-charge of a mobile offshore drilling unit be licensed and that their licenses be endorsed as qualified in mobile offshore drilling operations, including knowledge of U.S. Coast Guard regulations, stability characteristics of mobile offshore drilling units, the operation of ballast systems on mobile offshore drilling units, and the use of lifesaving equipment peculiar to mobile offshore drilling units.

M-83-10

Require that the person-in-charge of a mobile offshore drilling unit also be a certificated lifeboatman.

M-87-32

Implement for all U.S. vessels the second set of amendments to the 1974 Safety of Life at Sea Convention regarding improved lifesaving equipment which became effective internationally on July 1, 1986.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ James L. Kolstad
Acting Chairman

/s/ Jim Burnett
Member

/s/ Joseph T. Nall
Member

/s/ Lemoine V. Dickinson, Jr.
Member

JOHN K. LAUBER, Member, did not participate.

September 12, 1989

APPENDIXES

APPENDIX A

INVESTIGATION

This accident was investigated jointly by the National Transportation Safety Board and the U.S. Coast Guard. Public hearings were held in Halifax, Nova Scotia, Canada, from December 19 to December 22, 1988, and in Houston, Texas, on February 14, 1989. The Safety Board has considered all the facts in the investigative record that are pertinent to the Safety Board's statutory responsibility to determine the probable cause of the accident and to make recommendations. This report is based on the factual information developed during the joint investigation, on additional factual information developed by the Safety Board, and on independent analyses made by the Safety Board. The Safety Board's conclusions and recommendations were made independently of the Coast Guard.

APPENDIX B

PERSONNEL DATA

ROWAN GORILLA I

Rig Superintendent Jeffery Cox

Mr. Jeffery Cox, 32, had been employed by Rowan since 1976. He transferred to the Rowan offshore division in 1983 and was assigned as driller aboard the ROWAN GORILLA I while it was under construction in Vicksburg, Mississippi. After the rig arrived in Canada, he became a toolpusher on the ROWAN GORILLA I and in 1985, he became rig superintendent. He was documented as an able seaman by the U.S. Coast Guard.

Barge Engineer Clinton Cariou

Mr. Clinton Cariou, 27, was the senior barge engineer on the ROWAN GORILLA I. He had been employed by Rowan since 1980 and had been assigned to the ROWAN GORILLA I in 1983. He spent 2 years as a barge engineer trainee from 1983 to 1985 before qualifying as a barge engineer. He was documented as an able seaman by the U.S. Coast Guard.

Vice President Daniel F. McNease

Mr. Daniel McNease, 37, had been employed by Rowan for 14 years. He began his employment as a barge engineer trainee, then barge engineer, driller, toolpusher, rig manager, project manager for the construction of the ROWAN GORILLA I, and in 1983, he became area manager for Canada. At the time of the accident, he was Vice President of Rowandrill and responsible for the operations of Rowan rigs in the Gulf of Mexico and Canada. He was documented as an able seaman by the U.S. Coast Guard.

Rig Manager Walter Couch

Mr. Walter Couch, 41, had been employed by Rowan for 13 years. He began his employment as a painter, then roustabout, floor hand, barge engineer trainee, barge engineer, driller, tool pusher, rig superintendent, and finally rig manager. He had been rig manager of the ROWAN GORILLA I for 4 years and was documented as an able seaman by the U.S. Coast Guard.

Alternate Rig Superintendent Cyril Quinn

Mr. Cyril Quinn, 35, had been employed by Rowan since 1981. He was assigned to the ROWAN GORILLA I in 1983 and became rig superintendent in 1986. He was documented as an able seaman by the U.S. Coast Guard.

SMIT LONDON

Master Alexander G. Rijnsaardt

Captain Rijnsaardt, 44, had been sailing for 28 years with Smit Tax International on oceangoing tugs. He was licensed both by the Dutch Government and the Bahamian Government as master of oceangoing tugs, and had been sailing as master since 1973. He became master of the SMIT LONDON on October 20, 1988.

Second Officer Frank Van De Ven

Mr. Frank Van De Ven, 28, had been sailing for 11 years with Smit Tax International on oceangoing tugs. He was licensed both by the Dutch Government and the Bahamian Government as a second officer on oceangoing tugs. He boarded the SMIT LONDON for the first time when the tug departed Rotterdam in late November, 1988.

Second Engineer Piter Oosterhof

Mr. Piter Oosterhof had been sailing since 1982 with Smit Tax International on oceangoing tugs. He was licensed both by the Dutch Government and the Bahamian Government as second engineer on oceangoing tugs.

Tow Rider Jan Brinkman

Mr. Jan Brinkman had been sailing for 40 years of which 35 years had been on oceangoing tugs with Smit Tax International.

APPENDIX C

U.S. NATIONAL WEATHER SERVICE HIGH SEAS FORECASTS

The pertinent U.S. National Weather Service High Seas Forecasts along the intended trackline of the ROWAN GORILLA I were as follows:

Time/Date	Forecast
0700 December 8	Winds 25 knots or less, seas 8 feet or less until 1500 on December 9.
1900 December 8	A gale near latitude 62° N, longitude 40° W was moving northeast at 10 knots and weakening with 25- to 30-knots winds and 8- to 15-foot-high waves within 400 miles of its center.
0100 December 9	A low pressure would develop near Wilmington, North Carolina by 0900 on December 9 and move east-northeast at 35 knots and would be near latitude 40° N, longitude 56° W by 0900 on December 10 with 25- to 30-knots winds and 8- to 12-foot seas within 300 miles of its center.
0700 December 10	A gale near latitude 38° N, longitude 62° W would move northeast at 30 knots with 25- to 35-knot winds and 8- to 12-foot seas within 300 miles of its center.
1300 December 10	A storm near latitude 40° N, longitude 55° W would move northeast at 25 knots with 30- to 50-knot winds and 12- to 25-foot seas within 250 miles of its center. A low would form near latitude 40° N, longitude 60° W by 0900 on December 11 and move east. By 2100 on December 11, the low would be near latitude 40° N, longitude 55° W with a cold front extending to latitude 32° N, longitude 70° W. There would be 20- to 30-knots winds and 8- to 15-foot high waves west of the low and north of the cold front.
1900 December 10	By 0300 on December 12, a gale would be near latitude 43° N, longitude 58° W with 25- to 40-knot winds and 10- to 18-foot seas within 500 miles of its center.

0100 December 11	By 0900 on December 12, a gale would be near latitude 48° N, longitude 55° W with 25- to 40-knot winds and 10- to 18-foot waves within 450 miles of its center.
0100 December 12	A gale near latitude 42° N, longitude 55° W was moving north at 30 knots with 25- to 35-knot winds and 8- to 15-foot seas within 450 miles of the center.
1900 December 12	A gale near latitude 41° N, longitude 54° W at 1500 on December 12 and was moving northeast at 25 knots. By 0300 on December 14, the gale would be near latitude 52° N, longitude 38° W with 25- to 40-knot winds and 10- to 18-foot waves within 350 miles of the center. In addition, by 0300 on December 14, another gale would be near latitude 35° N, longitude 68° W with 30- to 45-knot winds and 12- to 22-foot seas within 550 miles to the northeast.
0100 December 13	At 2100 on December 12, a storm was developing near latitude 29° N, longitude 78° W and moving northeast at 25 knots. By 0900 on December 14, the storm would be near latitude 40° N, longitude 64° W with 35- to 50-knot winds and 15- to 25-foot seas within 350 miles to the northeast, and 30- to 45-knot winds and 10- to 20-foot-high waves within 500 miles of its center.
0700 December 13	At 0300 on December 13, a storm was developing near latitude 31° N, longitude 73° W and was moving northeast at 20 knots. By 1500 on December 14, the storm would be near latitude 40° N, longitude 61° W with 45- to 65-knot winds and 18- to 25-foot seas within 300 miles of the center.
1300 December 13	At 0900 on December 13, a storm was developing near latitude 31° N, longitude 72° W and was moving northeast at 20 knots. By 2100 on December 14, the storm would be near latitude 40° N, longitude 60° W with 50 to 65-knot winds and 22- to 30-foot seas within 300 miles of its center, 30- to 45-knot winds and 15- to 22-foot-high waves within 500 miles to the northwest, and 25 to 40 knot winds and 12- to 18-foot high waves within 700 miles to the southeast.

1900 December 13

At 1500 on December 13, a complex storm was developing near latitude 33° N, longitude 68° W and was moving to the northeast at 20 knots with 25- to 35-knot winds and 8- to 14-foot seas within 400 miles to the north. By 0900 on December 15, the storm would be near latitude 43° N, longitude 55° W with 50- to 65-knot winds and 22- to 30-foot waves within 350 miles of the center.

0100 December 14

At 2100 on December 13, a complex storm was developing near latitude 34° N, longitude 70 W with 25- to 40-knot winds and 8- to 15-foot seas within 400 miles of its center. By 0900 on December 15, the storm would be near latitude 47° N, longitude 55° W with 45- to 55-knot winds and 20- to 30-foot seas within 350 miles of its center.

0700 December 14

At 0300 on December 14, a storm was near latitude 37° N, longitude 67° W and was moving northeast at 25 knots with 30- to 50-knot winds and 10- to 18-foot waves within 300 miles of its center. By 1500 on December 15, the storm would be near latitude 48° N, longitude 52° W with 45- to 55-knot winds and 20- to 30-foot-high waves within 350 miles of its center.

1300 December 14

At 0900 on December 14, a storm was near latitude 39° N, longitude 64° W and was moving northeast at 25 knots. By 2100 on December 15, the storm would be near latitude 50° N, longitude 48° W with 45- to 70-knot winds and 20- to 30-foot-high waves within 300 miles of its center.

1900 December 14

At 1500 on December 14, a storm was near latitude 39° N, longitude 63° W and moving northeast at 20 knots. By 0300 on December 16, the storm would be near latitude 50° N, longitude 50° W with 50- to 70-knot winds and 20- to 30-foot-high waves within 300 miles of its center.

0100 December 15

At 2100 on December 14, a storm was near latitude 39° N, longitude 58° W and moving northeast at 30 knots. By 0900 on December 16, the storm would be near latitude 56° N, longitude 50° W with 50- to 70-knot winds

	and 25- to 35-foot waves within 300 miles of its center.
0700 December 15	At 0300 on December 15, a dangerous storm was near latitude 40° N, longitude 55° W and moving north-northeast at 30 knots.
1300 December 15	At 0900 on December 15, a dangerous storm was near latitude 42° N, longitude 55° W and moving north at 15 knots. There are 45- to 60-knot winds and 25- to 35-foot waves within 550 miles of its center.
1900 December 15	At 1500 on December 15, a storm was near latitude 47° N, longitude 49° W which was moving north-northwest at 25 knots and weakening to a gale. There are 35- to 50-knot winds and 22- to 32-foot waves within 650 miles of its center.
0100 December 16	At 2100 on December 15, a storm was near latitude 50° N, longitude 48° W and was moving north-northwest at 20 knots.

*U.S.GOVERNMENT PRINTING OFFICE:1990-242-320:00030-R