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The Hydrostatic Mooring System

**Final Technical Report
Main Report + Appendices A, B, & C
Volume 1 of 2**

Jens Korsgaard

Jens Korsgaard

Date Published August 8, 2000

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August 8, 2000

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Reference: Contract DE-FG36-98GO10321
The Hydrostatic Mooring

Dear Ms. Danz:

Please find enclosed the final technical report in the captioned matter. I wish to express gratitude for having been granted the grant, which enabled this work. The work carried out under this contract will go a long way toward making the Hydrostatic Mooring a commercial reality.

I also wish to complement everyone in the Department of Energy with whom I have had the fortune of coming into contact. It has been a true pleasure to work with your staff. I have found everyone truly competent and helpful, which is particularly important for an individual like myself.

Sincerely yours

Jens Korsgaard

EXECUTIVE SUMMARY

This document reports the work carried out by Jens Korsgaard under the U.S. Department of Energy (DOE) Innovation and Energy Program Contract No. DE-FG36-98GO10321. The work was carried out in the period October 10, 1998, to August 10, 2000. The object of the contract was proving the extraordinary performance of the Hydrostatic Mooring.

The Hydrostatic Mooring is a new type of Single Point Mooring, which moors oil tankers and similar large ships in the open ocean. There is a number of existing Single Point Moorings. All other Single Point Moorings have a mechanical coupling between the vessel and the mooring. This may be a gripping mechanism or an ordinary mooring hawser. Common for all Single Point Moorings including the Hydrostatic Mooring, is that they permit the ship to weathervane 360° about the mooring, thereby enabling it to assume a position that minimizes the forces from the winds, waves and currents.

All other Single Point Moorings have limitations on mooring operations due to weather, which limits the maximum sea state to between 2 and 4.5 m significant wave height. In cases with particularly favorable current conditions the operations limits may be somewhat higher for the other moorings. These limitations cause typical weather related downtimes between 5% and 30% in the open ocean. The Hydrostatic Mooring holds out the promise of being able to moor in 8 m significant wave height, thereby virtually eliminating weather downtime.

The mechanism that moors the Hydrostatic Mooring to the vessel is the suction cup principle, in which the mooring buoy itself is a giant suction cup and the vessel provides the power to reduce the pressure between the buoy and the vessel. The resulting compressive force between the vessel and the buoy is very large and the friction that results from this compressive force is the one that actually restrains the vessel.

All other Single Point Moorings have retrieval lines, which are retrieved by the vessel and hauled in, in order to effect the mooring. The Hydrostatic Mooring is brought into contact with the ship by variable buoyancy. This is remotely actuated from the ship when it maneuvers above the buoy at its resting position, 8 m below the keel. Consequently, there is no guiding force that will guide the mooring into its proper position. The ship must therefore be carefully navigated to a position above the mooring buoy and the proper time selected for actuating the variable buoyancy system aboard the buoy. The principal objective of this contract was to prove or disprove that this operation is feasible and reliable. A number of real time tests using the true real time performance of a tanker were carried out at Nichols Advanced Marine Sciences in Arlington, Virginia. A 150,000 DWT oil tanker was used for the tests. The oil tanker used had the minimum maneuvering characteristics allowed by the classification societies. Consequently, any real tanker would have the same or better maneuvering characteristics than the tanker used in the tests. The tanker was equipped with the standard equipment that is required for the use with the Hydrostatic Mooring, which includes an omni-directional bow thruster, in this case with a 200 kN thrust force.

Twenty-five tests were carried out in weather conditions ranging from flat calm to very stormy conditions with a significant wave height of 8 m. Unsteady winds and currents were also present in most of the tests. The mooring was successful in 100% of the twenty-five tests made. In 20% of the tests, the final location of the mooring buoy on the bottom of the ship would not permit the connection of the fluid transfer equipment. Consequently, in those cases, the mooring attempt would have to be repeated. It was found, however, in the tests, that the navigator continued to learn throughout the test period. In the final sixteen tests, which were made in the most adverse weather conditions, there was only one instance in which the buoy was not placed with the proper accuracy on the bottom of the ship. In the first 9 tests in more benign conditions there were 4 such instances. This buoy has, in its standard configuration, sufficient power aboard the buoy to perform eight mooring attempts. It was therefore concluded that the

mooring between a large oil tanker and the Hydrostatic Mooring could be carried out with extreme reliability in all wave conditions up to 8 m significant wave height.

The second objective of the project was to gain approval by the American Bureau of Shipping for the buoy concept and design. This entails carrying out preliminary design work, which was done by the author of this report and by Han-Padron Associates Consulting Engineers in New York through a subcontract. The design package was submitted to the ABS in two stages. The first package was submitted in April 2000, consisting of all the tests that were made at Nichols Advanced Marine Sciences and prior tests made at the Danish Maritime Institute in Denmark. The second submittal was on July 7, 2000 containing all the design work carried out in connection with this project.

As of the date of the publication of this report, the American Bureau of Shipping (ABS) had not completed their review of the submitted material and ABS has requested some supplemental calculations that will shortly be furnished to the ABS.

THE HYDROSTATIC MOORING SYSTEM

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1. INTRODUCTION

This report is the technical report from a contract between the Department of Energy and Jens Korsgaard contract number DE-FG36-98-GO10321.

The principal objective of the contract is to develop the Hydrostatic Mooring further. The project had two main components:

- To prove in a maneuvering simulator that a seafarer could in fact navigate the vessel with the required precision to mate to the Hydrostatic Mooring.
- To obtain the approval of the American Bureau of Shipping (ABS) for the mooring.

The ship maneuvering study was carried out at Nichols Advanced Marine, in Arlington, Virginia, in 1999.

In order to gain the ABS approval of the design, the existing design had to be developed further. This was done partly through a contract with Han-Padron Associates (HPA) in New York, and was partly done by the Author.

At the date of publication of this report, the ABS had not yet completed their review of the design.

The system of units used in this document is the SI system.

2. OVERVIEW OF THE HYDROSTATIC MOORING SYSTEM

2.1 CONCEPT

The Hydrostatic Mooring is a single point mooring of the type that attaches to the keel of the vessel. Existing similar concepts comprise the Submerged Turret Loading (STL) provided by Advanced Product Loading (Norway) and the Turret-Collet type buoy moorings provided by Single Buoy Moorings (Monaco) and SOFEC (USA). These existing systems rely on structural connectors of the hydraulic clamp type to effect the structural connection between the buoy and the vessel. The STL has the structural swivel built into the buoy whereas the turret-collet type buoy mooring has the structural swivel built into the vessel.

The Hydrostatic Mooring has the structural swivel built into the buoy, but in contrast to the other submerged systems relies on a combination of compressive and friction forces between the hull of the vessel and the buoy to transmit the mooring forces from the buoy to the vessel. The Hydrostatic Mooring is shaped like a giant suction cup and reducing the hydrostatic pressure in the volume between the buoy and the hull creates a large compressive force between the buoy and the vessel hull. The mooring is attached to the ship's hull as shown on Fig 2-1 below.

Fig 2-1 Hydrostatic Mooring Principle

The volume between the ship's hull and the mooring is isolated from the sea by the circular seal shown on Fig 2-1. The suction pump takes suction within this volume and lowers the absolute pressure to for example 50 kPa within the volume. The exterior pressure is at least atmospheric (100 kPa) thus the disk is pressed upward as indicated by the upward arrows. This upward force is resisted by the compression elements within the volume. The downward pointing arrows illustrate the compressive forces. These compressive forces resist any vertical mooring forces. There is friction between the hull and the compression elements. This friction provides the means to resist horizontal forces between the mooring buoy and the hull. The mooring lines shown in Fig 2-1 provide the means to transmit the mooring forces to the seabed.

The potential of this mooring system is illustrated by the following numerical example:

Ships draft in the mooring area:	5 meters
Sealing ring diameter	20 meters
Mooring pressure:	50 kPa (absolute)
External pressure:	150 kPa (absolute)
Friction coefficient:	20%

Mooring area calculated:	$\pi/4 \cdot 20^2 = 314 \text{ m}^2$
Compressive force calculated:	$314 \cdot (150 - 50) = 31400 \text{ kN}$
Max. horizontal force calculated:	$20\% \cdot 31400 = 6280 \text{ kN}$

The maximum horizontal force in this example is comparable to a normal design force for a Floating Production, Storage, and Offloading vessel (FPSO) in an extreme ocean environment. Several avenues are available to increase the force capability of the above sample mooring. The sealing ring diameter can in most cases be doubled, the friction coefficient can be increased by proper materials selection and finally ballasting operations can increase the pressure differential. In this manner this mooring can resist even

extreme ice forces. Consequently, the Hydrostatic Mooring has the capability of mooring all large ships in the Arctic or ocean environment.

A more detailed view of the Mooring concept is shown in Fig 2-2 below:

Fig 2-2 Hydrostatic Mooring Buoy Cross-Section

This more detailed view shows two annular seals (outer and inner seals) between which the hydrostatic pressure is lowered. This reduces the compressive force somewhat, but then permits the maintenance of for example atmospheric pressure in the center area of the buoy. The fluid connection is made within the structural swivel area. The fluid swivel is on the vessel. This is similar to the STL arrangement. Also note the fenders that prevent damaging impacts between the buoy and the vessel.

2.2 APPLICATION EXAMPLE

The application example is for a transport system in which water is transported from Manavgat in Turkey to Ashkelon in Israel. The vessels used are either VLCC (approximately 250,000 DWT) or ULCC (approximately 450,000 DWT).

The following describes only the Ashkelon mooring. The mooring in Turkey is similar. A buoy that has an outer sealing ring diameter of 21 m is chosen for either class of vessel. The vessel must have flat bottom plating in the mooring area with a width on the order of 28 m or more for this to work effectively and safely. The width of either class of vessel is more than 40 m, therefore, this is not a problem. Tests show that the mooring operation can easily be performed with a precision of 2 meters in conditions with wave heights of $H_s=5$ m or below regardless of cross currents and wind. Mooring is consistently possible on the first attempt in all wave heights up to $H_s=8$ meters regardless of wind and cross current conditions. The accuracy deteriorates to a typical error of 3 meters at 8 meter wave heights. Mooring operations are probably feasible in even higher wave heights, but this may be of theoretical interest only, because operations on the vessel will be curtailed in any event at these extreme conditions.

2.2.1 Met-Ocean Conditions Ashkelon

The environmental condition in Ashkelon and in Manavgat is described by the following:

• $H_s=2.0$ meters	Exceeded 50 days per year
• $H_s=5.0$ meters	Exceeded 3.8 days per year
• $H_s=6.0$ meters	Exceeded 0.6 days per year
• $H_s=8.0$ meters	Return Period 50 years

The current at Ashkelon is reported to be usually north going with a speed of 0.5 knots. For design purposes at this time a design current of 1.5 knots is assumed.

The wind speed is generally quite low at Ashkelon and the maximum recorded wind speed is 35 knots.

2.2.2 Mooring Design Conditions

A system designed for a maximum wave height of $H_s=5.0$ m will have 99% availability and weather delays is not a concern. The required precision for mooring can be set to be 2.0 m in accordance with the results from the maneuvering tests performed. In the actual design a 3.0 meter tolerance will be provided.

For purposes of this document the mooring is designed for a maximum horizontal mooring force of 6000 kN.

The buoy is secured to the ship by differential hydrostatic pressure. The present buoy is designed for water transport. It has two sealing rings, one at 10.5 m radius and another at 4 meter radius. The pressure in the area between the two sealing rings is typically maintained at 50 kPa (absolute). This is done through pumps aboard the moored vessel that take suction within the space between the two sealing rings. The vessels to be moored by this buoy must have a minimum width of flat bottom plate of 28 meters (60,000 DWT). There is no upper limit on ship size other than the limit on force caused by the combination of ship size and environmental conditions and potential water depth limitations.

The submergence of the hull may vary between 4 meters and 25 meters depending on the ship size and the loading condition. This corresponds to absolute hydrostatic pressures at the keel between 140 kPa and 290 kPa. The pressure within the sealing area is 50 kPa. Assuming a 4 meter submergence the differential hydrostatic pressure is 90 kPa. The area

is $\pi(10.5^2 - 4^2) = 295 \text{ m}^2$. The resulting compressive force between the buoy and the vessel is then 27000 kN. The net buoyancy of the combined buoy/mooring system must be added. This is normally negative but close to zero and is ignored. Consequently, a friction coefficient of 0.3 between the keel and the buoy permits a horizontal force of 8100 kN at a draft of 4 meters. At larger drafts the possible horizontal force increases to as much as 18000 kN. In consequence the vessel can control the friction capacity of the buoy and may in principle avoid dangerous combinations of force capability versus possible mooring force by increasing its draft.

The friction coefficient between the ship's bottom and the buoy is believed to be in the 50% to 80% range. Standard ablating anti-fouling paint coats the ship's bottom. The surfaces on the buoy that touch the ship are primarily composed of rubber fender elements. The rubber in these fender elements is specially formulated to have a large friction coefficient relative to wet anti-fouling paint.

The friction coefficient that is assumed for computational purposes is ordinarily in the 10% to 30% range, thereby providing an adequate safety factor against mooring failure. It should be noted that it is possible to determine the actual friction coefficient during unmooring by recording the combination of mooring force and pressure at the time of initiation of the separation process, i.e., when the buoy starts moving on the bottom of the vessel. Therefore, it is possible to monitor the efficacy of the system by measuring the buoy loading condition at initiation of motion upon separation at unmooring. This measurement may be done at each unmooring thereby providing for each ship that uses the mooring a continuous record of the friction coefficient between the buoy and the vessel.

The vessels arriving in Ashkelon are loaded and will discharge their cargo. For purposes of this document it is assumed that the maximum draft of the arriving vessel is 25 meters. The maximum wave condition for approach and mooring is set to $H_s = 5$ meters in this case. A safety margin

between the vessel and the buoy of 7.0 m is set. The buoy is 8 meters high requiring a minimum water depth in the mooring area of $25 + 7 + 8 = 40$ m.

The water depth in the chosen mooring area is only about 37 m. Therefore, in order to provide space for the buoy a circular area with a diameter of 100 m will be dredged to a depth of 44 m. The additional 4 m over depth allows for sedimentation for several years until maintenance dredging is required.

2.2.3 Cargo Transfer

The cargo to be transferred in the case at hand is fresh water and therefore unique in the sense that it is nonpolluting and normally can be discharged freely to the sea. This makes it possible to use simpler designs in the cargo transfer system with fewer safeguards against leakage and spills compared to petroleum transfer systems. Later in this section a normal petroleum or gas transfer system will be described.

The proposed water transfer system is shown in Fig 2-3.

Fig 2-3 Fresh Water Transfer System

ship. One disadvantage of the arrangement shown in Fig 2-3 is the downward pressure indicated by the arrows in the center of the buoy. This pressure counteracts the suction that presses the buoy onto the ship's keel. However, it acts on a much smaller area than the suction. As an example consider that the suction acts between two sealing circles with diameters 21 m and 8 m respectively. Assume that the differential hydrostatic pressure is - 90 kPa, then the compressive force is 27000 kN as previously calculated. Assume further that the differential hydrostatic pressure in the center of the buoy is +200 kPa, then the repulsive force in the center of the buoy is $\pi \cdot 4 \cdot 4 \cdot 200 = 10000$ kN resulting in a minimum net attractive force between the buoy and the vessel of 17000 kN. The latter only occurs at the end of the discharge process or in the beginning of the loading process when the vessel is ballasted. At any other time the compressive force and thereby the mooring capacity is larger.

The vessel monitors the mooring force at all times. Monitoring the mooring buoy position through the GPS positioning system does this. The known mooring response curve then provides the force. Therefore, the vessel can continuously monitor dangerous combinations of center well pressure and mooring capacity. In the event that such dangerous combination is approached then the vessel may take action by reducing the center well pressure. This would in turn reduce the cargo transfer rate.

2.3 PETROLEUM CARGO TRANSFER

A more common use of the buoy is for the transfer of oil and/or gas between the vessel and the riser. In this case the pressure in the center well of the buoy would normally be maintained at close to atmospheric pressure. In this case the center of the buoy would provide additional compressive force and thereby assist in the mooring.

Fig 2-4 Petroleum Cargo Transfer Fluid Paths

The mooring shown in Fig 2-4 is similar to the mooring shown in Fig 2-3 except that the fluids are transferred in separate pipes (Fluid Paths) as shown on Fig 2-4. In this case a fluid connection is established after mooring by connecting the pipes in the vessel to the pipes in the buoy at the connectors shown on Fig 2-4. Note that the buoy is not centered in the opening in the ship's bottom. Positioning the ship over the buoy for the mooring during the mooring operation cannot be done with complete accuracy. This is particularly so because of the 13 seconds delay between the decision to make the mooring and the actual mating between the buoy and the vessel. Test performed at Nichol's Advanced Marine in Arlington showed that the mating can be consistently performed with an accuracy of about 3 meters in conditions with $H_s = 8$ m. In lower wave heights the operation can be performed with better accuracy. It is expected that experienced operators of the system will consistently be able to perform the mooring with a deviation between the center of the buoy and the center of the hull opening of less than 2 meters.

Assume that the fluid pipe assembly has a diameter of 1.5 m and that the diameter of the inner sealing circle is 10 m. An opening in the bottom of

the vessel of 5.8 m then assures that it is possible to make the fluid connection whenever the deviation of the buoy is less than 2.1 m from the centered position. Check calculations: Opening $2 \times 2.1\text{m} + 1.5\text{m} = 5.7\text{ m} < 5.8\text{ m}$, Sealing circle $2 \times 2.1\text{m} + 5.8\text{m} = 10\text{m}$.

A 13.5 m diameter inner sealing circle with 7.5m opening in the bottom of the ship would in this case ensures a 3 m tolerance on the positioning of the buoy on the bottom of the ship.

The fluid paths rotate relative to the ship when the ship changes heading. Therefore, a fluid swivel is required. This is located on the vessel. This fluid swivel may be an ordinary swivel stack permitting unlimited rotation. Alternatively, the fluid swivel may be of the limited number of rotations kind. There are several such types. The limit on the number of revolutions is 1.5 in the case of a drag chain and may be 12 or more in the case of another swivel. Power to turn the swivel must be provided. A powered servomechanism may be used or torque may be transferred from the buoy to the swivel. The system proposed here use torque transfer. A long member of triangular cross section will serve the dual purpose of supporting

Fig 2-5 Petroleum Transfer System General Arrangement

the fluid paths and to serve as a torque bar. The buoy is placed on the bottom of the ship at random within the mooring area. Therefore, the swivel can be moved such that it is always placed vertically above the center of the buoy.

Fig 2-5 shows the general arrangement of the fluid transfer system. A fluid swivel on the deck of the ship is connected through a moonpool to the center of the buoy by means of a triangular torsion bar. The torsion bar is mated at the buoy to a triangular female receptacle. The fluid pipes are held to the torsion bar by sleeves. Thus alignment with the fluid connectors on the buoy is automatically achieved. The torsion bar can be raised and lowered relative to the fluid swivel. The fluid pipes can be raised or lowered relative to the torsion bar. During the mooring operation the torsion bar and the pipes are all in their upper position. Following the mooring the fluid swivel skid is centered above the buoy. Then the torsion bar is turned to align with the buoy orientation. The torsion bar is then guided into and seated in the torsion bar receptacle on the buoy. The fluid pipes are now lowered individually to each connector and connected. Each pipe is pressurized with nitrogen and the seal integrity is tested. Following the seal integrity test the nitrogen pressure is increased further. The sealing area is in fluid communication with the valve actuator in the corresponding valve in the buoy. The nitrogen pressure actuates the valve to open. The valve is equipped with spring return for automatic closure upon loss of sealing pressure. At disconnect the operation is reversed. Instead of the testing of seal integrity the pipes are flushed and cleaned such that no product escapes upon disconnect.

The fluid pipes are shown located on the exterior surface of the torsion bar in Fig 2-5. However, they would ordinarily be located inside the torsion bar. This location inside the torsion bar creates several advantages:

- The fluid pipes are shielded from impact damage
- The atmosphere inside the torsion bar may be maintained inert at low cost and with high reliability.

- Any leaking fluid is contained within the torsion bar. This provides a double barrier against escape.
- The torsion bar may have a larger cross section for the same overall assembly diameter. This enhances the structural capacity of the torsion bar.

The fluid pipes are equipped with several safety devices that ensure against all but minimal spills during emergency and/or accidental disconnect. Controlled emergency disconnect is initiated if:

- The buoy moves on the bottom of the ship. This is detected two ways, optically by an automatic monitoring system and mechanically by a continuous comparison between tilt sensors within the torsion bar and on deck.
- The mooring maintenance pressure rises to above a preset level. This pressure is measured continuously at all 3 pressure maintenance pumps.
- The vessel has an excessive excursion, either due to chain failure or due to excessive weather conditions. This is detected by the differential GPS system, which determines buoy deflection. Back-up systems may consist of acoustic systems detecting movement relative to beacons on the seabed or electronic triangulation systems such as for example Motorola Miniranger.
- Emergency conditions aboard the vessel such as fire or collision.

Controlled emergency disconnect comprises the following steps:

- Reducing nitrogen seal pressure. This causes closure of the valves on both sides of the connector, because these valves are maintained open by the seal pressure.
- If time permits purging of the fluid paths by nitrogen
- Blow down of Seal nitrogen and release of couplers

The vessel may now disconnect the mooring. In the event of accidental violent moves of the mooring buoy the nitrogen seal pressure maintenance system will automatically release all pressure and automatically cause closure of both the automatic valves on both sides of the coupler and the release of the coupler. This is automatic upon loss of sealing pressure. The content of approximately 20 m of pipe will be released within the torsion bar. Please note that all or nearly all this liquid will be trapped within the mooring moonpool and may be cleaned up by the ship's crew before the next mooring.

Uncontrolled disconnect is forced by the release of the seal pressure, either through rupture of the nitrogen piping or through the activation of emergency blowdown systems. The seal pressure release causes automatic valve closure (7 – 10 sec) and automatic release of couplers. The pipes within the torsion bar may optionally be equipped with break-away couplers that are actuated by the torsion bar being let down below a preset level. If so equipped, the actuation causes a short time release of the fluids (7 – 10 sec), closure of valves on both sides of the coupler and release of the couplers. All couplers will likely be lost in this event, the torsion bar will likely be damaged, and there may be some superficial hull damage in the moonpool area. The buoy will in this case drop to its storage position well clear of the vessel.

3. MANEUVERING TESTS

The initial development of the Hydrostatic Mooring was model tested at the Danish Maritime Institute in Denmark, which proved that it was physically possible to perform the mooring operation in adverse weather conditions with up to 7.7 m of significant wave height. See appendices B, C, and H. This was done with a free-floating ship model in the model basin, which was controlled by elastic ropes, in order to emulate the maneuvering required by the vessel prior to the mooring to the buoy. This procedure, while demonstrating that the mooring operation was physically feasible, did not properly account for the limitations of propulsion power and the human intervention factor in making the actual mooring.

The maneuvering that is required by a ship to meet with the Hydrostatic Mooring is to position the mooring area in the ship vertically above the buoy in a circle which has a 3 m radius. The navigator then judges the position of the vessel 13 seconds later. When this estimated position is ideal, he actuates the buoyancy control system in the mooring buoy by remote control, causing the buoy to rise in the water. Approximately 13 seconds later, the buoy impacts the bottom of the ship, thereby blocking a water intake in the center of the mooring area. This causes the buoy to be sucked on to the bottom of the ship and the mooring is accomplished.

By initial appearance, this procedure is nearly impossible because the mooring area of the vessel has to be brought into a position which is no more than 3 meters away from the theoretically ideal position in order to moor successfully. When one considers that a 150,000 DWT vessel is 280 m long and that this operation may take place during storm conditions at sea, this would appear to be an impossible task. In fact, this was the opinion of many experts, prior to the tests made at Nichols Advanced Marine.

The present project included tests of the ability of a practical seafarer to actually perform the maneuvers required to moor successfully to the Hydrostatic Mooring in adverse weather conditions. The Nichols Advanced Marine maneuvering simulator was used to emulate this operation. A

maneuvering simulator is similar to a flight simulator, and is capable of simulating all motions and to present a true real time response of the ship to the environmental forces and the application of rudder, engine power, and thruster power.

The maneuvering simulator actually existed prior to the tests, and only needed to be programmed with the parameters of the ship used. The actual ship was a 150,000 DWT vessel in partial loaded condition. Only one loading condition was tested. The Hydrostatic Mooring needed to be developed for incorporation in the maneuvering simulator. A mathematical model of the mooring was built to faithfully emulate the behavior of the Hydrostatic Mooring. This included the proper horizontal motions due to direct interaction with the waves and the current. It also included the correct vertical movement of the buoy, including the interaction with the vessel hull when approaching the keel. These features were cross-checked in the maneuvering simulation against the observed motion from the prior physical model test.

The maneuvering that is required to moor to the Hydrostatic Mooring system is a non-standard maneuver, which is not covered in any maneuvering textbook. Therefore, Captain James Atkinson, an experienced tanker navigator, was retained to develop the maneuvering procedures required to meet with the buoy, to train on the simulator for three days prior to the actual tests, and to perform the tests.

The tanker was equipped with an Elliott White Gill bow thruster type T3. This is a thruster that can deliver thrust with a delay of six seconds in any direction. This thruster comes in three versions with a 100 kN thrust, 150 kN thrust, and 200 kN thrust. Only the 150 kN and the 200 kN thrusters were tested. During the training prior to the actual tests, it was determined that the 150 kN thruster had inadequate thrusting power and therefore, the tests were only done with the 200 kN thruster. This is the largest unit that is manufactured by Elliot.

This is not a limitation on the application of the technology because several thrusters may be built into a large tank ship.

During the training exercises, the results and outcomes were not recorded, other than for training purposes and to improve operations. No report was made concerning the experience during the training exercises.

Following the training exercises, a program for twenty five tests was carried out. The program is listed below, in Table 3-1. All tests were made in deep water. The winds, the waves and the currents that were present in the test area are also listed in Table 3-1.

TABLE 3-1
Tests Conditions

Simulation	Wind		Waves		Current	
Run #	Speed (knots)	Direction (degrees from)	Significant Height (m)	Direction (degrees to)	Speed (knots)	Direction (degrees to)
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	2	180
13	20	0	3	180	0	0
14	20	0	3	180	0	0
15	20	45	3	225	1	180
16	20	45	3	225	1	180
17	20	90	3	270	1	180
18	20	90	3	270	1	180
19	25	0	5	180	0	0
20	25	0	5.1	180	0	0
21	25	45	5	225	1	180
22	25	45	5	225	1	180
23	25	90	5	270	1	180
24	25	90	5	270	1	180
25	25	90	5	270	2	180
26	25	90	5	180	2	180
27	40	0	8	180	0	0
28	40	0	8	180	0	0
29	40	0	8	180	1	135
30	40	0	8	180	1	135
31	40	0	8	180	1	90
32	40	0	8	180	1	90
33	40	0	8	180	2	90
34	40	0	8	180	2	90

It is notable that no existing mooring system can perform moorings in significant wave heights of 5 m and 8 m, which were used in the test program. Consequently, sixteen of the twenty-five tests were in conditions under which no existing mooring systems can safely perform the mooring operation.

All tests were successful, in the sense that the buoy safely met with the vessel and was securely held by the vessel following mooring. In order to transfer fluids, the deviation between the centerline of mooring area and the centerline of the buoy, should not exceed 2.8 m. It is seen from Table 3-2, that in five instances (20% of the tests) that the final position of the buoy

on the tanker were outside this margin. In these cases, the buoy would be released and the mooring attempt repeated. Table 3-2 lists the order in which the tests were performed. The tests were made in ever more difficult conditions. It is notable that among the last sixteen tests at 5m and 8 m wave heights, only one failed to place the buoy in a position that petroleum fluid transfer may be made. It is concluded that the navigator was not fully trained at the beginning of the tests. It was further concluded that a fully trained navigator can consistently place the mooring such that the buoy is properly positioned for fluid transfer in more than 90% of all attempts for conditions where the wave height is between 0 and 8 m.

The Hydrostatic Mooring would ordinarily be equipped with enough compressed air power to make 4 to 8 mooring attempts without being supplied with additional air. The maneuvering tests clearly demonstrate that the mooring between a large vessel of 150,000 DWT, and the Hydrostatic Mooring, can be made with extreme reliability, in all wave conditions up to a significant wave height of $H_s = 8$ m.

It was not tested, but it is probable in view of the results of these tests, that the mooring operation can be made with reasonable accuracy in even higher waves. This, however, may only have theoretical interest, because the operation of equipment aboard ship degrades at this level of wave height, and it may therefore not have practical interest to be able to moor beyond $H_s = 8$ m. Therefore, from a practical point of view, the Hydrostatic Mooring would eliminate weather downtime associated with the operations of a mooring system offshore. The importance of this can be appreciated from the fact that a typical offshore mooring has a downtime of between 5% and 30%.

TABLE 3-2
Tests Results

Simulation		Mating
Run #	Duration (sec)	Center to Center Distance (m)
10	1808	4.1
11	2156	0.9
12	1650	0.2
13	1785	1.25
14	3310	2.9
15	3328	3.1
16	2940	0.4
17	2872	1.1
18	2812	3.8
19	2205	2.6
20	2280	1.8
21	3664	2.5
22	1665	2.5
23	2160	2.0
24	2235	2.5
25	3465	1.8
26	3912	1.5
27	5704	5.1
28	2145	2.8
29	2595	1.8
30	1530	2.0
31	4566	1.9
32	2760	1.5
33	3065	1.9
34	3540	1.7

4. PRELIMINARY DESIGN

Prior to initiating this project, conceptual designs existed for the Hydrostatic Mooring, that are similar to the design that is featured in this report.

The previous designs were not adequate in detail and quality to gain approval by the American Bureau of Shipping (ABS), and therefore, further designs were undertaken to bring the level of design to a level that the approval by ABS can be gained. The specific areas that required further refinement were:

- The sealing system between the ship's hull and the buoy
- The buoyancy control system
- The main bearing between the two buoy parts
- Main structure
- An assessment of risk.

4.1 SEALING SYSTEM BETWEEN THE HULL AND THE BUOY

The sealing system between the hull and the buoy are subject to extreme conditions because the bottom of the ship is not designed to be a sealing surface. In addition, significant relative motion takes place during the mooring process, when the buoy initially contacts the bottom of the ship. The buoy is pulled in approximately 300 mm following contact with the bottom of the ship. Moreover, the bottom of the ship may not be plane. The structural system is designed for an out-of-plane deviation of the ship's bottom of 63 mm. The sealing ring around the perimeter of the buoy must cope with at least this unevenness of the bottom of the ship and must cope with the deflections which take place between the buoy and the vessel, when the buoy is subjected to large horizontal and vertical forces.

A review of possible structural systems to cope with these extreme conditions, reveal that only three systems were promising:

- Beam elements made from glass reinforced plastic
- Elements made from steel that were all connected to the main structure by hinges
- Elements made from steel that pivot on an edge of the main structure.

These structural elements must be able to resist the maximal external hydrostatic pressure in presence of absolute vacuum on the other side. This is a condition that may be encountered if the structural capacity of the mooring system is exceeded during a tear off of the mooring buoy from the bottom of the ship.

The glass fiber reinforced plastic elements are very attractive because there are no sliding contacts between the structural elements and the main structure. However, it was found that less than normal factors of safety would be required to make the system work. Therefore, this system was discarded.

Steel elements made from steel that are hinged to the main structure were feasible. The main problem with these elements is the very large structural capacity required of the hinges and potential wear of the pins that would constitute the bearings in the hinges.

The third option, structural elements that are loosely held to the structure and that pivots on an edge, was the solution selected. These elements can be made strong enough to cope with all differential pressures at normal factors of safety and can be made to safely deflect a distance which in the actual case exceeds 600 mm. This large deflection capability makes it possible to conform to all unevenness of the hull, and to maintain sealing contact when the buoy is subject to extreme forces. Furthermore, this large deflection prevents the sealing element from being damaged when

the exterior fenders are fully deflected to protect the buoy and the ship from mutual impact.

The design is featured in Appendix D, on Figs 1-6 through 1-8.

4.2 BUOYANCY CONTROL SYSTEM

The buoyancy control system must be capable of increasing the buoyancy of the buoy by approximately 15 metric tons per second for approximately 8 seconds in order to give the buoy the proper upward velocity and in order to constrain the time between actuation and actual mooring. This time should be as short as possible, in order to reduce the uncertainty associated with the navigator having to predict the future position of the ship when he makes the decision to moor.

A working design of the buoyancy control system existed prior to this project. This project refined the buoyancy control system. Refinements comprised:

- Simplification of the control systems previously used
- Provision of an automatic and passive buoyancy removal system
- Determination of the behavior of the system during multiple mooring attempts.

In the prior system, the buoyancy control system consisted of a permanent medium pressure tank, in which the internal water level could be controlled and thereby the buoyancy of the buoy slowly changed. This tank has been eliminated such that the buoyancy of the buoy can only be changed rapidly through the buoyancy control system, and alternatively changed by divers regulating the water level inside trim tanks. This reduces the complexity of the system and the cost. Particular details can be found in Appendix D, Chapter 3. Systems operations are depicted on on Fig 4-1 through 4- 3.

Hydrostatic Mooring -- Buoyancy Control

Mooring Condition: Start of Rapid Ascent

Time = $t + 0.5$ sec

At Time = t the vessel commanded valve 4 to open. Valve 4 opens fully in 0.5 sec.

Figure 4-1 Start of Rapid Ascent

Hydrostatic Mooring -- Buoyancy Control

Mooring Condition: Rapid Ascent

Time = $t + 4$ sec

Rapid Ascent. Air flowing through valve 4 increases the buoyancy at a rate of 15 tonnes/second. Bouy rises in the water at a rate of up to 1.5 m/sec.

Figure 4- 2 Rapid Ascent

Hydrostatic Mooring -- Buoyancy Control

Mooring Condition: Maximum Buoyancy

Time = $t + 9$ sec

The rapid ascent system automatically closes valve 4 when reaching maximum buoyancy. This is controlled by a timer in the control system.

Figure 4- 3 Maximum Buoyancy

The automatic and passive elimination of the buoyancy created by the buoyancy control system is achieved by having small holes in the rapid ascent buoyancy tank that will let all air out within 15 minutes after the tank is being filled. Since the tank only needs to work for approximately 13 seconds, it does not have to be airtight, and the provision of the controlled leaks greatly enhances the security of the system by making it impossible for biologically generated gases to be captured within the rapid ascent buoyancy volume. Such capture could cause the buoy to surface unexpectedly.

4.3 MAIN BEARING

The main bearing design that existed prior to this project was based on LUBRON sliding elements in contact with a ring, which was immersed in lubrication oil. This concept is reliable, however, the tolerance on the bearing ring is very small and represents a manufacturing problem. The tolerance is within what sophisticated machinery can do but it increases the cost of the bearing to have to comply with the tolerance requirements of the LUBRON bearing pads.

The oil bath in the previous design floated on top of the water, and therefore has the surface between the oil and the water pointing downwards. A potential problem is that any gas generated for whatever reason tends to accumulate above the oil bath and will tend to force the oil out of the bearing thereby potentially cause pollution of the water.

Another problem with the LUBRON bearing is that any grit that is present in the water may become mixed with the lubrication oil. This would cause rapid wear of the LUBRON bearing.

For these reasons, alternative options for the design of this bearing were explored in this project. It was found that Hillman rollers manufactured by the Hillman Company in New Jersey would have better characteristics than the LUBRON bearings.

These rollers could be operated such that they are immersed in seawater continuously. The potential problem that would originate from this is that marine growth would attach itself to the bearing surfaces and hardware. This could possibly interfere with the operation of the chains that guide the rollers. Testing would be required to ascertain whether this is a problem or not, therefore, a solution was found where this potential problem is avoided.

The buoy has a large amount of air available for purposes of providing the variable buoyancy during ascent. A very small fraction, less than 1% could be used to maintain the Hillman roller bearing in air using a trap of the type used for the lubrication oil in the LUBRON bearings. The Hillman rollers would be subjected to immersion in seawater when the buoy descends and the air in the trap compresses. Following the descent, a small amount of air would then be bled into the roller bearing housing. The marine growth, which might otherwise grow on the bearing elements, is then avoided.

The main disadvantage of this system is that another mechanical system is required to replenish the air that is compressed when the buoy descends.

The proposed mechanical system for this purpose is extraordinarily simple in that the main high-pressure system in the buoy would have an accumulator attached to the high-pressure air replenishing system. This accumulator is furnished with a very small continuous bleed connection into the roller bearing housing. Following disconnect of the buoy, this bleed connection will continue to bleed air into the roller bearing housing for an hour. No valves or any other control systems are required in this system.

4.4 STRUCTURAL DESIGN

In a specific structural design the buoy would ordinarily be made for a specific vessel at a specific location. Since the approval by the ABS is an approval in principle, it was agreed with ABS prior to the signing of the

contract that a sample design using a horizontal mooring force of 6,000 kN would be satisfactory.

The sample design is intended for tankers that transport water between Turkey and Israel. Since it is economical to use the very largest sizes of tankers in this traffic, the buoy was designed for the draft of a 500,000 DWT tanker, which is 25 meters.

The absolute lowest pressure that is possible on the upper surface of the buoy, when being moored to the tanker, is the vapor pressure of seawater, at the ambient temperature. This pressure is very close to absolute vacuum. Consequently, for design purposes it is considered that the hydrostatic pressure above the buoy may reach absolute vacuum.

The external pressure is the absolute hydrostatic pressure at the water depth in question. For the tankers in question, this ranges from 25 m maximum to a minimum of 4 m (350 kpa -140 kpa).

In addition, the mooring must be designed for a simultaneous application of a horizontal mooring force ranging from zero to 6,000 kN.

The structural system in the buoy must be able to withstand differential forces, which arise from unevenness of the ship's bottom. A general consideration of unevenness is that any point of the ship's bottom may deviate as much as 63 mm from the plane which most closely represents the position of the ship's bottom in the mooring area.

The contact element between the buoy and the ship's bottom are Trellex Morse Fender Bar fenders. These are solid rubber fenders with very high compressive force capability and relatively limited compression with a maximum compression of 150 mm.

Individual beams to provide the structural strength backing these fenders are provided. In addition, the fender area must be watertight and therefore a steel membrane is placed immediately below the fenders. Refer to the Drawings attached to Section 2 in Appendix D.

Beams are required to resist the large forces that are involved in this system. A network of steel I-beam resembling a honeycomb is consequently placed immediately below the surface area of the buoy. The voids between the beams could act as traps for gases that are present in the water and may trap some of the air that is let out when the mooring has been accomplished. Such trapped air could add sufficient buoyancy to the buoy that it would not descend after being released from the vessel. Therefore, the voids need to be filled with a material. For the purpose of this report, timber has been selected as the fill material in these areas. The timber provides a small amount of buoyancy, but more importantly, the timber provides structural assist to the I-beams by preventing buckling of the web plating, and also fills in the voids, thereby preventing the accumulation of any gas.

Other elements of the structural design the buoy are standard and are shown in Appendix D, Section 2.

4.5 FAILURE TREE ANALYSIS

The ABS, as one their requirements, require a failure tree analysis of the buoy to ascertain the sequences of events, which might lead to uncontrolled oil spills or other undesirable consequences of operating the buoy.

This, of course, is not a concern for a buoy design for transferring water. However, since the principal objective of the buoy design is to use it for petroleum transfer operation, the ABS requires such an analysis. This analysis is contained in Section 4 of Appendix D.

5. AMERICAN BUREAU OF SHIPPING APPROVAL

The American Bureau of Shipping (ABS) was retained in December 1999 to provide approval in principle for the mooring system. Two submittals were made to ABS. The initial submittal in April 2000 of the mooring tests and the maneuvering tests that were performed prior to and in connection with this project. This submittal is Appendices A, B, and C, in this report.

Following on July 7, Appendix D to this report was submitted to the ABS.

The correspondence by letter and e-mail with ABS is contained in Appendix E.

As of August 5, 2000, ABS requires the following calculations, which we will provide.

- Floating stability calculations of the buoy. This was actually tested in the physical model in Denmark and calculations exist for prior versions of the buoy. However, they need to be updated for the present design.
- Inclusion of corrosion allowance in the design of the members
- Calculation of stake piles used as anchors in the seabed. Han-Padron Associates carried out this work in late July, but has not yet been received.
- An assessment of mechanical wear of the fluid risers and the mooring chains is also required.

It is anticipated that these calculations will be submitted to ABS late August 2000.

6. CONCLUSIONS

The main conclusions from the work carried out under this contract are:

An ordinary seafarer can learn by training on a simulator, to moor large tanker vessels to the Hydrostatic Mooring, safely and quickly, in all weather conditions up to storms generating waves with a significant wave height of 8 m.

Complete conceptual design of the Hydrostatic Mooring buoy was carried out which proved that the buoy could be constructed entirely from commercially available standard components and materials. The design is robust, and damage resistant.

The mooring tests had a 100% success rate from the point of view of the buoy being securely attached and moored to the vessel following every mooring attempt. The tests had an 80% success rate from the point of view of the buoy being adequately centered such that petroleum transfer equipment on the vessel could be attached to the corresponding equipment on the buoy.

The results given in Table 3-2 of the mooring tests show a consistently improving performance from test to test by the Captain that performed the mooring operations. This is not surprising, in view of the fact that the Captain had only three days of training on the simulator prior to conducting the tests, that the maneuvering required is non-standard, and the test program itself lasted four days. One conclusion of the test performance is that the Captain was not fully trained at the initiation of the test.

It may therefore be concluded that a thoroughly trained navigator would probably be able to make the mooring such that the fluid transfer equipment can be connected with reliability in excess of 90%. Considering that the typical standard buoy has enough power aboard to make eight mooring attempts, this implies that the probability that the mooring attempt should fail because of the inability to connect the fluid transfer equipment is

of the order of 10^{-8} . It may therefore be concluded that the mooring operation between a Hydrostatic Mooring and a large tanker vessel can be carried out with near absolute reliability in all sea states up to a sea state where the significant wave height is 8 m.

Appendix A

MANEUVERING TEST REPORT BY NICHOLS

SHIP MANEUVERING STUDY
OF
HYDRO STATIC MOORING

Prepared for:

*Suction Mooring Technology
318 North Post Road
Princeton Junction, New Jersey 08550*

*Purchase Order
Letter, dated October 29, 1998*

Prepared by:

*Nichols Advanced Marine
1725 Jefferson Davis Hwy, Suite 1300*

February 1999

SHIP MANEUVERING STUDY
OF
MOORING TO HYDROSTATIC BUOY

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1 PREFACE

This report presents the results from a simulation study performed by Nichols Advanced Marine, Crystal City, Virginia, for Suction Mooring Technology, Princeton Junction, New Jersey. The study was conducted under funding from the Department of Energy for Energy Related Inventions Program project titled "The Hydrostatic Mooring", DE-FG36-98GO10321. The objective of the study was to investigate by use of a ship handling simulator how precisely an experienced mariner would be able to position a tanker in the 125,000 to 150,000 DWT range approaching a Hydrostatic Mooring buoy under heavy weather conditions. All simulation runs were conducted at Nichols Advance Marine.

2 INTRODUCTION

The hydrostatic mooring concept uses a moored buoy with a buoyancy chamber that enables the control of the vertical location of the buoy. The buoy is located about 6 meter below the draft of tanker during approach. The tanker is equipped with a moon pool, a hole in the bottom of the tanker with a diameter of 5 meter. The moon pool may be connected with a pipe to the free surface, but the moon pool itself is only a few meters high. When the center of the moon pool is above the buoy the mariner will push a button that will activate the buoyancy control system in the buoy. The buoy will move upwards to the bottom of the tanker in about 12 seconds. The water in the moon pool is removed by the bow thruster, which has the water intake from the moon pool. The bow thruster is an Elliot White Gill thruster type. When the buoy is in the mated location under the bottom of the tanker, it is fixed to the tanker by the pressure difference between the surrounding water and the pressure in the moonpool. Water leaking past the buoy / tanker bottom seal is removed continuously by a drainage pump.

The objective of the simulation study was to evaluate the difficulty for an experienced mariner to maneuver the tanker under heavy weather conditions to approach the buoy and connect. The buoy in connected location must cover the moon pool. The distance from the center of the buoy to the center of the moon pool should be less than 5 meters for making a fluid coupling. The buoy will be captured within a distance of 7.5 meters. The speed of the tanker at time of mating should be less than 2 knots.

This report presents results from 25 simulation runs which were carried out during the week of February 1 to 5, 1999 with a 150,000 DWT tanker. During all simulation runs, the simulator was under the command of Capt. James A. Atkinson. He is a very experienced mariner and pilot with more than 30 years of experience. The simulations were supervised by Mr. J. Korsgaard.

3 SHIP AND SIMULATION MODEL

The simulation of the maneuvering of the tanker and the buoy was carried out on Nichols Advanced Marine's engineering shiphandling simulator. The simulator was setup with ship control console and displays as follows:

- (1) Normal Ship Control Console with Helm and Engine Throttle, and a button for release of the buoy. The console displays ship heading, rudder angle, engine RPM, Doppler speed, which is the ship speed over ground. Lateral speed is given at the bow and the stern.
- (2) A virtual azimuth thruster control. The instruments were shown on a PC monitor, and controlled by a mouse. Thrust direction 0 to 359 degrees and throttle 0 to 100 percent.
- (3) Precision Navigation Display on a monitor at the ship control console shows an icon of the ownship and the mooring buoy and response in real time to motions of ship and the mooring buoy. The display simulates the input from DGPS position of the ship and buoy. A red vertical line on the screen was the track line to the buoy. Distances from the buoy to the center of the ship were given in east-north coordinates.
- (4) Nichols Advance Marine's Virtual Marine Scene generation program was used to create an Out of Window View from the bridge of the tanker with sea surface (3D waves) displayed with a monitor. The screen included a picture of the camera view from the center of the moon pool 3 meters above the bottom of the tanker. The opening in the bottom of the tanker was set to 10 m in diameter to give a larger viewing area, and also it is the area, where it is possible to make a fluid coupling. A red circle inside showed the 5 m diameter of the moon pool. Two thin cross hairs were placed over the opening to help the captain during the mating process. Furthermore, a third picture was provided that showed an under-water camera side view of the buoy and tanker with the moon pool. The last viewing point was detached from the ship and fixed in space, the other two viewing points were moving with the ship. This last picture was only used for the check-out of the simulations and in the familiarization of the mating procedure. In the evaluation simulation phase the picture was changed to an outside view of the tanker. The viewing point was located north of the buoy.
- (5) The buoy was white on the top with four concentric circles in black color. The innermost circle was 6 meter in diameter and 1 meter wide. On the edge of the buoy was a 12 sided polygon to show the fender on the top of the buoy. In the center of the buoy was a cross, one by one meter, for the identification of the center of the buoy.

3.1 Mathematical model

The simulator uses a physics-based 4-degree of freedom (4-DOF) hydrodynamic model for the maneuvering of the ship, which has been used for shiphandling bridge training simulators over many years in the U.S. and abroad. The simulator includes wave drift, wind and current forces. Furthermore, the hydrodynamic model contains a model for the Elliot White Gill thruster and machinery dynamics for a slow speed diesel engine.

3.2 Ship Characteristics

The selected ship is a tanker with the following characteristics:

Table 1 Ship Characteristics

Length, overall, m	289.59
Length, b.p., m	278.90
Beam, mld., m	44.20
Draft, m	13.72
Propulsion System	Direct Diesel
Displacement, tons	130287
Maximum Speed, knots	16.00
RPM	100.00

The main propulsion plant is a slow speed diesel engine, direct reversing, with a minimum engine speed of about 25 RPM, which will give the ship a speed of 4 knots. The number of starts is limited to 12 per hour. Definitive maneuvers were performed for turning, zig-zag, and stopping. A listing of the maneuvering characteristics are shown in Table 2, and plots of the maneuvers are shown in APPENDIX I.

Table 2 Maneuvering Characteristics for tanker

Turning Maneuver	
Approach speed [knots]	16.00
Rudder angle [degrees]	35 R
Non dimensional advance	3.28
Non dimensional transfer	1.31
Non dimensional steady diameter	2.10
Non dimensional tactical diameter	3.07
Time at 90 degrees	155.16
Time at 180 degrees	324.58
20/20 Zigzag	
Approach speed [knots]	12.00
First overshoot angle [degrees]	15.15
Second overshoot angle [degrees]	17.38
Third overshoot angle [degrees]	15.62
Fourth overshoot angle [degrees]	14.31

Stopping Maneuver	
Approach speed [knots]	16.00
Time to stop ship [sec]	886.25
Non dimensional advance	11.55
Non dimensional transfer	0.08
Final heading change [degrees]	46.19

The ship was equipped with an Elliot White Gill thruster, which uses a pump to draw water from the moon pool when the buoy is detached from the tanker. When the Gill thruster runs dry from the moon pool a valve will open and supply the thruster from the sea without losing its thrust. The Gill thruster is able to rotate 360 degrees and deliver a maximum of 15.3 tons thrust. After one day of simulation, it was judged to be too small, and the maximum thrust was increased to 20 tons. This is the largest unit available from the Gill thruster catalogue.

3.3 Wave Motions of Tanker

6-DOF ship motions of the tanker were calculated by using a linear strip theory approach to determine the response amplitude operators (RAO's) and phase angles relative to the waves in the frequency domain. The calculations follow normal seakeeping practice using a strip theory method according to Salvesen, et al., published in the Transactions of SNAME 1970. Added mass and damping are approximated by curve fits to model tests by Vugts, "The Hydrodynamic Coefficients for Swaying, Heaving, and Rolling Cylinders in a Free Surface. The on-line calculated frequency domain ship motion RAO's are converted into time domain motions by multiplying each regular wave component (10) of the sea spectrum with the appropriate RAO values and adding the results together. The spectrum is of the Bretschneider type, which matches the visual system.

The 6-DOF RAO's are shown in APPENDIX II. The RAO's are shown for 180, 150, 120, 90, 60, 30, 0 degrees heading, where 180 degrees is head sea, and 0 degrees is following sea. Each RAO is shown for wave length to ship length ratio from 0.4 to 5.0. The simulation program calculates the RAO's online for the actual wave history due to heading, ship speed and wave frequency.

3.4 Buoy Model

The suction mooring buoy main characteristics are two cylinders on top of each other with the following dimensions:

Diameter of top cylinder [m]	27.0
Height of top cylinder [m]	2.0
Diameter of lower cylinder [m]	6.0
Height of lower cylinder [m]	7.0
The lower cylinder is connected to the top cylinder by a cone.	
Total height of the buoy [m]	10.0
Displacement [tons]	800.0

The buoy was handled as a traffic ship in the simulation, which means that the position will be displayed together with motions due to waves. The buoy will have different motion characteristics in the initial location, which was set to be 20 m below the water surface (or 6 m below the keel) than when the buoys moves closer to the bottom of the tanker due to changes in wave motion and mass of the buoy.

A 6-DOF motion program was developed for the buoy motion using a similar linear strip theory approach as described in Section 3.3. However, there is no free surface effect for the buoy since it is submerged all the time. The restoring forces all come from the mooring system. The mass of the buoy was kept constant. The wave excitation forces were made a function of the water depth. Furthermore, the roll and sway RAO's for beam sea are equal to the pitch and surge RAO's for head sea, respectively. The yaw RAO is put to zero since the buoy is free to rotate. When the buoy raises up to 1.5 m below the tanker bottom the buoy pitch and roll motion are made equal to pitch and roll motion of the tanker, respectively. This is consistent with model test videos provided by Suction Mooring Technology. The RAO's for water depth of 20 meter are shown in APPENDIX III. The RAO's are shown for 180, 150, 120, 90, 60, 30, 0 degrees heading, where 180 degrees is head sea, and 0 degrees is following sea. Each RAO is shown for wave length to ship length ratio from 0.4 to 5.0. The simulation program calculates the RAO online for the immediate wave history due to heading, ship speed, wave frequency. As the buoy moves up towards the bottom of the tanker, the RAO's change as a function of water depth. This change may be insignificant as the transition only takes about 12 seconds, it was not included.

3.5 The Mating Process

The mating process is from the time the shiphandler pushes the release button until the buoy is located at the bottom of the tanker. The transition time is about 13 seconds. The simulator uses two input functions, buoy distance and buoy velocity as function of buoy time from release. The first two thirds of the distance from initial location to the tanker the simulator uses interpolation of the first curve. The rest of the vertical transition moves the buoy location by buoy velocity times the simulation time step. The second

method is added because the tanker and buoy motions change the distance between them due to wave motion during the time of transition, and could be longer than the distance in calm water.

The ship console was equipped with a release button.

The distance between the center of the buoy and the moon pool was calculated, and if the distance was greater than 5 meter the mating process was set to fail. In a similar manner if the speed of the tanker during mating became more than 2 knots the buoy would not hold the tanker and the mooring attempt fails.

3.6 Buoy Mooring System

When the buoy is mated the tanker is moored to the buoy. The mooring forces due to excursion of the tanker and buoy were calculated by interpolating a lookup table.

3.7 Scenario

The simulations were carried out in an open ocean scenario with 50 meter of water depth. The scenario did not contain any navigational aids.

4 ENVIRONMENT

The environment consists of contributions from current, wind, and waves, which are included in the maneuvering model.

4.1 Current Data

The maneuvering equations are written in terms of relative velocities and yaw rate to allow the introduction of a current velocity, which may vary along the length of the ship. The relative longitudinal and lateral current velocity in the body axis system are calculated and used in the maneuvering equations.

4.2 Wind Data

The wind velocity is assumed to consist of two components having the same direction: a steady or mean velocity and a random, time varying velocity, which is described by the Davenport wind spectrum. The unsteady wind velocity is divided into ten bands of equal energy and by representing each energy band by a sinusoidal velocity having one tenth of the total energy.

The input wind velocity is assumed for 10 meter above the sea level. The wind velocity is adjusted to the height of the wind center of the ship due to the boundary layer.

The wind related data for the tanker are the following:

Front wind area [m ²]:	739.2
Lateral wind area [m ²]:	3572.6
Wind center above water surface [m]	6.33

A 50 knot head wind will result in about 25 tons of nominal longitudinal force.

4.3 Wave Data

Ocean waves in a fully or partially developed sea creates two types of forces on the ship:

- First order oscillatory forces centered on the dominant wave encounter frequency.
- Second order drift forces, which consist of a steady (time independent) component and a low frequency component.

The first order forces are much larger in magnitude than the second order forces. The motions that results from the first order forces are included in the 6-DOF ship motion modeling described in Section 3.3 above. The second order wave drift forces are calculated and included as external forces in the simulation.

A calculation of the average drift forces was made based on RAO's from Dr. J.A. Pinkster, Low Frequency Second Order Wave Exciting Forces on Floating Structures, Publication No. 650, NSMB, Wageningen, Netherlands. The head sea RAO's were multiplied with the spectrum used in the simulator, and the results showed a reasonable agreement with simulated values as shown on the Figure 1 below.

5 REAL-TIME SIMULATIONS

Twenty five real-time simulation runs, run #10 to run # 34, were carried out with increasing severity of wind, waves, and current, see Table 3. All simulation runs were carried out twice for the same weather condition, except for one condition, run # 12, a 2 knots cross current with no wind and waves.

In preparation of real-time simulations, fast-time simulations were run simulating definitive maneuvers, see Section 3.2. Furthermore, deceleration tests, and ship speeds for different weather conditions were simulated. Three days were spent on familiarization of ship behavior with a number of environmental conditions trying different maneuvering techniques. Different approaches were tried, and the learning continued to the end of all the simulation runs, and more may be learned from continued simulation runs.

The approach was to start about 1500 to 2000 m south of the buoy depending on the weather condition. The simulation was started with a ship speed of 5 knots, and then the ship was decelerated down to about 0.2 knots when the moon pool of the ship arrived at the buoy, or the buoy came into camera view. Normally the engine was not stopped or reversed except in very few cases. The thruster was used as a braking force only in the initial runs, run # 10 to run # 23. Later the thruster was used as the only control device when hovering over the buoy after an equilibrium heading was found that approximately balances the forces. By using this technique the captain was able to stay over the buoy for a long time at almost zero speed (about 0.2 knots). This would allow the captain to make more than one mating attempt if necessary. The hydrostatic buoy allows for mating at ship speed of less than 2 knots. The different technique of using a high speed (0.5 to 1.0 knots) and then miss the mating would make it necessary to make a new approach might be more time consuming and less precise. The low speed approach was possible in all weather conditions.

In APPENDIX IV for each simulation run is a the captain's commentary, a log table of position, RPM, Doppler speed, heading, turn rate, rudder angle, Gill thruster, wind and current data, and finally a track plot of the last 15 minutes of the simulation run.

Table 3 Real-Time Simulations

Simulation			Wind		Waves		Current		Mating
Run #	Start Time	Length [secs]	Speed [knots]	Direction [degrees]	Significant Height [m]	Direction [degrees]	Speed [knots]	Direction [degrees]	Center to Center dist [m]
10	8:25	1808	0	0	0	0	0	0	4.1
11	9:25	2156	0	0	0	0	0	0	0.9
12	10:10	1650	0	0	0	0	2	180	0.2
13	10:45	1785	20	0	3	180	0	0	1.25
14	11:30	3310	20	0	3	180	0	0	2.9
15	13:30	3328	20	45	3	225	1	180	3.1
16	14:30	2940	20	45	3	225	1	180	0.4
17	15:35	2872	20	90	3	270	1	180	1.1
18	16:30	2812	20	90	3	270	1	180	3.8
19	8:00	2205	25	0	5	180	0	0	2.6
20	8:45	2280	25	0	5.1	180	0	0	1.8

21	9:30	3664	25	45	5	225	1	180	2.5
22	10:50	1665	25	45	5	225	1	180	2.5
23	11:30	2160	25	90	5	270	1	180	2.0
24	14:00	2235	25	90	5	270	1	180	2.5
25	14:40	3465	25	90	5	270	2	180	1.8
26	16:25	3912	25	90	5	270	2	180	1.5
27	9:25	5704	40	0	8	180	0	0	5.1
28	9:50	2145	40	0	8	180	0	0	2.8
29	10:40	2595	40	0	8	180	1	135	1.8
30	11:30	1530	40	0	8	180	1	135	2.0
31	13:15	4566	40	0	8	180	1	90	1.9
32	14:30	2760	40	0	8	180	1	90	1.5
33	15:25	3065	40	0	8	180	2	90	1.9
34	16:25	3540	40	0	8	180	2	90	1.7

The captain was able to make a mating of the buoy within the set criteria of 5 m from the center of the moon pool to the center of the buoy in all simulation runs except one, run # 27 (5.1 m off). This simulation run # 27 was very long, 5704 seconds, and it was stopped before a successful mating was achieved. If the captain had used a little longer time, he would have been able to make a closer mating by repeating the mating.

There is no correlation that shows that the second run with the same weather condition was shorter than the first run. However, in eight out of the twelve repeat runs the second mating was closer or equal to the target than the first one.

The results of all the run used for recording gave the following results:

Minimum distance	0.2 m
Maximum distance	5.1 m
Average distance	2.1 m
Standard deviation	1.1 m

The longer simulation time for the higher weather conditions was affected by an effort by the captain to make the mating within the moon pool diameter of 5 m, which was achieved with patience and a large portion of ship handling skills.

In all the recorded simulation runs (run # 10 to run # 34), a 20 tonnes static thrust bow thruster was used. The captain felt that the rudder rate, which is the minimum approved by the classification societies (2.33 degrees/min), was too slow. A higher rudder rate (e.g. 3.33 degrees/min) may improve the performance, but it was not tested. A high lift rudder might also improve the performance. The ship, as expected, was very slow to respond when the rudder was hard over.

6 AN EXPERIENCED PILOT'S EVALUATION

The following is the opinion of Captain Atkinson:

During the simulation runs of the week of February 1 to 5, 1999, I found the Nichols simulator to be very realistic. I was particularly pleased with how the movement typified how I would have expected a 150,000 TWD tanker to move in the sea states that were

simulated. Maneuvering was as anticipated for the type, size and draft of ship simulated, and when "hovering" with the moon pool over the buoy, was very much as I would expect with a real ship of the size simulated under the simulated conditions. I found it impossible to hold any balance of forces in equilibrium, as the ship not only moved continuously, but tended to accelerate and decelerate variously with the wave history based on the simulated wave spectra.

For the very stringent requirement of positioning the moon pool over the buoy and to achieve mating within a 5 meter radius of the buoy center, with the buoy also in varying cyclical motion, I found the minimal rudder rate of the simulated ship, while typical of some such ships, not high enough to satisfy me. That is not a criticism of the simulator, but it does relate to desirable design feature of a ship that might be either built or converted to serve as a shuttle vessel for suction mooring.

This week of simulation runs has been a very challenging and satisfying learning experience.

7 SUMMARY AND CONCLUSIONS

A simulation study has been carried out with a man-in-the-loop to study how successfully an experienced pilot could position a 150,000 TWD tanker above a hydrostatic buoy and perform the suction mooring mating. A representative 150,000 TWD tanker in a partly loaded condition was selected for use in the study. Definitive maneuvers were performed (turning, zig-zag, and stopping) to check that the mathematical model, used in the simulation study, had realistic maneuvering characteristics.

The most significant conclusions and recommendations include:

- The captain found the simulations with the 150,000 TWD tanker very realistic.
- The captain was able to move the moon pool of the ship over the buoy and keep it there by using small adjustments, waiting for small waves to occur.
- The captain was able to mate the buoy to the tanker within a prescribed limit of 5 m between the center of the moon pool and the center of the buoy in the majority of test runs, and only in one case, he exceeded 5.0 m with 5.1 m. This was possible in all the tested weather conditions up to 8 m significant wave height together with 40 knots wind and 2 knots of current. The wind and waves were collinear. The current direction was chosen for the following three configurations:
 1. Collinear with wind and waves.
 2. 45 degrees off the wind and wave direction.
 3. 90 degrees off the wind and wave direction.

In 75 percent of the repeat runs, the captain was able to mate the buoy to the tanker with a larger or equal accuracy than the previous run.

- An additional camera mounted in front of the moon pool is recommended. It might give the pilot more time to make appropriate maneuvers.
- A faster rudder rate is recommended, increase the test rate of 2.33 degrees/sec to 3.33 degrees/sec. The higher rate was not tested, but is believed to result in substantial improvement.
- A high lift rudder would be recommended. The ship was very slow to respond to hard over rudder. This change might reduce the mating time.
- The Elliot White Gill thruster used had a maximum static thrust of 20 tons, which is a minimum for proper performance for this type and size of ship.

APPENDIX I

Maneuvering Characteristics for Tanker

Turning Circle Trajectory
Left 20-20 Zig-Zag Maneuver
Stopping Maneuver Trajectory
Stopping Characteristics

Turning Circle Trajectory

Turning Maneuvering Characteristics:

Rudder Angle (degrees):	35.00R
Approach Speed (knots):	16.00
RPM:	79.06
Ship Length, L, (m):	278.90
T90 (secs):	155.16
T180 (secs):	324.58
Steady Speed in Turn (knots):	4.18
Speed Loss in Percent:	73.85
Advance (m):	916.94
Transfer (m):	365.04
Tactical Diam., TD (m):	856.58
Nondim Tactical Diam., TD/L:	3.07
Steady Turning Diam., D (m):	586.82
Nondim Steady Turn. Diam., D/L:	2.10
Final Drift Angle (degrees):	22.21
Steady roll angle (degrees):	0.17L
Water depth:	Deep

Date: 16-Feb-99 Time: 11:26:41

Left 20-20 Zig-Zag Maneuver

Ship Id: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Ship file no: 591

Run Id:

Zig-Zag Maneuvering Characteristics:

Approach Speed (knots):	12.00
RPM:	70.09
Ship Length, L, (m):	278.90
Time to reach head. change (sec):	89.47
Overshoot Angle (degrees):	15.15
Total Heading Change (degrees):	35.15
Width of Path at Execute (m):	31.05
Overshoot Width of Path (m):	575.34
Total Width of Path (m):	606.39
Reach (seconds):	327.46
2nd Overshoot Heading Angle (deg.):	17.38
3rd Overshoot Heading Angle (deg.):	15.62
Period (seconds):	603.54
4th Overshoot Heading Angle (deg.):	14.31

Water depth: Deep

Date: 16-Feb-99 Time: 11:30:39

Stopping Maneuver Trajectory

Ship Id: 150,000 ton, Tanker, partial load, 20 tons Gill thruster
Run Id:

Stop Maneuvering Characteristics

Rudder Angle (degrees):	0.00L
Approach Speed (knots):	16.00
Final RPM:	-62.45
Ship Length, L, (m):	278.90
T90 (secs):	0.00
T180 (secs):	0.00
Advance (m):	0.00
Advance/L:	0.00
Transfer (m):	0.00
Transfer/L:	0.00
Tactical Diam., TD (m):	0.00
Nomdim. Tactical Diam., TD/L:	0.00
Time to Stop Ship, T, (secs):	886.25
Advance in Stop (m):	3220.34
Advance in stop/L:	11.55
Transfer in Stop (m):	23.38
Transfer in stop/L:	0.08
Water depth:	Deep

Date: 16-Feb-99 Time: 11:31:40

Stopping Characteristics

Ship Id: 150,000 ton, Tanker, partial load, 20 tons Gill thruster
 Ship file no: 591
 Run Id:

Stopping Maneuver Characteristics:

Rudder Angle (degrees):	0.00R
Approach Speed (knots):	16.00
Initial RPM:	100.00
Engine Order AS:	-80.00
Ship Length, L, (feet):	915.03
Advance / L:	11.55
Transfer / L:	0.08
Final Heading Change (deg):	46.19
Time to Stop Ship (sec):	887.00

Date: 16-Feb-99 Time: 11:31:41

APPENDIX II

RAO's for Tanker

Heading 180, 150, 120, 90, 60, 30, 0 degrees at zero ship speed

Draft to depth ratio, $h/t = 3.64$

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 180.0

Ship speed (knots). = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	0.741	0.741	0.04	-179.87	0.02	9.27	0.01	87.25
0.50	0.657	0.657	0.09	113.22	0.05	-28.85	0.07	88.62
0.60	0.593	0.593	0.16	102.14	0.05	-85.58	0.08	97.99
0.80	0.495	0.495	0.12	59.71	0.29	-112.33	0.05	-141.86
1.00	0.423	0.423	0.25	10.96	0.47	-104.20	0.22	-104.59
1.20	0.368	0.368	0.40	3.31	0.58	-99.93	0.40	-96.69
1.40	0.324	0.324	0.51	1.43	0.66	-97.55	0.59	-92.24
1.60	0.289	0.289	0.59	0.78	0.71	-96.09	0.77	-88.97
1.80	0.261	0.261	0.65	0.49	0.75	-95.11	0.94	-86.29
2.00	0.237	0.237	0.70	0.34	0.78	-94.41	1.00	-83.95
2.50	0.193	0.193	0.78	0.17	0.84	-93.33	1.00	-79.00
3.00	0.162	0.162	0.83	0.10	0.87	-92.69	1.00	-74.77
3.50	0.140	0.140	0.86	0.07	0.89	-92.26	1.00	-71.00
4.00	0.123	0.123	0.88	0.05	0.91	-91.96	1.00	-67.55
5.00	0.099	0.099	0.91	0.00	0.93	-91.58	1.00	-61.41

Non Dimensional Ship Motions

ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 150.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	0.741	0.741	0.04	136.52	0.02	-29.34	0.02	81.22
0.50	0.657	0.657	0.10	90.07	0.03	-79.19	0.05	88.74
0.60	0.593	0.593	0.13	75.55	0.11	-129.92	0.04	110.92
0.80	0.495	0.495	0.20	13.34	0.37	-115.10	0.10	-110.60
1.00	0.423	0.423	0.38	1.68	0.50	-104.65	0.26	-98.16
1.20	0.368	0.368	0.51	0.18	0.58	-99.87	0.42	-92.71
1.40	0.324	0.324	0.60	-0.05	0.63	-97.33	0.58	-88.94
1.60	0.289	0.289	0.67	-0.05	0.67	-95.81	0.73	-85.91
1.80	0.261	0.261	0.72	-0.03	0.69	-94.82	0.88	-83.29
2.00	0.237	0.237	0.75	-0.01	0.71	-94.13	1.00	-80.95
2.50	0.193	0.193	0.82	0.01	0.75	-93.08	1.00	-75.82
3.00	0.162	0.162	0.85	0.02	0.77	-92.46	1.00	-71.37
3.50	0.140	0.140	0.88	0.02	0.78	-92.07	1.00	-67.37
4.00	0.123	0.123	0.90	0.02	0.79	-91.78	1.00	-63.72
5.00	0.099	0.099	0.92	-0.01	0.81	-91.44	1.00	-57.27

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	0.741	0.741	0.02	-50.71	0.03	1.02	0.01	1.34
0.50	0.657	0.657	0.04	-7.30	0.10	15.58	0.01	119.06
0.60	0.593	0.593	0.03	25.52	0.11	28.17	0.04	165.96
0.80	0.495	0.495	0.05	87.87	0.11	-148.95	0.12	174.09
1.00	0.423	0.423	0.11	84.83	0.33	-114.53	0.20	177.49
1.20	0.368	0.368	0.20	85.69	0.44	-100.92	0.27	179.69
1.40	0.324	0.324	0.29	87.30	0.48	-94.40	0.32	-179.05
1.60	0.289	0.289	0.36	88.30	0.49	-91.33	0.38	-178.05
1.80	0.261	0.261	0.43	89.00	0.49	-89.46	0.43	-177.29
2.00	0.237	0.237	0.50	89.41	0.49	-88.36	0.48	-176.62
2.50	0.193	0.193	0.66	89.37	0.49	-88.01	0.61	-175.62
3.00	0.162	0.162	0.82	88.65	0.48	-89.15	0.73	-174.74
3.50	0.140	0.140	0.96	88.84	0.47	-88.78	0.85	-173.31
4.00	0.123	0.123	1.10	88.98	0.46	-88.50	0.97	-171.93
5.00	0.099	0.099	1.34	89.18	0.44	-88.12	1.19	-169.27

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 120.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave		Pitch		Surge	
			z/h	Phase	Theta/kh	Phase	x/h	Phase
0.40	0.741	0.741	0.06	3.44	0.04	-153.74	0.01	65.12
0.50	0.657	0.657	0.16	-38.53	0.13	-163.02	0.02	-104.62
0.60	0.593	0.593	0.37	-38.38	0.26	-148.14	0.06	-98.78
0.80	0.495	0.495	0.66	-16.76	0.40	-117.78	0.16	-91.18
1.00	0.423	0.423	0.75	-7.60	0.43	-105.06	0.26	-85.83
1.20	0.368	0.368	0.80	-3.96	0.44	-99.60	0.35	-81.49
1.40	0.324	0.324	0.82	-2.28	0.44	-96.82	0.43	-77.73
1.60	0.289	0.289	0.84	-1.40	0.44	-95.22	0.52	-74.35
1.80	0.261	0.261	0.86	-0.90	0.45	-94.21	0.61	-71.26
2.00	0.237	0.237	0.87	-0.61	0.45	-93.53	0.71	-68.40
2.50	0.193	0.193	0.89	-0.27	0.46	-92.55	0.96	-62.02
3.00	0.162	0.162	0.91	-0.13	0.46	-92.00	1.00	-56.53
3.50	0.140	0.140	0.92	-0.07	0.47	-91.65	1.00	-51.77
4.00	0.123	0.123	0.93	-0.04	0.47	-91.42	1.00	-47.62
5.00	0.099	0.099	0.94	-0.04	0.47	-91.14	1.00	-40.80

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway		Roll		Yaw	
			y/h	Phase	fi/kh	Phase	psi/kh	Phase
0.40	0.741	0.741	0.04	54.53	0.03	32.66	0.05	171.49
0.50	0.657	0.657	0.09	117.94	0.16	-176.59	0.10	174.35
0.60	0.593	0.593	0.14	130.53	0.46	-161.15	0.15	176.59
0.80	0.495	0.495	0.18	106.84	1.03	-135.35	0.23	179.68
1.00	0.423	0.423	0.33	88.10	1.27	-112.30	0.29	-177.95
1.20	0.368	0.368	0.50	87.32	1.25	-100.09	0.34	-176.45
1.40	0.324	0.324	0.64	88.42	1.17	-94.05	0.38	-175.28
1.60	0.289	0.289	0.77	89.32	1.09	-90.95	0.43	-174.17
1.80	0.261	0.261	0.88	89.92	1.04	-89.09	0.48	-173.24
2.00	0.237	0.237	0.99	90.24	1.00	-88.04	0.52	-172.37
2.50	0.193	0.193	1.25	90.01	0.93	-87.77	0.65	-170.73
3.00	0.162	0.162	1.50	89.16	0.89	-88.98	0.77	-169.15
3.50	0.140	0.140	1.74	89.28	0.85	-88.64	0.89	-166.99
4.00	0.123	0.123	1.97	89.38	0.82	-88.37	1.02	-164.87
5.00	0.099	0.099	2.38	89.50	0.79	-88.02	1.25	-160.79

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 90.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave		Pitch		Surge	
			z/h	Phase	Theta/kh	Phase	x/h	Phase
0.40	0.741	0.741	0.26	-62.53	0.01	-16.11	0.01	-180.00
0.50	0.657	0.657	0.50	-64.11	0.02	2.11	0.00	-180.00
0.60	0.593	0.593	0.78	-51.34	0.03	41.18	0.00	0.00
0.80	0.495	0.495	1.01	-23.45	0.03	109.82	0.03	0.00
1.00	0.423	0.423	1.00	-10.94	0.02	139.74	0.06	0.00
1.20	0.368	0.368	0.97	-5.79	0.02	153.36	0.10	0.00
1.40	0.324	0.324	0.95	-3.37	0.01	160.78	0.14	0.00
1.60	0.289	0.289	0.94	-2.10	0.01	165.31	0.19	0.00
1.80	0.261	0.261	0.93	-1.38	0.01	168.34	0.25	0.00
2.00	0.237	0.237	0.93	-0.94	0.01	170.48	0.31	0.00
2.50	0.193	0.193	0.93	-0.43	0.01	173.64	0.50	0.00
3.00	0.162	0.162	0.94	-0.22	0.01	175.51	0.73	0.00
3.50	0.140	0.140	0.94	-0.12	0.01	176.65	1.00	0.00
4.00	0.123	0.123	0.95	-0.07	0.00	177.40	0.78	0.00
5.00	0.099	0.099	0.95	-0.06	0.00	178.45	0.51	0.00

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway		Roll		Yaw	
			y/h	Phase	fi/kh	Phase	psi/kh	Phase
0.40	0.741	0.741	0.41	157.02	0.69	-170.48	0.01	-65.05
0.50	0.657	0.657	0.40	151.32	0.98	-165.58	0.01	-73.95
0.60	0.593	0.593	0.37	147.87	1.37	-157.16	0.01	-85.25
0.80	0.495	0.495	0.31	115.88	1.90	-134.12	0.02	-90.71
1.00	0.423	0.423	0.49	91.85	1.96	-112.13	0.03	-84.66
1.20	0.368	0.368	0.69	89.20	1.77	-99.43	0.03	-82.99
1.40	0.324	0.324	0.84	89.85	1.56	-93.65	0.04	-82.65
1.60	0.289	0.289	0.97	90.59	1.41	-90.57	0.05	-82.39
1.80	0.261	0.261	1.09	91.06	1.31	-88.72	0.07	-82.56
2.00	0.237	0.237	1.21	91.28	1.24	-87.69	0.08	-83.70
2.50	0.193	0.193	1.50	90.85	1.13	-87.47	0.13	-87.24
3.00	0.162	0.162	1.78	89.86	1.06	-88.73	0.19	-90.10
3.50	0.140	0.140	2.05	89.89	1.01	-88.42	0.25	-90.07
4.00	0.123	0.123	2.31	89.91	0.97	-88.18	0.32	-90.05
5.00	0.099	0.099	2.78	89.94	0.92	-87.87	0.49	-90.03

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 60.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	0.741	0.741	0.04	29.15	0.04	45.80	0.01	-65.12
0.50	0.657	0.657	0.10	-22.92	0.13	30.39	0.02	104.62
0.60	0.593	0.593	0.25	-41.21	0.28	43.79	0.06	98.78
0.80	0.495	0.495	0.59	-23.81	0.43	74.05	0.16	91.18
1.00	0.423	0.423	0.73	-11.43	0.44	85.30	0.26	85.83
1.20	0.368	0.368	0.79	-6.11	0.44	89.26	0.35	81.49
1.40	0.324	0.324	0.82	-3.59	0.45	90.83	0.43	77.73
1.60	0.289	0.289	0.84	-2.26	0.45	91.50	0.52	74.35
1.80	0.261	0.261	0.86	-1.49	0.45	91.77	0.61	71.26
2.00	0.237	0.237	0.87	-1.03	0.45	91.86	0.71	68.40
2.50	0.193	0.193	0.89	-0.49	0.46	91.79	0.42	62.02
3.00	0.162	0.162	0.91	-0.25	0.46	91.62	0.34	56.53
3.50	0.140	0.140	0.92	-0.14	0.47	91.44	0.27	51.77
4.00	0.123	0.123	0.93	-0.09	0.47	91.29	0.22	47.62
5.00	0.099	0.099	0.94	-0.07	0.47	91.04	0.16	40.80

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	0.741	0.741	0.04	57.91	0.04	25.42	0.05	0.41
0.50	0.657	0.657	0.09	121.12	0.13	-174.54	0.10	-0.41
0.60	0.593	0.593	0.14	134.08	0.41	-159.08	0.15	-0.10
0.80	0.495	0.495	0.19	113.17	0.98	-134.29	0.23	-0.25
1.00	0.423	0.423	0.33	92.95	1.22	-111.66	0.29	-0.58
1.20	0.368	0.368	0.50	90.75	1.22	-99.61	0.34	-1.04
1.40	0.324	0.324	0.64	91.15	1.15	-93.69	0.39	-1.72
1.60	0.289	0.289	0.76	91.70	1.08	-90.55	0.44	-2.48
1.80	0.261	0.261	0.87	92.05	1.03	-88.65	0.49	-3.44
2.00	0.237	0.237	0.98	92.20	0.99	-87.55	0.54	-4.55
2.50	0.193	0.193	1.25	91.65	0.93	-87.26	0.65	-7.77
3.00	0.162	0.162	1.50	90.57	0.89	-88.50	0.77	-10.86
3.50	0.140	0.140	1.74	90.50	0.85	-88.22	0.89	-13.02
4.00	0.123	0.123	1.97	90.46	0.82	-88.00	1.02	-15.13
5.00	0.099	0.099	2.38	90.38	0.78	-87.72	1.25	-19.21

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 30.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	0.741	0.741	0.04	-179.22	0.02	175.70	0.02	-81.22
0.50	0.657	0.657	0.08	118.60	0.04	133.72	0.05	-88.74
0.60	0.593	0.593	0.11	118.23	0.10	74.52	0.04	-110.92
0.80	0.495	0.495	0.11	-20.90	0.36	80.22	0.10	110.60
1.00	0.423	0.423	0.34	-11.32	0.51	88.26	0.26	98.16
1.20	0.368	0.368	0.50	-6.16	0.58	91.19	0.42	92.71
1.40	0.324	0.324	0.59	-3.66	0.63	92.27	0.58	88.94
1.60	0.289	0.289	0.66	-2.33	0.67	92.66	0.73	85.91
1.80	0.261	0.261	0.71	-1.56	0.69	92.75	0.88	83.29
2.00	0.237	0.237	0.75	-1.09	0.71	92.72	1.00	80.95
2.50	0.193	0.193	0.82	-0.53	0.75	92.43	0.14	75.82
3.00	0.162	0.162	0.85	-0.28	0.77	92.14	0.11	71.37
3.50	0.140	0.140	0.88	-0.17	0.78	91.89	0.09	67.37
4.00	0.123	0.123	0.90	-0.11	0.79	91.68	0.08	63.72
5.00	0.099	0.099	0.92	-0.08	0.81	91.35	0.06	57.27

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	0.741	0.741	0.02	-35.74	0.02	16.78	0.01	-172.61
0.50	0.657	0.657	0.04	0.74	0.10	22.54	0.00	-32.69
0.60	0.593	0.593	0.04	31.06	0.12	34.03	0.04	-1.44
0.80	0.495	0.495	0.05	98.38	0.08	-162.14	0.12	1.32
1.00	0.423	0.423	0.11	93.13	0.30	-116.53	0.20	2.38
1.20	0.368	0.368	0.20	91.54	0.42	-101.34	0.27	2.13
1.40	0.324	0.324	0.28	91.95	0.47	-94.48	0.33	1.67
1.60	0.289	0.289	0.36	92.37	0.48	-91.05	0.38	1.05
1.80	0.261	0.261	0.43	92.65	0.48	-88.97	0.44	0.30
2.00	0.237	0.237	0.50	92.78	0.48	-87.71	0.49	-0.55
2.50	0.193	0.193	0.66	92.20	0.48	-87.21	0.61	-2.99
3.00	0.162	0.162	0.82	91.08	0.48	-88.37	0.73	-5.26
3.50	0.140	0.140	0.96	90.95	0.46	-88.09	0.85	-6.69
4.00	0.123	0.123	1.10	90.85	0.45	-87.88	0.97	-8.07
5.00	0.099	0.099	1.34	90.70	0.44	-87.61	1.19	-10.74

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Ship Motions

Ship file: 0591

Shipid: 150,000 ton, Tanker, partial load, 20 tons Gill thruster

Heading (degrees) = 0.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	0.741	0.741	0.04	-142.30	0.01	-130.58	0.01	-87.25
0.50	0.657	0.657	0.06	150.11	0.05	175.80	0.07	-88.62
0.60	0.593	0.593	0.13	130.19	0.05	133.50	0.08	-97.99
0.80	0.495	0.495	0.02	149.61	0.27	84.74	0.05	141.86
1.00	0.423	0.423	0.21	-11.61	0.47	89.96	0.22	104.59
1.20	0.368	0.368	0.38	-6.32	0.58	92.21	0.40	96.69
1.40	0.324	0.324	0.50	-3.76	0.66	93.01	0.59	92.24
1.60	0.289	0.289	0.58	-2.40	0.71	93.24	0.77	88.97
1.80	0.261	0.261	0.65	-1.62	0.75	93.24	0.94	86.29
2.00	0.237	0.237	0.70	-1.14	0.79	93.13	1.00	83.95
2.50	0.193	0.193	0.78	-0.55	0.84	92.75	0.53	79.00
3.00	0.162	0.162	0.83	-0.30	0.87	92.39	0.41	74.77
3.50	0.140	0.140	0.86	-0.18	0.89	92.10	0.34	71.00
4.00	0.123	0.123	0.88	-0.12	0.91	91.86	0.28	67.55
5.00	0.099	0.099	0.91	-0.08	0.93	91.49	0.22	61.41

APPENDIX III

RAO's for Buoy

Heading 180, 150, 120, 90, 60, 30, 0 degrees at zero speed

Draft to depth ratio, $h/t \approx 10.00$

Non Dimensional Traffic Ship Motions

Ship file: 1000

Shipid: Suction Mooring Sys

Heading (degrees) = 180.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave		Pitch		Surge	
			z/h	Phase	Theta/kh	Phase	x/h	Phase
0.40	2.389	2.389	0.00	-126.12	0.00	89.08	0.01	59.53
0.50	2.136	2.136	0.00	178.14	0.00	77.57	0.03	114.83
0.60	1.950	1.950	0.00	168.35	0.00	-85.55	0.03	166.10
0.80	1.689	1.689	0.01	7.89	0.01	-90.23	0.10	-99.48
1.00	1.511	1.511	0.03	3.05	0.04	-93.11	0.22	-82.97
1.20	1.379	1.379	0.06	0.47	0.07	-96.62	0.33	-77.10
1.40	1.277	1.277	0.10	-2.05	0.11	-100.75	0.42	-74.11
1.60	1.194	1.194	0.14	-4.72	0.15	-104.74	0.50	-72.23
1.80	1.126	1.126	0.18	-7.32	0.19	-107.45	0.57	-70.85
2.00	1.068	1.068	0.22	-9.41	0.25	-108.25	0.63	-69.70
2.50	0.955	0.955	0.33	-10.94	0.38	-104.84	0.74	-67.21
3.00	0.872	0.872	0.43	-9.17	0.47	-100.42	0.83	-64.86
3.50	0.807	0.807	0.51	-7.06	0.54	-97.40	0.90	-62.54
4.00	0.755	0.755	0.56	-5.42	0.59	-95.48	0.97	-60.24
5.00	0.676	0.676	0.65	-3.42	0.66	-93.35	1.00	-55.77

Non Dimensional Traffic Ship Motions

Ship file: 1000

Shipid: Suction Mooring Sys

Heading (degrees) = 150.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	-179.95	0.00	87.19	0.01	137.04
0.50	2.136	2.136	0.00	174.72	0.00	-85.09	0.04	-98.39
0.60	1.950	1.950	0.00	24.13	0.00	-88.85	0.05	-56.97
0.80	1.689	1.689	0.01	3.29	0.02	-91.30	0.12	43.93
1.00	1.511	1.511	0.04	0.82	0.04	-93.97	0.20	66.38
1.20	1.379	1.379	0.07	-1.32	0.07	-97.44	0.20	73.80
1.40	1.277	1.277	0.11	-3.71	0.10	-101.55	0.15	75.72
1.60	1.194	1.194	0.15	-6.32	0.14	-105.48	0.08	68.45
1.80	1.126	1.126	0.19	-8.80	0.18	-108.07	0.03	-14.37
2.00	1.068	1.068	0.23	-10.72	0.22	-108.74	0.09	-65.27
2.50	0.955	0.955	0.35	-11.74	0.34	-105.08	0.27	-71.45
3.00	0.872	0.872	0.45	-9.62	0.42	-100.54	0.41	-68.82
3.50	0.807	0.807	0.52	-7.32	0.48	-97.48	0.53	-65.46
4.00	0.755	0.755	0.57	-5.59	0.52	-95.53	0.63	-62.12
5.00	0.676	0.676	0.65	-3.50	0.58	-93.37	0.79	-55.94

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	2.389	2.389	0.00	-76.57	0.00	95.35	0.00	14.23
0.50	2.136	2.136	0.00	-70.83	0.00	-80.79	0.00	27.62
0.60	1.950	1.950	0.00	-69.90	0.00	-80.65	0.00	-163.65
0.80	1.689	1.689	0.01	118.56	0.01	-75.48	0.02	-160.00
1.00	1.511	1.511	0.04	118.40	0.02	-70.39	0.05	-158.27
1.20	1.379	1.379	0.08	118.48	0.04	-66.37	0.09	-157.29
1.40	1.277	1.277	0.11	118.40	0.07	-63.81	0.12	-157.25
1.60	1.194	1.194	0.15	118.49	0.10	-62.74	0.16	-157.21
1.80	1.126	1.126	0.18	117.94	0.13	-61.98	0.19	-157.88
2.00	1.068	1.068	0.21	116.76	0.17	-61.60	0.21	-159.14
2.50	0.955	0.955	0.27	113.25	0.27	-62.07	0.27	-161.96
3.00	0.872	0.872	0.32	110.40	0.39	-63.04	0.31	-164.45
3.50	0.807	0.807	0.36	107.24	0.53	-64.82	0.35	-166.55
4.00	0.755	0.755	0.40	104.63	0.67	-66.50	0.39	-168.35
5.00	0.676	0.676	0.45	100.82	0.97	-68.39	0.44	-170.79

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Traffic Ship Motions

Ship file: 1000
 Shipid: Suction Mooring Sys
 Heading (degrees) = 120.0
 Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	2.18	0.00	-89.90	0.01	-47.24
0.50	2.136	2.136	0.00	0.89	0.00	-90.42	0.00	-40.00
0.60	1.950	1.950	0.01	0.31	0.01	-91.04	0.02	-65.95
0.80	1.689	1.689	0.03	-0.84	0.02	-92.79	0.07	61.50
1.00	1.511	1.511	0.06	-2.33	0.03	-95.38	0.26	94.32
1.20	1.379	1.379	0.10	-4.27	0.05	-98.89	0.42	106.53
1.40	1.277	1.277	0.14	-6.64	0.07	-103.02	0.51	115.04
1.60	1.194	1.194	0.18	-9.20	0.09	-106.85	0.53	122.12
1.80	1.126	1.126	0.22	-11.53	0.11	-109.24	0.52	128.49
2.00	1.068	1.068	0.26	-13.15	0.14	-109.67	0.49	134.49
2.50	0.955	0.955	0.38	-13.24	0.21	-105.54	0.38	149.35
3.00	0.872	0.872	0.47	-10.48	0.25	-100.79	0.27	167.09
3.50	0.807	0.807	0.54	-7.83	0.28	-97.62	0.18	-165.68
4.00	0.755	0.755	0.60	-5.92	0.31	-95.62	0.15	-123.38
5.00	0.676	0.676	0.67	-3.65	0.34	-93.41	0.27	-65.97

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	2.389	2.389	0.00	-55.27	0.00	-82.22	0.00	-166.88
0.50	2.136	2.136	0.00	107.60	0.00	-81.00	0.00	-164.37
0.60	1.950	1.950	0.02	111.04	0.00	-78.28	0.01	-162.50
0.80	1.689	1.689	0.07	114.59	0.02	-72.66	0.04	-159.75
1.00	1.511	1.511	0.14	116.56	0.05	-67.91	0.08	-158.16
1.20	1.379	1.379	0.21	117.24	0.09	-64.33	0.11	-157.24
1.40	1.277	1.277	0.28	117.50	0.14	-62.10	0.15	-157.20
1.60	1.194	1.194	0.34	117.75	0.19	-61.25	0.18	-157.18
1.80	1.126	1.126	0.39	117.35	0.25	-60.68	0.21	-157.87
2.00	1.068	1.068	0.43	116.33	0.31	-60.46	0.23	-159.12
2.50	0.955	0.955	0.52	112.89	0.49	-60.40	0.28	-161.93
3.00	0.872	0.872	0.59	110.14	0.69	-61.39	0.33	-164.43
3.50	0.807	0.807	0.66	106.99	0.92	-63.15	0.36	-166.54
4.00	0.755	0.755	0.72	104.39	1.17	-64.78	0.39	-168.35
5.00	0.676	0.676	0.80	100.70	1.69	-67.49	0.44	-170.79

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Traffic Ship Motions

Ship file: 1000
 Shipid: Suction Mooring Sys
 Heading (degrees) = 90.0
 Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	-0.32	0.00	-86.24	0.01	180.00
0.50	2.136	2.136	0.01	-0.59	0.00	-73.55	0.01	180.00
0.60	1.950	1.950	0.02	-0.96	0.00	-77.11	0.01	-180.00
0.80	1.689	1.689	0.05	-2.01	0.00	-56.97	0.04	180.00
1.00	1.511	1.511	0.08	-3.51	0.00	-52.52	0.13	180.00
1.20	1.379	1.379	0.12	-5.51	0.00	-23.94	0.26	180.00
1.40	1.277	1.277	0.15	-7.93	0.00	0.83	0.38	180.00
1.60	1.194	1.194	0.19	-10.50	0.00	-9.31	0.47	180.00
1.80	1.126	1.126	0.23	-12.78	0.00	56.58	0.52	180.00
2.00	1.068	1.068	0.28	-14.27	0.00	44.10	0.55	180.00
2.50	0.955	0.955	0.39	-13.95	0.00	82.43	0.55	180.00
3.00	0.872	0.872	0.49	-10.88	0.00	128.14	0.48	180.00
3.50	0.807	0.807	0.56	-8.08	0.00	173.18	0.38	180.00
4.00	0.755	0.755	0.61	-6.07	0.00	111.63	0.27	-180.00
5.00	0.676	0.676	0.68	-3.73	0.00	154.83	0.06	-180.00

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	2.389	2.389	0.01	106.55	0.00	-85.65	0.00	176.60
0.50	2.136	2.136	0.03	109.03	0.00	-81.16	0.00	-164.84
0.60	1.950	1.950	0.05	111.08	0.01	-77.42	0.00	-173.49
0.80	1.689	1.689	0.13	114.17	0.03	-71.40	0.00	168.13
1.00	1.511	1.511	0.22	116.11	0.07	-66.75	0.00	163.97
1.20	1.379	1.379	0.30	116.84	0.11	-63.36	0.00	-158.11
1.40	1.277	1.277	0.37	117.16	0.17	-61.26	0.00	-155.94
1.60	1.194	1.194	0.43	117.45	0.23	-60.52	0.00	173.73
1.80	1.126	1.126	0.49	117.10	0.30	-60.03	0.00	-151.23
2.00	1.068	1.068	0.54	116.05	0.37	-59.09	0.00	170.31
2.50	0.955	0.955	0.63	112.76	0.58	-59.85	0.00	136.70
3.00	0.872	0.872	0.71	110.06	0.81	-60.91	0.00	-179.95
3.50	0.807	0.807	0.78	106.93	1.08	-62.74	0.00	-154.24
4.00	0.755	0.755	0.84	104.34	1.36	-64.40	0.00	-156.02
5.00	0.676	0.676	0.94	100.53	1.95	-66.17	0.00	-81.06

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Traffic Ship Motions

Ship file: 1000

Shipid: Suction Mooring Sys

Heading (degrees) = 60.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	2.18	0.00	90.10	0.01	47.24
0.50	2.136	2.136	0.00	0.89	0.00	89.58	0.00	40.00
0.60	1.950	1.950	0.01	0.31	0.01	88.96	0.02	65.95
0.80	1.689	1.689	0.03	-0.84	0.02	87.21	0.07	-61.50
1.00	1.511	1.511	0.06	-2.33	0.03	84.62	0.26	-94.32
1.20	1.379	1.379	0.10	-4.27	0.05	81.11	0.42	-106.53
1.40	1.277	1.277	0.14	-6.64	0.07	76.98	0.51	-115.04
1.60	1.194	1.194	0.18	-9.20	0.09	73.15	0.53	-122.12
1.80	1.126	1.126	0.22	-11.53	0.11	70.76	0.52	-128.49
2.00	1.068	1.068	0.26	-13.15	0.14	70.33	0.49	-134.49
2.50	0.955	0.955	0.38	-13.24	0.21	74.46	0.38	-149.35
3.00	0.872	0.872	0.47	-10.48	0.25	79.21	0.27	-167.09
3.50	0.807	0.807	0.54	-7.83	0.28	82.38	0.18	165.68
4.00	0.755	0.755	0.60	-5.92	0.31	84.38	0.15	123.38
5.00	0.676	0.676	0.67	-3.65	0.34	86.59	0.27	65.97

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	2.389	2.389	0.00	-55.27	0.00	-82.22	0.00	13.12
0.50	2.136	2.136	0.00	107.60	0.00	-81.00	0.00	15.63
0.60	1.950	1.950	0.02	111.04	0.00	-78.28	0.01	17.50
0.80	1.689	1.689	0.07	114.59	0.02	-72.66	0.04	20.25
1.00	1.511	1.511	0.14	116.56	0.05	-67.91	0.08	21.84
1.20	1.379	1.379	0.21	117.24	0.09	-64.33	0.11	22.76
1.40	1.277	1.277	0.28	117.50	0.14	-62.10	0.15	22.80
1.60	1.194	1.194	0.34	117.75	0.19	-61.25	0.18	22.82
1.80	1.126	1.126	0.39	117.35	0.25	-60.68	0.21	22.13
2.00	1.068	1.068	0.43	116.33	0.31	-60.46	0.23	20.88
2.50	0.955	0.955	0.52	112.89	0.49	-60.40	0.28	18.07
3.00	0.872	0.872	0.59	110.14	0.69	-61.39	0.33	15.57
3.50	0.807	0.807	0.66	106.99	0.92	-63.15	0.36	13.46
4.00	0.755	0.755	0.72	104.39	1.17	-64.78	0.39	11.65
5.00	0.676	0.676	0.80	100.70	1.69	-67.49	0.44	9.21

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Traffic Ship Motions

Ship file: 1000
 Shipid: Suction Mooring Sys
 Heading (degrees) = 30.0
 Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	-179.95	0.00	-92.81	0.01	-137.04
0.50	2.136	2.136	0.00	174.72	0.00	94.91	0.04	98.39
0.60	1.950	1.950	0.00	24.13	0.00	91.15	0.05	56.97
0.80	1.689	1.689	0.01	3.29	0.02	88.70	0.12	-43.93
1.00	1.511	1.511	0.04	0.82	0.04	86.03	0.20	-66.38
1.20	1.379	1.379	0.07	-1.32	0.07	82.56	0.20	-73.80
1.40	1.277	1.277	0.11	-3.71	0.10	78.45	0.15	-75.72
1.60	1.194	1.194	0.15	-6.32	0.14	74.52	0.08	-68.45
1.80	1.126	1.126	0.19	-8.80	0.18	71.93	0.03	14.37
2.00	1.068	1.068	0.23	-10.72	0.22	71.26	0.09	65.27
2.50	0.955	0.955	0.35	-11.74	0.34	74.92	0.27	71.45
3.00	0.872	0.872	0.45	-9.62	0.42	79.46	0.41	68.82
3.50	0.807	0.807	0.52	-7.32	0.48	82.52	0.53	65.46
4.00	0.755	0.755	0.57	-5.59	0.52	84.47	0.63	62.12
5.00	0.676	0.676	0.65	-3.50	0.58	86.63	0.79	55.94

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Sway y/h	Phase	Roll fi/kh	Phase	Yaw psi/kh	Phase
0.40	2.389	2.389	0.00	-76.57	0.00	95.35	0.00	-165.77
0.50	2.136	2.136	0.00	-70.83	0.00	-80.79	0.00	-152.38
0.60	1.950	1.950	0.00	-69.90	0.00	-80.65	0.00	16.35
0.80	1.689	1.689	0.01	118.56	0.01	-75.48	0.02	20.00
1.00	1.511	1.511	0.04	118.40	0.02	-70.39	0.05	21.73
1.20	1.379	1.379	0.08	118.48	0.04	-66.37	0.09	22.71
1.40	1.277	1.277	0.11	118.40	0.07	-63.81	0.12	22.75
1.60	1.194	1.194	0.15	118.49	0.10	-62.74	0.16	22.79
1.80	1.126	1.126	0.18	117.94	0.13	-61.98	0.19	22.12
2.00	1.068	1.068	0.21	116.76	0.17	-61.60	0.21	20.86
2.50	0.955	0.955	0.27	113.25	0.27	-62.07	0.27	18.04
3.00	0.872	0.872	0.32	110.40	0.39	-63.04	0.31	15.55
3.50	0.807	0.807	0.36	107.24	0.53	-64.82	0.35	13.45
4.00	0.755	0.755	0.40	104.63	0.67	-66.50	0.39	11.65
5.00	0.676	0.676	0.45	100.82	0.97	-68.39	0.44	9.21

Viscous contributions for roll motion, Kappa4 = 1.50

Non Dimensional Traffic Ship Motions

Ship file: 1000

Shipid: Suction Mooring Sys

Heading (degrees) = 0.0

Ship speed (knots) = 0.0

Wave L./ Ship L.	Omegae 2pi/s	Omega 2pi/s	Heave z/h	Phase	Pitch Theta/kh	Phase	Surge x/h	Phase
0.40	2.389	2.389	0.00	-126.12	0.00	-90.92	0.01	-59.53
0.50	2.136	2.136	0.00	178.14	0.00	-102.43	0.03	-114.83
0.60	1.950	1.950	0.00	168.35	0.00	94.45	0.03	-166.10
0.80	1.689	1.689	0.01	7.89	0.01	89.77	0.10	99.48
1.00	1.511	1.511	0.03	3.05	0.04	86.89	0.22	82.97
1.20	1.379	1.379	0.06	0.47	0.07	83.38	0.33	77.10
1.40	1.277	1.277	0.10	-2.05	0.11	79.25	0.42	74.11
1.60	1.194	1.194	0.14	-4.72	0.15	75.26	0.50	72.23
1.80	1.126	1.126	0.18	-7.32	0.19	72.55	0.57	70.85
2.00	1.068	1.068	0.22	-9.41	0.25	71.75	0.63	69.70
2.50	0.955	0.955	0.33	-10.94	0.38	75.16	0.74	67.21
3.00	0.872	0.872	0.43	-9.17	0.47	79.58	0.83	64.86
3.50	0.807	0.807	0.51	-7.06	0.54	82.60	0.90	62.54
4.00	0.755	0.755	0.56	-5.42	0.59	84.52	0.97	60.24
5.00	0.676	0.676	0.65	-3.42	0.66	86.65	1.00	55.77

APPENDIX IV

SIMULATION RESULTS

Run # 10 to Run # 34

Hands-On Simulation

Log Report of Ship Handling

Simulation Track Plot

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 10
Start Time: 08:39
Length of run [secs]: 1808

Date: 3 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	0	Direction: 0
Sea State, Significant wave height [m]:..	0	Direction: 0
Current Speed [knots]:.....	0	Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 4.1

Evaluation:

Normal deceleration did not happen, because of wrong setting of the thruster at start, otherwise it was a normal approach. The captain made several heading changes to the right to offset some left set (The thruster was 1 degree off). On the final closure the speed was about 0.2 knots. The center of the buoy was a little to the right. It appeared to come in within the limits but just failed to do so. At this point we were almost stopped and we could easily have pulled the moon pool to the center of the buoy by use of the thruster and stop the engine.

Shiphhandling Simulator

Exercise date & time: 03-Feb-99
08:39:35

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 750 Suction Mooring System
 Scenario: 110 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 590 150k tanker in partial load - Suction Mooring
 Exercise identification: Run #10

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Knots	Deg	Knots	Deg
00:08:20	-1	-1033	26	0	2.95	0.02	-0.03	360	0.292	3.3	98.0	181	0	180
00:08:30	-1	-1018	26	0	2.91	0.02	-0.04	360	0.335	2.1	98.0	181	0	180
00:08:40	-1	-1003	26	0	2.87	0.02	-0.04	360	0.351	1.1	98.0	181	0	180
00:08:50	-1	-989	26	0	2.82	0.01	-0.04	360	0.340	0.4	98.0	181	0	180
00:09:00	-1	-974	26	0	2.78	0.01	-0.04	000	0.307	-0.7	98.0	181	0	180
00:09:10	-1	-960	26	0	2.74	0.01	-0.03	000	0.257	-1.8	98.0	181	0	180
00:09:20	-1	-946	26	0	2.70	0.00	-0.03	000	0.192	-2.3	98.0	181	0	180
00:09:30	-2	-932	26	0	2.66	0.00	-0.02	000	0.121	-2.9	98.0	181	0	180
00:09:40	-2	-919	26	0	2.62	-0.01	-0.02	000	0.046	-2.8	98.0	181	0	180
00:09:50	-2	-905	26	0	2.58	-0.01	-0.01	000	-0.022	-2.8	98.0	181	0	180
00:10:00	-2	-892	26	0	2.54	-0.02	0.00	000	-0.085	-2.8	98.0	181	0	180
00:10:10	-2	-879	26	0	2.50	-0.02	0.00	000	-0.140	-2.2	98.0	181	0	180
00:10:20	-2	-866	26	0	2.46	-0.02	0.01	000	-0.181	-1.6	98.0	181	0	180
00:10:30	-2	-854	26	0	2.42	-0.02	0.01	000	-0.206	-1.0	98.0	181	0	180
00:10:40	-2	-841	26	0	2.38	-0.02	0.01	000	-0.216	-0.5	98.0	181	0	180
00:10:50	-2	-829	26	0	2.34	-0.02	0.01	000	-0.211	0.1	98.0	181	0	180
00:11:00	-2	-817	26	0	2.31	-0.02	0.01	360	-0.193	0.7	98.0	181	0	180
00:11:10	-2	-806	26	0	2.28	-0.02	0.01	360	-0.164	1.2	52.0	181	0	180
00:11:20	-2	-794	26	0	2.28	-0.01	0.01	360	-0.127	1.8	52.0	181	0	180
00:11:30	-2	-782	26	0	2.29	-0.01	0.00	360	-0.083	1.7	25.0	181	0	180
00:11:40	-2	-770	26	0	2.30	-0.01	0.00	360	-0.039	2.3	25.0	181	0	180
00:11:50	-2	-758	26	0	2.32	0.00	0.00	360	0.011	2.2	50.0	181	0	180
00:12:00	-2	-746	26	0	2.32	0.00	-0.01	360	0.055	1.7	50.0	181	0	180
00:12:10	-2	-734	26	0	2.32	0.00	-0.02	360	0.122	9.3	50.0	181	0	180
00:12:20	-2	-722	26	0	2.33	0.02	-0.05	360	0.489	18.9	50.0	181	0	180
00:12:30	-2	-711	26	0	2.33	0.04	-0.09	000	0.854	16.4	50.0	181	0	180
00:12:40	-2	-699	26	0	2.33	0.06	-0.12	000	1.136	13.5	50.0	181	0	180
00:12:50	-2	-687	26	0	2.32	0.07	-0.14	000	1.320	9.5	75.0	181	0	180
00:13:00	-2	-675	26	0	2.30	0.06	-0.14	001	1.266	-7.7	75.0	181	0	180
00:13:10	-2	-663	26	0	2.29	0.03	-0.11	001	0.883	-15.6	75.0	181	0	180
00:13:20	-2	-651	26	0	2.25	0.00	-0.07	001	0.461	-17.1	99.0	181	0	180
00:13:30	-2	-640	26	0	2.21	-0.02	-0.03	001	0.041	-18.0	99.0	181	0	180
00:13:40	-2	-628	26	0	2.17	-0.04	0.01	001	-0.348	-17.3	99.0	181	0	180
00:13:50	-2	-617	26	0	2.13	-0.06	0.05	001	-0.684	-15.4	99.0	181	0	180
00:14:00	-2	-606	26	0	2.09	-0.07	0.07	001	-0.949	-13.0	99.0	181	0	180
00:14:10	-2	-596	26	0	2.06	-0.07	0.08	001	-0.986	4.6	99.0	181	0	180
00:14:20	-2	-585	26	0	2.03	-0.05	0.06	000	-0.724	10.6	77.0	181	0	180
00:14:30	-2	-575	26	0	2.01	-0.04	0.03	000	-0.431	12.1	77.0	181	0	180
00:14:40	-2	-565	26	0	2.00	-0.02	0.00	000	-0.133	13.0	77.0	181	0	180
00:14:50	-2	-554	26	0	1.98	0.00	-0.02	000	0.075	1.6	77.0	181	0	180
00:15:00	-2	-544	26	0	1.97	-0.01	-0.01	000	-0.020	-5.1	77.0	181	0	180
00:15:10	-2	-534	26	0	1.96	-0.02	0.00	000	-0.130	-5.0	77.0	181	0	180
00:15:20	-2	-524	26	0	1.94	-0.02	0.01	000	-0.228	-4.4	77.0	181	0	180
00:15:30	-2	-514	26	0	1.93	-0.02	0.02	000	-0.305	-3.8	77.0	181	0	180
00:15:40	-2	-504	26	0	1.92	-0.03	0.03	000	-0.356	-2.6	77.0	181	0	180
00:15:50	-2	-494	26	0	1.90	-0.03	0.03	000	-0.382	-1.5	77.0	181	0	180
00:16:00	-1	-485	26	0	1.89	-0.03	0.03	000	-0.383	-0.3	77.0	181	0	180
00:16:10	-1	-475	26	0	1.88	-0.02	0.03	360	-0.360	0.8	77.0	181	0	180
00:16:20	-1	-465	26	0	1.86	-0.02	0.03	360	-0.311	4.7	77.0	181	0	180
00:16:30	-1	-456	26	0	1.85	0.00	0.00	360	0.003	20.3	77.0	181	0	180
00:16:40	-2	-446	26	0	1.84	0.02	-0.04	360	0.418	19.4	77.0	181	0	180
00:16:50	-2	-437	26	0	1.82	0.04	-0.08	000	0.776	17.5	77.0	181	0	180
00:17:00	-2	-427	26	0	1.81	0.06	-0.11	000	1.060	14.5	77.0	181	0	180
00:17:10	-2	-418	26	0	1.80	0.06	-0.12	000	1.090	-4.5	77.0	181	0	180
00:17:20	-2	-409	26	0	1.79	0.05	-0.11	001	1.003	7.8	77.0	181	0	180
00:17:30	-2	-400	26	0	1.77	0.05	-0.12	001	1.076	4.9	77.0	181	0	180
00:17:40	-2	-391	26	0	1.76	0.05	-0.12	001	1.079	1.5	77.0	181	0	180
00:17:50	-2	-382	26	0	1.75	0.03	-0.10	001	0.841	-17.5	77.0	181	0	180
00:18:00	-2	-373	26	0	1.73	0.00	-0.06	001	0.372	-21.0	100.0	181	0	180
00:18:10	-2	-364	26	0	1.69	-0.03	-0.01	001	-0.084	-20.8	100.0	181	0	180
00:18:20	-2	-355	26	0	1.65	-0.05	0.03	001	-0.503	-19.9	100.0	181	0	180
00:18:30	-2	-347	26	0	1.62	-0.07	0.06	001	-0.827	-10.5	100.0	181	0	180
00:18:40	-2	-339	26	0	1.58	-0.06	0.06	001	-0.816	2.9	100.0	181	0	180
00:18:50	-2	-330	26	0	1.55	-0.06	0.06	001	-0.712	-1.7	100.0	181	0	180
00:19:00	-1	-323	26	0	1.52	-0.06	0.07	001	-0.857	-10.6	100.0	181	0	180
00:19:10	-1	-315	26	0	1.48	-0.07	0.09	000	-0.994	-7.6	100.0	181	0	180
00:19:20	-1	-307	26	0	1.45	-0.07	0.10	000	-1.062	-4.2	100.0	181	0	180
00:19:30	-1	-300	26	0	1.42	-0.07	0.09	000	-1.014	7.4	100.0	181	0	180
00:19:40	-1	-293	26	0	1.39	-0.04	0.06	360	-0.653	19.1	100.0	181	0	180
00:19:50	-1	-286	26	0	1.35	-0.02	0.02	360	-0.228	20.5	100.0	181	0	180
00:20:00	-1	-279	26	0	1.32	0.01	-0.02	360	0.181	20.1	100.0	181	0	180
00:20:10	-1	-272	26	0	1.29	0.03	-0.06	360	0.548	18.6	100.0	181	0	180
00:20:20	-1	-266	26	0	1.25	0.05	-0.09	000	0.855	16.1	100.0	181	0	180

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North			Long	Bow	Stern						Knots	Deg	Knots	Deg
00:20:30	-1	-259	26	0	1.22	0.06	-0.11	000	1.090	13.0	100.0	181	0	180	0.0	180
00:20:40	-1	-253	26	0	1.19	0.06	-0.13	000	1.244	9.5	100.0	181	0	180	0.0	180
00:20:50	-2	-247	26	0	1.16	0.07	-0.14	001	1.314	5.4	100.0	181	0	180	0.0	180
00:21:00	-2	-241	26	0	1.13	0.06	-0.14	001	1.302	1.4	100.0	181	0	180	0.0	180
00:21:10	-2	-235	26	0	1.10	0.06	-0.14	001	1.216	-2.4	100.0	181	0	180	0.0	180
00:21:20	-2	-230	26	0	1.07	0.05	-0.12	001	1.066	-5.7	100.0	181	0	180	0.0	180
00:21:30	-2	-224	26	0	1.04	0.03	-0.10	001	0.867	-8.3	100.0	181	0	180	0.0	180
00:21:40	-2	-219	26	0	1.01	0.02	-0.08	002	0.633	-10.3	100.0	181	0	180	0.0	180
00:21:50	-2	-214	26	0	0.98	0.00	-0.06	002	0.379	-11.7	100.0	181	0	180	0.0	180
00:22:00	-2	-209	26	0	0.95	-0.01	-0.03	002	0.124	-12.0	100.0	181	0	180	0.0	180
00:22:10	-2	-204	26	0	0.92	-0.03	-0.01	002	-0.125	-11.8	100.0	181	0	180	0.0	180
00:22:20	-2	-200	26	0	0.89	-0.04	0.01	002	-0.344	-10.8	100.0	181	0	180	0.0	180
00:22:30	-2	-195	26	0	0.86	-0.05	0.03	002	-0.529	-9.4	100.0	181	0	180	0.0	180
00:22:40	-2	-191	26	0	0.83	-0.06	0.04	001	-0.671	-7.5	100.0	181	0	180	0.0	180
00:22:50	-2	-187	26	0	0.80	-0.07	0.05	001	-0.765	-5.1	100.0	181	0	180	0.0	180
00:23:00	-2	-182	26	0	0.77	-0.07	0.06	001	-0.808	-2.7	100.0	181	0	180	0.0	180
00:23:10	-2	-179	26	0	0.75	-0.07	0.06	001	-0.803	0.1	100.0	181	0	180	0.0	180
00:23:20	-2	-175	26	0	0.72	-0.06	0.06	001	-0.754	2.4	100.0	181	0	180	0.0	180
00:23:30	-2	-171	26	0	0.69	-0.06	0.05	001	-0.666	4.5	100.0	181	0	180	0.0	180
00:23:40	-2	-168	26	0	0.66	-0.05	0.04	001	-0.547	6.0	100.0	181	0	180	0.0	180
00:23:50	-2	-164	26	0	0.64	-0.05	0.04	001	-0.591	-10.2	100.0	181	0	180	0.0	180
00:24:00	-2	-161	26	0	0.61	-0.06	0.05	001	-0.670	3.3	100.0	181	0	180	0.0	180
00:24:10	-1	-158	26	0	0.58	-0.04	0.03	000	-0.473	11.1	100.0	181	0	180	0.0	180
00:24:20	-2	-155	26	0	0.55	-0.03	0.01	000	-0.244	11.8	100.0	181	0	180	0.0	180
00:24:30	-2	-152	26	0	0.53	-0.02	-0.01	000	-0.019	11.9	100.0	181	0	180	0.0	180
00:24:40	-2	-150	26	0	0.50	0.00	-0.04	000	0.295	26.0	100.0	181	0	180	0.0	180
00:24:50	-2	-147	26	0	0.47	0.03	-0.09	000	0.781	26.2	100.0	181	0	180	0.0	180
00:25:00	-2	-145	26	0	0.44	0.05	-0.13	001	1.181	21.7	100.0	181	0	180	0.0	180
00:25:10	-2	-143	26	0	0.41	0.07	-0.16	001	1.477	16.6	100.0	181	0	180	0.0	180
00:25:20	-2	-141	26	0	0.39	0.08	-0.18	001	1.659	11.3	100.0	181	0	180	0.0	180
00:25:30	-3	-139	26	0	0.36	0.08	-0.19	001	1.727	5.6	75.0	181	0	180	0.0	180
00:25:40	-3	-137	26	0	0.37	0.08	-0.19	002	1.694	0.8	52.0	181	0	180	0.0	180
00:25:50	-3	-135	26	0	0.39	0.07	-0.17	002	1.578	-3.7	52.0	181	0	180	0.0	180
00:26:00	-3	-133	26	0	0.40	0.06	-0.16	002	1.391	-7.5	52.0	181	0	180	0.0	180
00:26:10	-3	-131	26	0	0.39	0.05	-0.13	002	1.149	-10.8	99.0	181	0	180	0.0	180
00:26:20	-3	-129	26	0	0.37	0.03	-0.11	003	0.866	-12.9	77.0	181	0	180	0.0	180
00:26:30	-4	-127	26	0	0.37	0.01	-0.08	003	0.564	-14.2	77.0	181	0	180	0.0	180
00:26:40	-4	-125	26	0	0.37	-0.01	-0.05	003	0.261	-14.4	77.0	181	0	180	0.0	180
00:26:50	-4	-123	26	0	0.36	-0.03	-0.02	003	-0.034	-17.5	77.0	181	0	180	0.0	180
00:27:00	-4	-121	26	0	0.36	-0.06	0.03	003	-0.547	-35.0	77.0	181	0	180	0.0	180
00:27:10	-4	-119	26	0	0.35	-0.10	0.09	003	-1.184	-35.0	77.0	181	0	180	0.0	180
00:27:20	-3	-118	26	0	0.34	-0.13	0.15	002	-1.794	-35.0	77.0	181	0	180	0.0	180
00:27:30	-3	-116	26	0	0.33	-0.17	0.21	002	-2.376	-35.0	77.0	181	0	180	0.0	180
00:27:40	-3	-114	26	0	0.32	-0.20	0.26	002	-2.927	-35.0	77.0	181	0	180	0.0	180
00:27:50	-3	-113	26	0	0.32	-0.22	0.31	001	-3.338	-21.3	77.0	181	0	180	0.0	180
00:28:00	-3	-111	26	0	0.31	-0.22	0.31	000	-3.398	-2.3	77.0	181	0	180	0.0	180
00:28:10	-2	-109	26	0	0.31	-0.20	0.29	360	-3.105	16.7	77.0	181	0	180	0.0	180
00:28:20	-2	-108	26	0	0.29	-0.16	0.23	359	-2.484	35.0	100.0	181	0	180	0.0	180
00:28:30	-2	-106	26	0	0.27	-0.12	0.16	359	-1.743	35.0	76.0	181	0	180	0.0	180
00:28:40	-2	-105	26	0	0.26	-0.08	0.09	359	-1.040	35.0	76.0	181	0	180	0.0	180
00:28:50	-2	-104	26	0	0.26	-0.04	0.02	359	-0.367	35.0	76.0	181	0	180	0.0	180
00:29:00	-2	-102	26	0	0.25	0.00	-0.04	359	0.279	35.0	76.0	181	0	180	0.0	180
00:29:10	-2	-101	26	0	0.24	0.04	-0.10	359	0.901	35.0	76.0	181	0	180	0.0	180
00:29:20	-3	-100	26	0	0.24	0.08	-0.16	359	1.496	35.0	76.0	181	0	180	0.0	180
00:29:30	-3	-99	26	0	0.23	0.11	-0.22	359	2.062	35.0	76.0	181	0	180	0.0	180
00:29:40	-3	-98	26	0	0.20	0.15	-0.27	360	2.647	35.0	76.0	181	0	180	0.0	180
00:29:50	-3	-97	26	0	0.14	0.20	-0.32	000	3.316	35.0	0.0	181	0	180	0.0	180
00:30:00	-4	-96	0	0	0.06	0.26	-0.35	001	3.890	35.0	0.0	181	0	180	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

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00:16:10
00:16:00
00:15:50

00:15 Start Time [hrs:min:sec]: 00:08:20
00:14 End Time [hrs:min:sec]: 00:30:08
00:14 Delta Plot Time [sec]: 30
00:14 East-West Scale [m]: 926.
00:13 East-West Scale [Nm]: 0.5000

Date: 03-Feb-99 Time: 08:39:35

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 11

Date: 3 February 1999

Start Time: 09:24

Length of run [secs]: 2156

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 0 Direction: 0

Sea State, Significant wave height [m]:.. 0 Direction: 0

Current Speed [knots]:..... 0 Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 0.9

Evaluation:

Everything went well. Started deceleration immediately by reducing RPM to 25 and using full reverse thruster. In the latter part of the approach the captain made several small heading adjustments. Deceleration was done in the following way: 3 knots at 1000 m from the buoy to the moon pool, and at 500 m the speed was 2 knots. Just before attachment the speed was 0.2 knots – perfect mating, about 1 m off.

Shiphhandling Simulator

Exercise date & time: 03-Feb-99
09:24:26

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 750 Suction Mooring System
 Scenario: 110 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 590 150k tanker in partial load - Suction Mooring
 Exercise identification: *Run # 11*

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:13:20	0	-789	26	0	2.39	0.00	0.00	360	0.002	0.0	75.0	180	0	180	0.0	180
00:13:30	0	-776	26	0	2.38	0.00	0.00	360	-0.008	0.5	75.0	180	0	180	0.0	180
00:13:40	0	-764	26	0	2.36	0.00	0.00	360	-0.004	0.6	75.0	180	0	180	0.0	180
00:13:50	0	-752	26	0	2.35	0.00	0.00	360	0.000	0.6	75.0	180	0	180	0.0	180
00:14:00	0	-740	26	0	2.33	0.00	0.00	360	0.003	0.6	75.0	180	0	180	0.0	180
00:14:10	0	-728	26	0	2.32	0.00	0.00	360	0.006	0.6	75.0	180	0	180	0.0	180
00:14:20	0	-716	26	0	2.30	0.00	0.00	360	0.000	0.0	75.0	180	0	180	0.0	180
00:14:30	1	-704	26	0	2.29	0.00	0.00	360	-0.005	0.6	75.0	180	0	180	0.0	180
00:14:40	1	-692	26	0	2.27	0.00	0.00	360	-0.002	0.6	75.0	180	0	180	0.0	180
00:14:50	1	-681	26	0	2.26	0.00	0.00	360	0.001	0.6	75.0	180	0	180	0.0	180
00:15:00	1	-669	26	0	2.25	0.00	0.00	360	0.004	0.6	75.0	180	0	180	0.0	180
00:15:10	1	-658	26	0	2.23	0.00	0.00	360	0.002	0.0	75.0	180	0	180	0.0	180
00:15:20	1	-646	26	0	2.22	0.00	0.00	360	-0.005	0.6	100.0	180	0	180	0.0	180
00:15:30	1	-635	26	0	2.18	0.00	0.00	360	-0.001	0.6	100.0	180	0	180	0.0	180
00:15:40	1	-624	26	0	2.14	0.00	0.00	360	0.002	0.6	100.0	180	0	180	0.0	180
00:15:50	1	-613	26	0	2.10	0.00	0.00	360	0.006	0.6	100.0	180	0	180	0.0	180
00:16:00	1	-602	26	0	2.06	0.00	0.00	360	-0.004	0.0	100.0	180	0	180	0.0	180
00:16:10	1	-592	26	0	2.03	0.00	0.01	360	-0.107	-0.5	100.0	180	0	180	0.0	180
00:16:20	1	-581	26	0	1.99	0.00	0.01	360	-0.096	0.6	100.0	180	0	180	0.0	180
00:16:30	1	-571	26	0	1.95	0.00	0.01	360	-0.080	0.2	100.0	180	0	180	0.0	180
00:16:40	1	-561	26	0	1.92	-0.01	0.03	360	-0.288	-16.1	100.0	180	0	180	0.0	180
00:16:50	1	-551	26	0	1.88	-0.03	0.07	360	-0.616	-13.9	100.0	180	0	180	0.0	180
00:17:00	1	-542	26	0	1.84	-0.03	0.07	360	-0.675	5.1	100.0	180	0	180	0.0	180
00:17:10	1	-532	26	0	1.81	-0.02	0.06	360	-0.515	7.1	100.0	180	0	180	0.0	180
00:17:20	1	-523	26	0	1.77	-0.01	0.04	360	-0.336	8.1	100.0	180	0	180	0.0	180
00:17:30	1	-514	26	0	1.74	0.00	0.03	360	-0.151	8.5	100.0	180	0	180	0.0	180
00:17:40	1	-505	26	0	1.70	0.01	0.01	360	0.033	9.0	100.0	180	0	180	0.0	180
00:17:50	1	-497	26	0	1.67	0.02	-0.01	360	0.199	8.3	100.0	180	0	180	0.0	180
00:18:00	1	-488	26	0	1.63	0.03	-0.02	360	0.341	7.6	100.0	180	0	180	0.0	180
00:18:10	1	-480	26	0	1.60	0.04	-0.03	360	0.452	6.4	100.0	180	0	180	0.0	180
00:18:20	1	-472	26	0	1.56	0.03	-0.03	360	0.372	-11.3	100.0	180	0	180	0.0	180
00:18:30	1	-464	26	0	1.53	0.01	0.00	360	0.067	-13.6	100.0	180	0	180	0.0	180
00:18:40	1	-456	26	0	1.50	0.00	0.03	360	-0.222	-13.3	100.0	180	0	180	0.0	180
00:18:50	1	-448	26	0	1.46	-0.01	0.04	360	-0.366	1.5	100.0	180	0	180	0.0	180
00:19:00	1	-441	26	0	1.43	0.00	0.03	360	-0.235	6.5	100.0	180	0	180	0.0	180
00:19:10	1	-434	26	0	1.40	-0.01	0.04	360	-0.298	-10.4	100.0	180	0	180	0.0	180
00:19:20	1	-426	26	0	1.37	-0.02	0.06	360	-0.490	-9.1	100.0	180	0	180	0.0	180
00:19:30	1	-420	26	0	1.33	-0.03	0.07	359	-0.639	-7.3	100.0	180	0	180	0.0	180
00:19:40	1	-413	26	0	1.30	-0.03	0.09	359	-0.739	-5.0	100.0	180	0	180	0.0	180
00:19:50	1	-406	26	0	1.27	-0.03	0.09	359	-0.788	-2.6	100.0	180	0	180	0.0	180
00:20:00	1	-400	26	0	1.24	-0.03	0.09	359	-0.787	-0.4	100.0	180	0	180	0.0	180
00:20:10	1	-393	26	0	1.21	-0.03	0.09	359	-0.740	1.8	100.0	180	0	180	0.0	180
00:20:20	1	-387	26	0	1.18	-0.02	0.08	359	-0.654	4.0	100.0	180	0	180	0.0	180
00:20:30	1	-381	26	0	1.15	-0.01	0.07	359	-0.535	5.6	100.0	180	0	180	0.0	180
00:20:40	1	-375	26	0	1.12	0.00	0.06	359	-0.395	7.2	100.0	180	0	180	0.0	180
00:20:50	1	-370	26	0	1.09	0.01	0.04	359	-0.188	17.6	100.0	180	0	180	0.0	180
00:21:00	1	-364	26	0	1.05	0.04	-0.01	359	0.277	25.0	100.0	180	0	180	0.0	180
00:21:10	1	-359	26	0	1.02	0.06	-0.05	359	0.723	23.4	100.0	180	0	180	0.0	180
00:21:20	1	-354	26	0	0.99	0.08	-0.09	359	1.095	20.1	100.0	180	0	180	0.0	180
00:21:30	1	-349	26	0	0.96	0.10	-0.12	359	1.377	15.8	100.0	180	0	180	0.0	180
00:21:40	1	-344	26	0	0.93	0.11	-0.14	359	1.559	11.0	100.0	180	0	180	0.0	180
00:21:50	1	-339	26	0	0.90	0.11	-0.15	360	1.638	6.3	100.0	180	0	180	0.0	180
00:22:00	1	-334	26	0	0.87	0.11	-0.15	360	1.618	1.2	100.0	180	0	180	0.0	180
00:22:10	0	-330	26	0	0.84	0.10	-0.14	000	1.507	-3.2	100.0	180	0	180	0.0	180
00:22:20	0	-326	26	0	0.82	0.09	-0.12	000	1.320	-7.5	100.0	180	0	180	0.0	180
00:22:30	0	-322	26	0	0.79	0.07	-0.10	001	1.073	-10.6	100.0	180	0	180	0.0	180
00:22:40	0	-318	26	0	0.78	0.05	-0.07	001	0.785	-13.0	74.0	180	0	180	0.0	180
00:22:50	0	-314	26	0	0.77	0.03	-0.04	001	0.474	-14.8	74.0	180	0	180	0.0	180
00:23:00	0	-310	26	0	0.77	0.01	-0.01	001	0.160	-15.4	74.0	180	0	180	0.0	180
00:23:10	0	-306	26	0	0.77	-0.01	0.02	001	-0.144	-15.0	74.0	180	0	180	0.0	180
00:23:20	1	-302	26	0	0.76	-0.02	0.04	001	-0.414	-13.4	74.0	180	0	180	0.0	180
00:23:30	1	-298	26	0	0.76	-0.03	0.07	001	-0.651	-15.8	74.0	180	0	180	0.0	180
00:23:40	1	-294	26	0	0.76	-0.06	0.11	001	-1.082	-26.5	74.0	180	0	180	0.0	180
00:23:50	1	-290	26	0	0.75	-0.08	0.15	000	-1.497	-21.8	74.0	180	0	180	0.0	180
00:24:00	1	-286	26	0	0.75	-0.10	0.18	000	-1.795	-16.3	74.0	180	0	180	0.0	180
00:24:10	1	-282	26	0	0.74	-0.11	0.20	360	-1.969	-10.4	74.0	180	0	180	0.0	180
00:24:20	2	-279	26	0	0.74	-0.11	0.21	359	-2.018	-4.2	74.0	180	0	180	0.0	180
00:24:30	2	-275	26	0	0.74	-0.10	0.21	359	-1.951	1.4	74.0	180	0	180	0.0	180
00:24:40	2	-271	26	0	0.73	-0.09	0.19	359	-1.781	6.8	74.0	180	0	180	0.0	180
00:24:50	2	-267	26	0	0.73	-0.07	0.17	358	-1.525	11.5	74.0	180	0	180	0.0	180
00:25:00	2	-263	26	0	0.73	-0.05	0.14	358	-1.206	14.9	74.0	180	0	180	0.0	180
00:25:10	2	-260	26	0	0.73	-0.03	0.10	358	-0.844	17.7	74.0	180	0	180	0.0	180
00:25:20	2	-256	26	0	0.72	-0.01	0.07	358	-0.464	18.8	74.0	180	0	180	0.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:25:30	2	-252	26	0	0.72	0.02	0.03	358	-0.086	19.3	74.0	180	0	180	0.0	180
00:25:40	2	-249	26	0	0.71	0.04	0.00	358	0.269	18.7	74.0	180	0	180	0.0	180
00:25:50	2	-245	26	0	0.69	0.06	-0.04	358	0.581	16.5	98.0	180	0	180	0.0	180
00:26:00	2	-241	26	0	0.68	0.07	-0.06	358	0.838	13.8	76.0	180	0	180	0.0	180
00:26:10	2	-238	26	0	0.68	0.09	-0.09	358	1.156	27.9	76.0	180	0	180	0.0	180
00:26:20	2	-234	26	0	0.67	0.11	-0.14	359	1.590	23.7	76.0	180	0	180	0.0	180
00:26:30	2	-231	26	0	0.67	0.13	-0.17	359	1.900	18.0	76.0	180	0	180	0.0	180
00:26:40	2	-228	26	0	0.66	0.14	-0.19	359	2.057	6.3	76.0	180	0	180	0.0	180
00:26:50	2	-224	26	0	0.66	0.13	-0.17	359	1.888	-12.3	76.0	180	0	180	0.0	180
00:27:00	1	-221	26	0	0.65	0.10	-0.14	360	1.518	-16.8	76.0	180	0	180	0.0	180
00:27:10	1	-217	26	0	0.65	0.08	-0.10	000	1.095	-20.0	76.0	180	0	180	0.0	180
00:27:20	1	-214	26	0	0.64	0.05	-0.05	000	0.644	-21.9	76.0	180	0	180	0.0	180
00:27:30	1	-211	26	0	0.64	0.02	-0.01	000	0.193	-22.3	76.0	180	0	180	0.0	180
00:27:40	1	-208	26	0	0.63	-0.01	0.03	000	-0.235	-21.5	76.0	180	0	180	0.0	180
00:27:50	2	-204	26	0	0.63	-0.03	0.07	000	-0.616	-19.2	76.0	180	0	180	0.0	180
00:28:00	2	-201	26	0	0.62	-0.05	0.10	000	-0.933	-16.2	76.0	180	0	180	0.0	180
00:28:10	2	-198	26	0	0.62	-0.06	0.12	360	-1.173	-13.0	76.0	180	0	180	0.0	180
00:28:20	2	-195	26	0	0.62	-0.07	0.14	360	-1.328	-8.7	76.0	180	0	180	0.0	180
00:28:30	2	-192	26	0	0.61	-0.07	0.15	359	-1.433	-13.5	76.0	180	0	180	0.0	180
00:28:40	2	-188	26	0	0.61	-0.09	0.18	359	-1.716	-17.0	76.0	180	0	180	0.0	180
00:28:50	3	-185	26	0	0.60	-0.10	0.20	359	-1.908	-11.5	76.0	180	0	180	0.0	180
00:29:00	3	-182	26	0	0.60	-0.10	0.21	359	-1.977	-5.2	76.0	180	0	180	0.0	180
00:29:10	3	-179	26	0	0.59	-0.10	0.21	358	-1.932	0.5	76.0	180	0	180	0.0	180
00:29:20	3	-176	26	0	0.59	-0.09	0.19	358	-1.783	5.8	76.0	180	0	180	0.0	180
00:29:30	3	-173	26	0	0.59	-0.07	0.17	358	-1.550	10.4	76.0	180	0	180	0.0	180
00:29:40	3	-170	26	0	0.58	-0.05	0.15	357	-1.251	14.3	76.0	180	0	180	0.0	180
00:29:50	3	-167	26	0	0.58	-0.03	0.11	357	-0.909	16.5	76.0	180	0	180	0.0	180
00:30:00	3	-164	26	0	0.57	-0.01	0.08	357	-0.520	24.9	76.0	180	0	180	0.0	180
00:30:10	3	-161	26	0	0.57	0.03	0.01	357	0.105	35.0	76.0	180	0	180	0.0	180
00:30:20	3	-158	26	0	0.56	0.07	-0.05	357	0.737	32.9	76.0	180	0	180	0.0	180
00:30:30	3	-155	26	0	0.55	0.10	-0.10	357	1.280	28.8	100.0	180	0	180	0.0	180
00:30:40	3	-153	26	0	0.52	0.13	-0.14	358	1.706	23.1	100.0	180	0	180	0.0	180
00:30:50	3	-150	26	0	0.49	0.14	-0.18	358	2.050	28.3	100.0	180	0	180	0.0	180
00:31:00	3	-148	26	0	0.46	0.17	-0.22	358	2.507	26.2	100.0	180	0	180	0.0	180
00:31:10	3	-145	26	0	0.43	0.19	-0.25	359	2.789	17.2	100.0	180	0	180	0.0	180
00:31:20	2	-143	26	0	0.40	0.19	-0.26	359	2.882	7.9	100.0	180	0	180	0.0	180
00:31:30	2	-141	26	0	0.38	0.18	-0.26	360	2.798	-2.5	100.0	180	0	180	0.0	180
00:31:40	2	-139	26	0	0.35	0.16	-0.22	000	2.436	-21.5	100.0	180	0	180	0.0	180
00:31:50	2	-137	26	0	0.32	0.12	-0.16	000	1.799	-31.4	100.0	180	0	180	0.0	180
00:32:00	2	-136	26	0	0.29	0.08	-0.10	001	1.101	-35.0	100.0	180	0	180	0.0	180
00:32:10	2	-134	26	0	0.26	0.04	-0.03	001	0.409	-35.0	100.0	180	0	180	0.0	180
00:32:20	2	-133	26	0	0.23	0.00	0.04	001	-0.256	-35.0	100.0	180	0	180	0.0	180
00:32:30	2	-132	26	0	0.20	-0.04	0.10	001	-0.894	-35.0	100.0	180	0	180	0.0	180
00:32:40	2	-131	26	0	0.18	-0.08	0.16	000	-1.504	-34.7	75.0	180	0	180	0.0	180
00:32:50	2	-130	26	0	0.19	-0.11	0.21	000	-2.009	-27.2	50.0	180	0	180	0.0	180
00:33:00	3	-129	26	0	0.21	-0.13	0.24	360	-2.349	-19.7	28.0	180	0	180	0.0	180
00:33:10	3	-128	26	0	0.23	-0.14	0.26	359	-2.540	-12.7	50.0	180	0	180	0.0	180
00:33:20	3	-127	26	0	0.25	-0.14	0.27	359	-2.589	-5.4	50.0	180	0	180	0.0	180
00:33:30	4	-126	26	0	0.26	-0.14	0.26	359	-2.509	0.9	50.0	180	0	180	0.0	180
00:33:40	4	-124	26	0	0.28	-0.12	0.24	358	-2.319	6.8	50.0	180	0	180	0.0	180
00:33:50	4	-123	26	0	0.29	-0.11	0.22	358	-2.040	12.0	50.0	180	0	180	0.0	180
00:34:00	4	-121	26	0	0.31	-0.08	0.18	357	-1.693	16.0	50.0	180	0	180	0.0	180
00:34:10	4	-119	26	0	0.33	-0.06	0.15	357	-1.301	18.8	50.0	180	0	180	0.0	180
00:34:20	5	-118	26	0	0.34	-0.03	0.09	357	-0.743	35.0	50.0	180	0	180	0.0	180
00:34:30	5	-116	26	0	0.35	0.02	0.03	357	-0.070	35.0	50.0	180	0	180	0.0	180
00:34:40	5	-114	26	0	0.36	0.05	-0.04	357	0.562	29.9	50.0	180	0	180	0.0	180
00:34:50	4	-112	26	0	0.38	0.07	-0.07	357	0.910	12.9	50.0	180	0	180	0.0	180
00:35:00	4	-110	26	0	0.39	0.08	-0.09	357	1.071	9.1	74.0	180	0	180	0.0	180
00:35:10	4	-108	26	0	0.39	0.09	-0.10	357	1.160	5.5	74.0	180	0	180	0.0	180
00:35:20	4	-106	26	0	0.36	0.09	-0.10	358	1.176	1.8	100.0	180	0	180	0.0	180
00:35:30	4	-104	26	0	0.34	0.08	-0.09	358	1.122	-3.1	100.0	180	0	180	0.0	180
00:35:40	4	-103	26	0	0.31	0.07	-0.07	358	0.835	-22.1	100.0	180	0	180	0.0	180
00:35:50	4	-101	26	0	0.28	0.04	-0.02	358	0.386	-22.5	100.0	180	0	180	0.0	180
00:36:00	4	-100	26	0	0.25	0.01	0.02	358	-0.042	-21.2	100.0	180	0	180	0.0	180
00:36:10	4	-99	25	0	0.20	-0.01	0.05	358	-0.420	-18.5	0.0	180	0	180	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

00:21:20
00:20:50
00:20:20
00:19:50
00:19:20
00:18:50
00:18:20
00:17:50

00:17 Start Time [hrs:min:sec]: 00:13:20
00:16 End Time [hrs:min:sec]: 00:36:15
00:16 Delta Plot Time [sec]: 30
00:15 East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

Date: 03-Feb-99 Time: 09:24:26

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 12
Start Time: 10:06
Length of run [secs]: 1650

Date: 3 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	0	Direction: 0
Sea State, Significant wave height [m]:..	0	Direction: 0
Current Speed [knots]:.....	2	Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 0.2

Evaluation:

Very successful run.

Very similar to run # 11. It tracked well. Recommend start of simulation 1700 m south of the buoy instead of 1500 m.

Shiphhandling Simulator

Exercise date & time: 03-Feb-99
10:06:45

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #12**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Knots	Deg	Knots	Deg
00:08:20	0	-596	26	0	1.83	-0.01	0.04	000	-0.324	-0.9	76.0	180	2.0	180
00:08:30	0	-587	26	0	1.80	-0.01	0.04	000	-0.321	0.2	76.0	180	2.0	180
00:08:40	0	-577	26	0	1.77	-0.03	0.06	360	-0.538	-16.5	76.0	180	2.0	180
00:08:50	1	-568	26	0	1.74	-0.05	0.10	360	-0.962	-14.0	76.0	180	2.0	180
00:09:00	1	-560	26	0	1.71	-0.07	0.13	360	-1.267	-10.4	76.0	180	2.0	180
00:09:10	1	-551	26	0	1.68	-0.08	0.15	359	-1.443	-6.3	76.0	180	2.0	180
00:09:20	1	-542	26	0	1.65	-0.08	0.16	359	-1.493	-1.7	76.0	180	2.0	180
00:09:30	1	-534	26	0	1.62	-0.07	0.15	359	-1.425	2.7	76.0	180	2.0	180
00:09:40	1	-526	26	0	1.59	-0.06	0.14	359	-1.258	6.6	76.0	180	2.0	180
00:09:50	1	-518	26	0	1.56	-0.05	0.11	358	-1.015	9.8	76.0	180	2.0	180
00:10:00	1	-510	26	0	1.53	-0.03	0.08	358	-0.721	12.4	76.0	180	2.0	180
00:10:10	1	-502	26	0	1.50	-0.02	0.05	358	-0.403	13.8	76.0	180	2.0	180
00:10:20	1	-494	26	0	1.47	0.01	0.00	358	0.033	26.6	76.0	180	2.0	180
00:10:30	0	-487	26	0	1.44	0.05	-0.08	358	0.774	30.3	76.0	180	2.0	180
00:10:40	0	-479	26	0	1.41	0.08	-0.14	358	1.402	26.4	76.0	180	2.0	180
00:10:50	0	-472	26	0	1.38	0.10	-0.19	359	1.868	21.0	50.0	180	2.0	180
00:11:00	-1	-465	26	0	1.37	0.11	-0.23	359	2.155	15.0	50.0	180	2.0	180
00:11:10	-1	-458	26	0	1.36	0.12	-0.24	359	2.262	8.2	50.0	180	2.0	180
00:11:20	-2	-451	26	0	1.36	0.11	-0.24	360	2.199	1.5	50.0	180	2.0	180
00:11:30	-2	-444	26	0	1.35	0.10	-0.23	000	2.079	7.7	50.0	180	2.0	180
00:11:40	-2	-437	26	0	1.34	0.10	-0.24	001	2.197	6.5	50.0	180	2.0	180
00:11:50	-3	-430	26	0	1.33	0.10	-0.24	001	2.157	-0.1	50.0	180	2.0	180
00:12:00	-3	-423	26	0	1.33	0.09	-0.22	001	1.968	-6.3	50.0	180	2.0	180
00:12:10	-3	-417	26	0	1.32	0.07	-0.19	002	1.659	-11.5	50.0	180	2.0	180
00:12:20	-3	-410	26	0	1.31	0.05	-0.15	002	1.263	-15.2	50.0	180	2.0	180
00:12:30	-3	-403	26	0	1.31	0.03	-0.10	002	0.817	-18.2	27.0	180	2.0	180
00:12:40	-3	-396	26	0	1.31	0.00	-0.05	002	0.357	-19.5	27.0	180	2.0	180
00:12:50	-3	-390	26	0	1.32	-0.02	-0.01	002	-0.087	-19.6	27.0	180	2.0	180
00:13:00	-3	-383	26	0	1.32	-0.04	0.04	002	-0.486	-18.2	27.0	180	2.0	180
00:13:10	-2	-376	26	0	1.32	-0.05	0.08	002	-0.814	-16.2	27.0	180	2.0	180
00:13:20	-2	-369	26	0	1.32	-0.06	0.11	002	-1.058	-13.1	27.0	180	2.0	180
00:13:30	-2	-362	26	0	1.33	-0.07	0.13	002	-1.208	-9.6	27.0	180	2.0	180
00:13:40	-1	-356	26	0	1.33	-0.08	0.16	001	-1.525	-23.4	27.0	180	2.0	180
00:13:50	-1	-349	26	0	1.29	-0.10	0.20	001	-1.918	-17.9	100.0	180	2.0	180
00:14:00	0	-342	26	0	1.24	-0.11	0.23	001	-2.133	-11.5	78.0	180	2.0	180
00:14:10	0	-336	26	0	1.21	-0.11	0.24	000	-2.179	-4.7	78.0	180	2.0	180
00:14:20	0	-330	26	0	1.18	-0.10	0.23	000	-2.068	1.5	78.0	180	2.0	180
00:14:30	1	-324	26	0	1.16	-0.08	0.21	360	-1.827	7.4	78.0	180	2.0	180
00:14:40	1	-318	26	0	1.13	-0.06	0.17	359	-1.487	12.2	78.0	180	2.0	180
00:14:50	1	-312	26	0	1.10	-0.04	0.13	359	-1.081	15.2	78.0	180	2.0	180
00:15:00	1	-307	26	0	1.08	-0.01	0.09	359	-0.644	17.6	78.0	180	2.0	180
00:15:10	1	-301	26	0	1.05	0.01	0.05	359	-0.210	18.2	78.0	180	2.0	180
00:15:20	1	-296	26	0	1.02	0.03	0.00	359	0.200	17.9	78.0	180	2.0	180
00:15:30	1	-291	26	0	1.00	0.05	-0.03	359	0.552	16.3	78.0	180	2.0	180
00:15:40	1	-285	26	0	0.98	0.07	-0.07	359	0.831	14.2	50.0	180	2.0	180
00:15:50	1	-280	26	0	0.97	0.07	-0.09	359	1.029	11.1	74.0	180	2.0	180
00:16:00	1	-275	26	0	0.95	0.08	-0.10	360	1.140	7.6	74.0	180	2.0	180
00:16:10	1	-271	26	0	0.93	0.08	-0.11	360	1.165	4.2	74.0	180	2.0	180
00:16:20	1	-266	26	0	0.91	0.07	-0.10	360	1.111	0.8	74.0	180	2.0	180
00:16:30	1	-261	26	0	0.89	0.06	-0.09	000	0.990	-2.4	74.0	180	2.0	180
00:16:40	1	-257	26	0	0.87	0.04	-0.06	000	0.640	-20.0	74.0	180	2.0	180
00:16:50	1	-252	26	0	0.85	0.00	0.00	000	0.030	-22.6	74.0	180	2.0	180
00:17:00	1	-248	26	0	0.83	-0.03	0.05	000	-0.518	-21.2	74.0	180	2.0	180
00:17:10	1	-244	26	0	0.81	-0.05	0.10	000	-0.974	-18.3	74.0	180	2.0	180
00:17:20	1	-240	26	0	0.79	-0.07	0.13	360	-1.315	-14.4	74.0	180	2.0	180
00:17:30	1	-236	26	0	0.77	-0.09	0.16	360	-1.531	-9.6	74.0	180	2.0	180
00:17:40	1	-232	26	0	0.75	-0.09	0.17	359	-1.621	-4.8	74.0	180	2.0	180
00:17:50	1	-228	26	0	0.73	-0.09	0.16	359	-1.593	0.2	74.0	180	2.0	180
00:18:00	2	-224	26	0	0.72	-0.08	0.15	359	-1.463	4.7	74.0	180	2.0	180
00:18:10	2	-220	26	0	0.70	-0.07	0.13	359	-1.251	8.3	74.0	180	2.0	180
00:18:20	2	-217	26	0	0.68	-0.05	0.10	358	-0.981	11.3	74.0	180	2.0	180
00:18:30	2	-213	26	0	0.66	-0.04	0.07	358	-0.676	13.6	66.0	180	2.0	180
00:18:40	2	-210	26	0	0.65	-0.02	0.04	358	-0.362	14.2	66.0	180	2.0	180
00:18:50	2	-207	26	0	0.64	-0.01	0.00	358	-0.057	14.7	66.0	180	2.0	180
00:19:00	1	-203	26	0	0.63	0.01	-0.03	358	0.221	13.7	66.0	180	2.0	180
00:19:10	1	-200	26	0	0.62	0.02	-0.05	358	0.453	12.1	66.0	180	2.0	180
00:19:20	1	-197	26	0	0.61	0.04	-0.09	358	0.830	27.7	66.0	180	2.0	180
00:19:30	1	-194	26	0	0.59	0.07	-0.14	359	1.330	23.4	66.0	180	2.0	180
00:19:40	1	-191	26	0	0.58	0.09	-0.18	359	1.689	18.1	66.0	180	2.0	180
00:19:50	0	-188	26	0	0.57	0.10	-0.20	359	1.898	12.4	66.0	180	2.0	180
00:20:00	0	-185	26	0	0.56	0.10	-0.21	359	1.961	6.1	66.0	180	2.0	180
00:20:10	0	-182	26	0	0.55	0.09	-0.20	360	1.891	0.4	66.0	180	2.0	180
00:20:20	-1	-179	26	0	0.54	0.08	-0.19	000	1.709	-4.8	66.0	180	2.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:20:30	-1	-177	26	0	0.52	0.07	-0.16	000	1.441	-8.9	76.0	180	0	000	2.0	180
00:20:40	-1	-174	26	0	0.50	0.05	-0.13	001	1.165	-2.7	76.0	180	0	000	2.0	180
00:20:50	-1	-172	26	0	0.49	0.05	-0.13	001	1.170	2.2	76.0	180	0	000	2.0	180
00:21:00	-1	-169	26	0	0.47	0.05	-0.13	001	1.131	-1.1	76.0	180	0	000	2.0	180
00:21:10	-2	-167	26	0	0.46	0.05	-0.11	001	1.021	-4.3	63.0	180	0	000	2.0	180
00:21:20	-2	-164	26	0	0.45	0.04	-0.10	001	0.860	-6.8	63.0	180	0	000	2.0	180
00:21:30	-2	-162	26	0	0.45	0.03	-0.08	001	0.664	-8.5	52.0	180	0	000	2.0	180
00:21:40	-2	-160	26	0	0.45	0.02	-0.05	001	0.449	-9.6	52.0	180	0	000	2.0	180
00:21:50	-2	-157	26	0	0.45	0.01	-0.03	002	0.232	-10.2	52.0	180	0	000	2.0	180
00:22:00	-2	-155	26	0	0.45	0.00	-0.01	002	0.025	-10.2	52.0	180	0	000	2.0	180
00:22:10	-2	-153	26	0	0.45	-0.01	0.02	002	-0.188	-16.0	52.0	180	0	000	2.0	180
00:22:20	-2	-151	26	0	0.45	-0.04	0.07	001	-0.676	-24.7	52.0	180	0	000	2.0	180
00:22:30	-1	-148	26	0	0.45	-0.06	0.11	001	-1.124	-20.8	52.0	180	0	000	2.0	180
00:22:40	-1	-146	26	0	0.44	-0.08	0.15	001	-1.449	-16.4	52.0	180	0	000	2.0	180
00:22:50	-1	-144	26	0	0.44	-0.09	0.17	001	-1.644	-10.9	52.0	180	0	000	2.0	180
00:23:00	-1	-141	26	0	0.45	-0.09	0.18	001	-1.713	-5.7	52.0	180	0	000	2.0	180
00:23:10	-1	-139	26	0	0.44	-0.09	0.17	000	-1.667	-0.6	76.0	180	0	000	2.0	180
00:23:20	0	-137	26	0	0.43	-0.08	0.16	000	-1.523	3.6	76.0	180	0	000	2.0	180
00:23:30	0	-135	26	0	0.41	-0.07	0.14	360	-1.301	7.7	76.0	180	0	000	2.0	180
00:23:40	0	-133	26	0	0.39	-0.05	0.11	360	-1.025	10.4	76.0	180	0	000	2.0	180
00:23:50	0	-131	26	0	0.38	-0.03	0.08	359	-0.722	12.4	67.0	180	0	000	2.0	180
00:24:00	0	-129	26	0	0.37	-0.01	0.05	359	-0.413	13.2	67.0	180	0	000	2.0	180
00:24:10	0	-127	26	0	0.36	0.00	0.02	359	-0.122	12.8	67.0	180	0	000	2.0	180
00:24:20	0	-125	26	0	0.35	0.02	-0.01	359	0.138	11.9	67.0	180	0	000	2.0	180
00:24:30	0	-123	26	0	0.34	0.03	-0.03	359	0.355	10.6	67.0	180	0	000	2.0	180
00:24:40	0	-121	26	0	0.33	0.04	-0.05	359	0.520	8.9	67.0	180	0	000	2.0	180
00:24:50	0	-120	26	0	0.32	0.04	-0.06	360	0.630	6.7	79.0	180	0	000	2.0	180
00:25:00	0	-118	26	0	0.30	0.05	-0.06	360	0.684	4.1	79.0	180	0	000	2.0	180
00:25:10	0	-117	26	0	0.29	0.04	-0.06	360	0.687	1.7	70.0	180	0	000	2.0	180
00:25:20	0	-115	26	0	0.28	0.04	-0.06	360	0.645	0.1	63.0	180	0	000	2.0	180
00:25:30	0	-114	26	0	0.27	0.04	-0.05	360	0.571	-1.3	63.0	180	0	000	2.0	180
00:25:40	0	-112	26	0	0.27	0.03	-0.04	000	0.474	-2.7	63.0	180	0	000	2.0	180
00:25:50	0	-111	26	0	0.26	0.02	-0.03	000	0.364	-3.3	63.0	180	0	000	2.0	180
00:26:00	0	-110	26	0	0.26	0.02	-0.02	000	0.247	-3.9	63.0	180	0	000	2.0	180
00:26:10	0	-108	26	0	0.26	0.01	-0.01	000	0.135	-4.0	63.0	180	0	000	2.0	180
00:26:20	0	-107	26	0	0.25	0.00	0.00	000	0.033	-4.1	63.0	180	0	000	2.0	180
00:26:30	0	-106	26	0	0.25	0.00	0.01	000	-0.060	-3.7	63.0	180	0	000	2.0	180
00:26:40	0	-104	26	0	0.24	0.00	0.02	000	-0.127	-2.8	63.0	180	0	000	2.0	180
00:26:50	0	-103	26	0	0.24	-0.01	0.02	000	-0.178	-1.9	63.0	180	0	000	2.0	180
00:27:00	0	-102	26	0	0.23	-0.01	0.02	000	-0.210	-1.2	63.0	180	0	000	2.0	180
00:27:10	0	-101	26	0	0.23	-0.01	0.03	000	-0.223	-0.5	63.0	180	0	000	2.0	180
00:27:20	0	-100	26	0	0.22	-0.01	0.03	000	-0.223	0.1	63.0	180	0	000	2.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

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00:27:30

00:08 Start Time [hrs:min:sec]: 00:08:20
00:08 End Time [hrs:min:sec]: 00:27:30
00:08 Delta Plot Time [sec]: 30
00:08 East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

Date: 03-Feb-99 Time: 10:06:49

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 13

Date: 3 February 1999

Start Time: 10:46

Length of run [secs]: 1785

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 20 Direction: 0

Sea State, Significant wave height [m]:.. 3 Direction: 180

Current Speed [knots]:..... 0 Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 1.25

Evaluation:

Successful run.

Everything worked out okay.

A quicker response of the autopilot might help the course keeping.

The deceleration plan worked out well, 0.3 knots at mating.

Shiphandling Simulator

Exercise date & time: 03-Feb-99

10:46:47

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run #13

Time HH:MM:SS	Position (m)		RPM	Speed (Knots)			Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Port	Stbd	Long			%	Deg	Knots	Deg	Knots	Deg
00:08:20	0	-873	28	0	2.76	0.00	0.01	360	-0.050	0.6	100.0	180	22	000
00:08:30	0	-859	28	0	2.69	0.00	0.01	360	-0.043	0.6	55.0	180	23	000
00:08:40	0	-845	28	0	2.67	0.00	0.01	360	-0.034	1.1	47.0	180	17	000
00:08:50	0	-832	28	0	2.64	0.00	0.00	360	-0.014	1.1	47.0	180	20	000
00:09:00	0	-818	28	0	2.63	0.00	0.00	360	0.003	1.1	76.0	180	15	000
00:09:10	0	-805	28	0	2.61	0.00	0.00	360	0.021	1.1	76.0	180	14	000
00:09:20	0	-791	28	0	2.54	0.00	0.00	360	0.035	0.5	76.0	180	13	000
00:09:30	0	-778	28	0	2.50	0.00	0.00	360	0.036	0.5	76.0	180	20	000
00:09:40	0	-766	28	0	2.45	0.01	0.00	360	0.065	5.8	76.0	180	18	000
00:09:50	0	-753	28	0	2.39	0.01	-0.01	360	0.080	0.5	76.0	180	20	000
00:10:00	0	-741	28	0	2.36	0.01	0.00	360	0.069	0.0	76.0	180	17	000
00:10:10	0	-729	28	0	2.33	0.00	0.00	000	0.055	0.0	76.0	180	18	000
00:10:20	0	-717	28	0	2.31	0.00	0.00	000	0.041	0.0	76.0	180	16	000
00:10:30	0	-705	28	0	2.30	0.00	0.00	000	0.027	-0.6	76.0	180	19	000
00:10:40	0	-693	28	0	2.26	0.00	0.00	000	0.003	-0.6	76.0	180	17	000
00:10:50	0	-682	28	0	2.22	0.00	0.00	000	-0.021	-0.6	50.0	180	20	000
00:11:00	0	-670	28	0	2.23	0.00	0.01	000	-0.034	0.0	50.0	180	19	000
00:11:10	0	-659	28	0	2.22	0.00	0.01	000	-0.041	0.0	50.0	180	21	000
00:11:20	0	-647	28	0	2.20	0.00	0.01	000	-0.048	0.0	50.0	180	20	000
00:11:30	0	-636	28	0	2.18	0.00	0.01	360	-0.054	0.0	50.0	180	23	000
00:11:40	0	-625	28	0	2.16	0.00	0.01	360	-0.055	0.6	50.0	180	22	000
00:11:50	0	-614	28	0	2.12	0.00	0.01	360	-0.048	0.6	50.0	180	23	000
00:12:00	0	-603	28	0	2.08	0.00	0.01	360	-0.041	0.6	50.0	180	20	000
00:12:10	0	-593	28	0	2.05	0.00	0.01	360	-0.035	0.6	50.0	180	19	000
00:12:20	0	-582	28	0	2.06	0.00	0.01	360	-0.028	0.6	50.0	180	18	000
00:12:30	0	-571	28	0	2.05	0.00	0.00	360	-0.010	1.1	50.0	180	18	000
00:12:40	0	-561	28	0	2.04	0.00	0.00	360	-0.007	1.1	50.0	180	17	000
00:12:50	0	-550	28	0	2.04	0.00	0.00	360	0.023	1.1	50.0	180	19	000
00:13:00	0	-540	28	0	2.01	0.00	0.00	360	0.027	0.5	75.0	180	18	000
00:13:10	0	-530	28	0	2.00	0.00	0.00	360	0.028	0.5	75.0	180	14	000
00:13:20	0	-519	28	0	1.97	0.01	0.00	360	0.065	0.5	75.0	180	15	000
00:13:30	0	-509	28	0	1.95	0.01	0.00	360	0.064	0.5	75.0	180	17	000
00:13:40	0	-499	28	0	1.93	0.00	0.00	360	0.055	0.0	75.0	180	18	000
00:13:50	0	-489	28	0	1.90	0.00	0.00	000	0.042	0.0	75.0	180	18	000
00:14:00	0	-480	28	0	1.84	0.00	0.00	000	0.030	0.0	52.0	180	21	000
00:14:10	0	-470	28	0	1.81	0.00	0.00	000	0.018	0.0	52.0	180	18	000
00:14:20	0	-461	28	0	1.80	0.00	0.00	000	0.008	0.0	52.0	180	18	000
00:14:30	0	-452	28	0	1.78	0.00	0.00	000	-0.002	0.0	52.0	180	17	000
00:14:40	0	-443	28	0	1.78	0.00	0.00	000	-0.011	0.0	52.0	180	16	000
00:14:50	0	-434	28	0	1.77	0.00	0.00	000	-0.019	0.0	52.0	180	16	000
00:15:00	0	-425	28	0	1.77	0.00	0.00	000	-0.027	0.0	52.0	180	24	000
00:15:10	0	-416	28	0	1.74	0.00	0.01	000	-0.034	0.0	52.0	180	22	000
00:15:20	0	-407	28	0	1.73	0.00	0.01	360	-0.044	-1.9	52.0	180	20	000
00:15:30	0	-398	28	0	1.74	-0.02	0.03	360	-0.319	-17.2	52.0	180	20	000
00:15:40	0	-389	28	0	1.73	-0.04	0.07	360	-0.701	-15.3	52.0	180	23	000
00:15:50	1	-380	28	0	1.74	-0.06	0.10	360	-1.009	-12.8	52.0	180	17	000
00:16:00	1	-371	28	0	1.71	-0.07	0.13	360	-1.229	-9.3	77.0	180	19	000
00:16:10	1	-362	28	0	1.64	-0.07	0.14	359	-1.351	-5.2	100.0	180	16	000
00:16:20	1	-354	28	0	1.58	-0.07	0.14	359	-1.380	-1.2	100.0	180	17	000
00:16:30	1	-346	28	0	1.52	-0.07	0.14	359	-1.316	3.3	100.0	180	17	000
00:16:40	1	-338	28	0	1.45	-0.05	0.12	359	-1.110	6.5	100.0	180	21	000
00:16:50	1	-331	28	0	1.41	-0.04	0.10	359	-0.886	9.7	100.0	180	15	000
00:17:00	1	-324	28	0	1.37	-0.03	0.07	358	-0.657	11.8	100.0	180	20	000
00:17:10	1	-317	28	0	1.30	-0.01	0.04	358	-0.310	20.4	100.0	180	24	000
00:17:20	0	-311	28	0	1.24	0.02	-0.02	358	0.287	30.7	100.0	180	22	000
00:17:30	0	-304	28	0	1.19	0.06	-0.08	358	0.897	28.4	100.0	180	14	000
00:17:40	0	-298	28	0	1.18	0.08	-0.14	359	1.395	24.0	75.0	180	18	000
00:17:50	0	-292	28	0	1.16	0.11	-0.19	359	1.901	34.5	75.0	180	17	000
00:18:00	-1	-286	28	0	1.15	0.14	-0.25	359	2.495	29.5	75.0	180	18	000
00:18:10	-1	-280	28	0	1.12	0.16	-0.30	360	2.894	21.2	75.0	180	19	000
00:18:20	-1	-275	28	0	1.09	0.16	-0.32	000	3.076	11.9	75.0	180	20	000
00:18:30	-2	-269	28	0	1.05	0.16	-0.32	001	3.054	2.3	75.0	180	17	000
00:18:40	-2	-264	28	0	1.01	0.14	-0.30	001	2.845	-6.6	75.0	180	22	000
00:18:50	-2	-259	28	0	0.97	0.12	-0.27	002	2.461	-14.2	75.0	180	18	000
00:19:00	-3	-254	28	0	0.97	0.09	-0.22	002	1.966	-20.3	75.0	180	13	000
00:19:10	-3	-249	28	0	0.93	0.06	-0.16	002	1.398	-24.8	75.0	180	16	000
00:19:20	-3	-244	28	0	0.89	0.02	-0.10	002	0.750	-27.5	75.0	180	23	000
00:19:30	-3	-240	28	0	0.86	-0.01	-0.04	003	0.165	-27.8	100.0	180	18	000
00:19:40	-3	-235	28	0	0.80	-0.03	0.02	003	-0.364	-27.1	100.0	180	16	000
00:19:50	-2	-231	38	0	0.77	-0.08	0.10	002	-1.119	-23.6	100.0	180	17	000
00:20:00	-2	-227	38	0	0.77	-0.12	0.17	002	-1.878	-18.0	100.0	180	18	000
00:20:10	-2	-223	38	0	0.78	-0.14	0.22	002	-2.260	-11.2	100.0	180	18	000
00:20:20	-2	-219	38	0	0.77	-0.14	0.24	001	-2.381	-3.8	100.0	180	21	000

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg	
00:20:30	-1	-215	38	0	0.74	-0.14	0.27	001	-2.638	-13.8	100.0	180	19	000	0.0	180
00:20:40	-1	-212	38	0	0.71	-0.15	0.29	001	-2.815	-5.0	100.0	180	20	000	0.0	180
00:20:50	0	-208	38	0	0.69	-0.14	0.28	000	-2.668	2.9	100.0	180	25	000	0.0	180
00:21:00	0	-205	35	0	0.67	-0.11	0.24	360	-2.253	10.1	100.0	180	22	000	0.0	180
00:21:10	0	-201	29	0	0.62	-0.08	0.20	359	-1.827	15.3	100.0	180	17	000	0.0	180
00:21:20	1	-198	29	0	0.57	-0.05	0.16	359	-1.340	19.6	100.0	180	20	000	0.0	180
00:21:30	1	-195	29	0	0.51	-0.02	0.11	359	-0.826	22.2	100.0	180	24	000	0.0	180
00:21:40	1	-193	29	0	0.49	0.00	0.05	359	-0.312	22.7	73.0	180	18	000	0.0	180
00:21:50	1	-190	29	0	0.47	0.03	0.00	359	0.190	21.5	53.0	180	16	000	0.0	180
00:22:00	1	-188	29	0	0.45	0.06	-0.04	359	0.652	19.1	53.0	180	15	000	0.0	180
00:22:10	1	-186	33	0	0.51	0.08	-0.08	359	1.041	16.2	53.0	180	17	000	0.0	180
00:22:20	1	-183	33	0	0.51	0.10	-0.12	359	1.365	11.5	75.0	180	19	000	0.0	180
00:22:30	1	-180	33	0	0.51	0.11	-0.14	359	1.540	6.7	75.0	180	21	000	0.0	180
00:22:40	1	-178	33	0	0.51	0.11	-0.14	360	1.567	2.0	75.0	180	16	000	0.0	180
00:22:50	1	-175	33	0	0.51	0.10	-0.13	360	1.455	-2.3	75.0	180	18	000	0.0	180
00:23:00	0	-172	33	0	0.49	0.08	-0.11	000	1.190	-13.4	75.0	180	17	000	0.0	180
00:23:10	0	-170	33	0	0.48	0.04	-0.04	000	0.491	-24.9	75.0	180	15	000	0.0	180
00:23:20	0	-168	33	0	0.47	0.00	0.03	000	-0.212	-17.2	75.0	180	10	000	0.0	180
00:23:30	1	-165	33	0	0.47	-0.02	0.05	000	-0.452	-3.9	75.0	180	17	000	0.0	180
00:23:40	1	-163	33	0	0.45	-0.02	0.06	000	-0.518	-2.0	75.0	180	19	000	0.0	180
00:23:50	1	-160	33	0	0.43	-0.03	0.08	000	-0.667	-13.8	75.0	180	23	000	0.0	180
00:24:00	1	-158	33	0	0.41	-0.05	0.12	360	-1.101	-14.3	75.0	180	20	000	0.0	180
00:24:10	1	-156	33	0	0.40	-0.07	0.15	360	-1.396	-9.4	75.0	180	21	000	0.0	180
00:24:20	1	-154	33	0	0.42	-0.08	0.16	359	-1.539	-4.7	75.0	180	20	000	0.0	180
00:24:30	2	-152	33	0	0.42	-0.08	0.16	359	-1.531	-0.2	75.0	180	23	000	0.0	180
00:24:40	2	-150	29	0	0.42	-0.07	0.15	359	-1.421	4.0	75.0	180	19	000	0.0	180
00:24:50	2	-148	27	0	0.42	-0.07	0.14	359	-1.286	7.6	75.0	180	20	000	0.0	180
00:25:00	2	-145	27	0	0.39	-0.06	0.11	359	-1.111	11.2	75.0	180	19	000	0.0	180
00:25:10	2	-144	27	0	0.35	-0.05	0.08	358	-0.830	18.4	75.0	180	21	000	0.0	180
00:25:20	2	-142	27	0	0.34	-0.02	0.03	358	-0.302	31.5	51.0	180	18	000	0.0	180
00:25:30	2	-140	27	0	0.34	0.01	-0.03	358	0.250	30.1	51.0	180	19	000	0.0	180
00:25:40	2	-138	27	0	0.32	0.04	-0.08	358	0.753	26.5	51.0	180	18	000	0.0	180
00:25:50	2	-137	27	0	0.31	0.06	-0.12	359	1.163	22.1	51.0	180	22	000	0.0	180
00:26:00	1	-135	27	0	0.29	0.07	-0.16	359	1.432	16.8	28.0	180	19	000	0.0	180
00:26:10	1	-134	27	0	0.29	0.07	-0.17	359	1.541	1.6	28.0	180	18	000	0.0	180
00:26:20	1	-132	27	0	0.29	0.06	-0.15	359	1.329	-9.9	28.0	180	15	000	0.0	180
00:26:30	1	-131	27	0	0.30	0.04	-0.12	359	1.040	-12.0	0.0	180	18	000	0.0	180
00:26:40	0	-129	27	0	0.33	0.02	-0.09	360	0.734	-13.3	26.0	180	17	000	0.0	180
00:26:50	0	-127	27	0	0.35	0.00	-0.06	360	0.414	-13.8	26.0	180	18	000	0.0	180
00:27:00	0	-125	27	0	0.37	-0.02	-0.03	360	0.102	-13.9	26.0	180	19	000	0.0	180
00:27:10	0	-124	27	0	0.36	-0.03	0.00	360	-0.181	-12.4	26.0	180	19	000	0.0	180
00:27:20	0	-122	27	0	0.37	-0.05	0.02	360	-0.429	-11.0	26.0	180	17	000	0.0	180
00:27:30	0	-120	27	0	0.39	-0.06	0.04	360	-0.625	-8.8	26.0	180	18	000	0.0	180
00:27:40	0	-118	27	0	0.41	-0.07	0.05	359	-0.776	-6.2	26.0	180	17	000	0.0	180
00:27:50	0	-116	27	0	0.38	-0.08	0.06	359	-0.853	-3.6	51.0	180	18	000	0.0	180
00:28:00	0	-114	27	0	0.39	-0.08	0.06	359	-0.906	-0.7	51.0	180	22	000	0.0	180
00:28:10	0	-112	27	0	0.37	-0.08	0.05	359	-0.802	14.7	51.0	180	22	000	0.0	180
00:28:20	-1	-110	27	0	0.33	-0.05	0.00	359	-0.310	33.7	51.0	180	18	000	0.0	180
00:28:30	-1	-108	27	0	0.32	-0.01	-0.07	359	0.371	35.0	51.0	180	17	000	0.0	180
00:28:40	-1	-107	27	0	0.31	0.03	-0.13	359	1.024	35.0	51.0	180	17	000	0.0	180
00:28:50	-1	-105	27	0	0.31	0.07	-0.19	359	1.650	35.0	51.0	180	13	000	0.0	180
00:29:00	-2	-103	27	0	0.32	0.10	-0.25	360	2.252	35.0	51.0	180	17	000	0.0	180
00:29:10	-2	-102	27	0	0.31	0.14	-0.31	000	2.813	35.0	51.0	180	20	000	0.0	180
00:29:20	-3	-100	27	0	0.30	0.17	-0.36	001	3.333	31.9	51.0	180	20	000	0.0	180
00:29:30	-3	-99	27	0	0.28	0.20	-0.39	001	3.735	19.1	51.0	180	19	000	0.0	180
00:29:40	-3	-97	27	0	0.21	0.24	-0.40	002	4.025	1.8	6.0	180	23	000	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

00:17:50
00:17:20
00:16:50
00:16:20
00:15:50
00:15:20
00:14:50
00:14:20
00:13:50

00:1 Start Time [hrs:min:sec]: 00:08:20
00:1 End Time [hrs:min:sec]: 00:29:45
00:1 Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
00:1 East-West Scale [Nm]: 0.5000

Date: 03-Feb-99 Time: 10:46:47

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 14
Start Time: 11:27
Length of run [secs]: 3310

Date: 3 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	20	Direction: 0
Sea State, Significant wave height [m]:..	3	Direction: 180
Current Speed [knots]:.....	0	Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.9

Evaluation:

Deceleration phase went well.

On the final closure the buoy did not center quite as well as desired (about 5 m off). The captain released the buoy and maneuvered back. In repositioning the ship it was necessary to maintain heading control within 10 degrees of the up force direction. In order to do this, it was necessary to use propeller, rudder and thruster. The mating was tried three times with the final mating with the buoy 2.9 m off center.

Shiphandling Simulator

Exercise date & time: 03-Feb-99
11:27:14

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 14**

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North		Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:30:00	1	-179	25	0	0.57	0.01	0.01	000	0.032	-23.1	51.0	180	20	000	0.0	180
00:30:10	1	-176	25	0	0.57	-0.01	0.05	000	-0.361	-22.3	51.0	180	20	000	0.0	180
00:30:20	1	-173	25	0	0.53	-0.03	0.08	000	-0.706	-19.8	51.0	180	20	000	0.0	180
00:30:30	1	-171	25	0	0.49	-0.05	0.11	000	-0.994	-16.2	51.0	180	16	000	0.0	180
00:30:40	1	-168	25	0	0.48	-0.06	0.13	360	-1.206	-12.3	51.0	180	21	000	0.0	180
00:30:50	2	-166	25	0	0.47	-0.07	0.15	360	-1.344	-8.0	51.0	180	18	000	0.0	180
00:31:00	2	-164	25	0	0.45	-0.07	0.15	359	-1.386	-3.7	51.0	180	18	000	0.0	180
00:31:10	2	-161	25	0	0.45	-0.07	0.15	359	-1.368	0.2	51.0	180	22	000	0.0	180
00:31:20	2	-159	25	0	0.45	-0.06	0.14	359	-1.306	4.0	51.0	180	25	000	0.0	180
00:31:30	2	-157	25	0	0.44	-0.06	0.13	359	-1.175	7.7	51.0	180	16	000	0.0	180
00:31:40	2	-154	25	0	0.42	-0.05	0.11	359	-0.997	10.7	51.0	180	17	000	0.0	180
00:31:50	2	-152	25	0	0.43	-0.04	0.09	358	-0.794	12.9	51.0	180	15	000	0.0	180
00:32:00	3	-150	25	0	0.43	-0.02	0.06	358	-0.545	13.9	51.0	180	15	000	0.0	180
00:32:10	3	-148	25	0	0.45	-0.02	0.04	358	-0.355	15.0	51.0	180	14	000	0.0	180
00:32:20	2	-145	25	0	0.43	-0.01	0.01	358	-0.137	15.0	51.0	180	19	000	0.0	180
00:32:30	2	-143	25	0	0.41	0.00	-0.01	358	0.061	14.5	51.0	180	15	000	0.0	180
00:32:40	2	-141	25	0	0.38	0.00	-0.04	358	0.213	14.0	51.0	180	19	000	0.0	180
00:32:50	2	-139	25	0	0.37	0.00	-0.06	358	0.359	12.4	51.0	180	20	000	0.0	180
00:33:00	2	-137	25	0	0.34	0.01	-0.07	358	0.546	10.5	51.0	180	17	000	0.0	180
00:33:10	2	-136	25	0	0.33	0.02	-0.08	358	0.659	7.8	51.0	180	13	000	0.0	180
00:33:20	1	-134	25	0	0.34	0.03	-0.10	359	0.804	19.9	51.0	180	23	000	0.0	180
00:33:30	1	-132	25	0	0.32	0.04	-0.13	359	1.099	19.6	51.0	180	23	000	0.0	180
00:33:40	1	-131	25	0	0.30	0.05	-0.16	359	1.313	14.5	51.0	180	20	000	0.0	180
00:33:50	1	-129	25	0	0.29	0.06	-0.17	359	1.447	10.0	51.0	180	19	000	0.0	180
00:34:00	0	-128	25	0	0.30	0.06	-0.18	359	1.477	5.5	51.0	180	21	000	0.0	180
00:34:10	0	-126	25	0	0.30	0.06	-0.17	360	1.459	1.0	51.0	180	19	000	0.0	180
00:34:20	0	-125	25	0	0.31	0.05	-0.17	360	1.364	-2.9	51.0	180	22	000	0.0	180
00:34:30	-1	-123	25	0	0.30	0.04	-0.15	000	1.219	-5.8	51.0	180	20	000	0.0	180
00:34:40	-1	-122	25	0	0.29	0.03	-0.13	000	1.032	-9.2	51.0	180	18	000	0.0	180
00:34:50	-1	-120	25	0	0.27	0.02	-0.11	000	0.823	-10.8	36.0	180	21	000	0.0	180
00:35:00	-1	-119	25	0	0.25	0.00	-0.09	001	0.587	-12.4	36.0	180	23	000	0.0	180
00:35:10	-2	-118	25	0	0.24	-0.01	-0.06	001	0.335	-12.9	36.0	180	17	000	0.0	180
00:35:20	-2	-116	25	0	0.25	-0.02	-0.04	001	0.108	-12.4	36.0	180	15	000	0.0	180
00:35:30	-2	-115	25	0	0.24	-0.03	-0.02	001	-0.095	-11.4	36.0	180	20	000	0.0	180
00:35:40	-2	-114	25	0	0.23	-0.04	0.00	001	-0.290	-9.8	36.0	180	19	000	0.0	180
00:35:50	-2	-113	25	0	0.21	-0.05	0.02	001	-0.426	-7.8	36.0	180	15	000	0.0	180
00:36:00	-2	-112	25	0	0.23	-0.06	0.03	000	-0.526	-6.3	36.0	180	13	000	0.0	180
00:36:10	-2	-110	25	0	0.23	-0.06	0.04	000	-0.603	-4.3	26.0	180	14	000	0.0	180
00:36:20	-2	-109	25	0	0.24	-0.06	0.04	000	-0.640	-1.9	26.0	180	16	000	0.0	180
00:36:30	-2	-108	25	0	0.28	-0.05	0.03	000	-0.508	16.1	26.0	180	21	000	0.0	180
00:36:40	-2	-106	25	0	0.30	-0.03	0.00	000	-0.204	16.6	0.0	180	19	000	0.0	180
00:36:50	-2	-105	25	0	0.28	-0.02	-0.03	000	0.077	19.0	0.0	180	20	000	0.0	180
00:37:00	-3	-103	25	0	0.29	0.01	-0.07	000	0.559	35.0	0.0	180	22	000	0.0	180
00:37:10	-3	-102	25	0	0.27	0.05	-0.13	000	1.134	35.0	0.0	180	22	000	0.0	180
00:37:20	-3	-101	25	0	0.27	0.08	-0.18	001	1.687	35.0	0.0	180	14	000	0.0	180
00:37:30	-3	-99	25	0	0.27	0.12	-0.23	001	2.220	35.0	0.0	180	15	000	0.0	180
00:37:40	-4	-98	25	0	0.21	0.16	-0.29	001	2.847	35.0	0.0	180	18	000	0.0	180
00:37:50	-4	-97	25	0	0.13	0.22	-0.33	002	3.483	35.0	0.0	180	23	000	0.0	180
00:38:00	-4	-96	25	0	0.13	0.25	-0.37	002	3.953	35.0	0.0	180	20	000	0.0	180
00:38:10	-4	-96	25	0	0.10	0.28	-0.41	003	4.368	35.0	50.0	180	20	000	0.0	180
00:38:20	-5	-95	25	0	0.06	0.29	-0.43	004	4.612	35.0	99.0	180	18	000	0.0	180
00:38:30	-5	-95	25	0	0.04	0.32	-0.45	005	4.936	35.0	99.0	180	22	000	0.0	180
00:38:40	-5	-95	0	0	-0.01	0.34	-0.44	006	4.951	16.7	99.0	180	19	000	0.0	180
00:38:50	-6	-95	0	0	-0.06	0.32	-0.43	006	4.730	13.3	99.0	212	18	000	0.0	180
00:39:00	-6	-95	0	0	-0.15	0.31	-0.42	007	4.609	32.3	99.0	212	16	000	0.0	180
00:39:10	-6	-96	0	0	-0.18	0.32	-0.41	008	4.687	27.2	99.0	244	21	000	0.0	180
00:39:20	-7	-97	0	0	-0.23	0.31	-0.41	009	4.602	19.7	99.0	266	18	000	0.0	180
00:39:30	-7	-99	0	0	-0.28	0.30	-0.41	009	4.511	10.4	99.0	266	18	000	0.0	180
00:39:40	-8	-100	0	0	-0.29	0.25	-0.41	010	4.241	-0.9	99.0	266	16	000	0.0	180
00:39:50	-9	-101	33	0	-0.28	0.24	-0.41	011	4.076	-12.8	99.0	266	22	000	0.0	180
00:40:00	-9	-103	33	0	-0.30	0.22	-0.36	011	3.687	-22.5	99.0	214	22	000	0.0	180
00:40:10	-10	-104	33	0	-0.34	0.19	-0.29	012	3.051	-29.2	99.0	214	22	000	0.0	180
00:40:20	-10	-106	33	0	-0.36	0.14	-0.21	012	2.199	-33.7	99.0	272	16	000	0.0	180
00:40:30	-11	-108	43	0	-0.32	0.01	-0.09	013	0.637	-33.4	99.0	272	19	000	0.0	180
00:40:40	-12	-109	49	0	-0.23	-0.11	0.07	013	-1.140	-24.9	99.0	272	19	000	0.0	180
00:40:50	-12	-110	43	0	-0.13	-0.21	0.16	012	-2.403	-6.9	99.0	272	20	000	0.0	180
00:41:00	-12	-110	30	0	-0.07	-0.27	0.15	012	-2.691	12.1	99.0	272	17	000	0.0	180
00:41:10	-13	-111	30	0	-0.05	-0.20	0.09	012	-1.842	20.9	99.0	211	19	000	0.0	180
00:41:20	-13	-111	30	0	-0.08	-0.13	0.05	011	-1.187	9.6	99.0	211	16	000	0.0	180
00:41:30	-13	-111	30	0	-0.11	-0.10	0.03	011	-0.851	5.7	99.0	211	18	000	0.0	180
00:41:40	-13	-112	30	0	-0.15	-0.10	0.01	011	-0.676	5.3	99.0	211	15	000	0.0	180
00:41:50	-14	-113	30	0	-0.13	-0.06	-0.01	011	-0.298	3.8	99.0	304	14	000	0.0	180
00:42:00	-14	-113	42	0	-0.06	-0.06	-0.04	011	-0.168	4.3	99.0	304	18	000	0.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg
00:42:10	-14	-113	43	0	0.02	-0.05	-0.06	011	0.031	1.6	99.0	304	23	000	0.0
00:42:20	-15	-113	42	0	0.08	-0.05	-0.07	011	0.136	0.1	99.0	239	20	000	0.0
00:42:30	-15	-112	42	0	0.11	-0.05	-0.08	011	0.191	-0.7	99.0	239	17	000	0.0
00:42:40	-15	-112	42	0	0.13	-0.07	-0.08	011	0.061	-3.4	99.0	239	19	000	0.0
00:42:50	-15	-111	43	0	0.17	-0.16	-0.02	011	-0.898	-22.4	99.0	239	18	000	0.0
00:43:00	-16	-110	43	0	0.21	-0.28	0.12	011	-2.538	-35.0	99.0	239	17	000	0.0
00:43:10	-16	-109	43	0	0.24	-0.41	0.27	010	-4.328	-35.0	99.0	239	20	000	0.0
00:43:20	-16	-107	43	0	0.28	-0.48	0.40	009	-5.599	-35.0	99.0	239	21	000	0.0
00:43:30	-16	-106	43	0	0.29	-0.56	0.53	008	-6.914	-35.0	99.0	239	21	000	0.0
00:43:40	-16	-104	43	0	0.31	-0.63	0.61	007	-7.870	-20.7	99.0	239	25	000	0.0
00:43:50	-15	-103	42	0	0.35	-0.57	0.62	006	-7.509	-1.7	99.0	116	22	000	0.0
00:44:00	-15	-101	42	0	0.39	-0.43	0.54	004	-6.180	17.3	99.0	146	19	000	0.0
00:44:10	-15	-99	25	0	0.34	-0.34	0.45	004	-5.053	35.0	99.0	146	20	000	0.0
00:44:20	-14	-97	25	0	0.30	-0.25	0.38	003	-3.958	35.0	99.0	167	22	000	0.0
00:44:30	-14	-96	25	0	0.25	-0.15	0.31	002	-2.945	35.0	99.0	145	15	000	0.0
00:44:40	-13	-95	25	0	0.18	-0.08	0.26	002	-2.142	19.3	99.0	145	16	000	0.0
00:44:50	-13	-94	25	0	0.12	-0.03	0.24	001	-1.739	0.3	99.0	145	16	000	0.0
00:45:00	-12	-93	25	0	0.09	-0.01	0.26	001	-1.687	-18.7	99.0	145	15	000	0.0
00:45:10	-11	-93	25	0	0.06	-0.01	0.30	001	-1.936	-35.0	99.0	145	15	000	0.0
00:45:20	-11	-93	25	0	0.02	-0.01	0.35	001	-2.254	-30.8	99.0	145	22	000	0.0
00:45:30	-10	-93	40	0	0.01	-0.01	0.41	000	-2.686	-22.9	99.0	145	18	000	0.0
00:45:40	-9	-93	42	0	0.02	-0.02	0.47	360	-3.112	-13.5	99.0	145	18	000	0.0
00:45:50	-7	-93	41	0	0.03	0.00	0.48	359	-3.097	-5.6	99.0	145	17	000	0.0
00:46:00	-6	-92	42	0	0.07	0.04	0.45	359	-2.619	9.9	99.0	145	17	000	0.0
00:46:10	-5	-92	42	0	0.08	0.10	0.40	358	-1.907	3.7	99.0	145	13	000	0.0
00:46:20	-4	-91	29	0	0.09	0.14	0.37	358	-1.447	6.4	99.0	145	21	000	0.0
00:46:30	-2	-91	26	0	0.07	0.17	0.35	358	-1.143	9.1	99.0	145	20	000	0.0
00:46:40	-1	-91	26	0	0.01	0.19	0.32	358	-0.839	10.6	99.0	145	20	000	0.0
00:46:50	0	-91	0	0	-0.06	0.22	0.31	358	-0.584	11.5	99.0	145	21	000	0.0
00:47:00	2	-91	0	0	-0.14	0.23	0.32	357	-0.550	12.8	99.0	145	23	000	0.0
00:47:10	3	-92	0	0	-0.20	0.25	0.32	357	-0.472	13.9	99.0	178	16	000	0.0
00:47:20	5	-93	0	0	-0.29	0.25	0.31	357	-0.388	14.6	99.0	178	20	000	0.0
00:47:30	6	-95	0	0	-0.36	0.24	0.30	357	-0.397	15.7	99.0	217	22	000	0.0
00:47:40	8	-97	0	0	-0.42	0.21	0.29	357	-0.491	16.9	99.0	217	21	000	0.0
00:47:50	9	-99	0	0	-0.41	0.16	0.27	357	-0.673	19.1	99.0	327	18	000	0.0
00:48:00	10	-101	0	0	-0.40	0.13	0.26	357	-0.782	21.8	99.0	327	22	000	0.0
00:48:10	11	-103	0	0	-0.35	0.10	0.24	357	-0.894	25.2	99.0	027	16	000	0.0
00:48:20	12	-105	0	0	-0.39	0.14	0.25	357	-0.708	26.7	99.0	145	17	000	0.0
00:48:30	13	-107	0	0	-0.43	0.15	0.25	357	-0.636	28.5	99.0	065	18	000	0.0
00:48:40	15	-109	0	0	-0.40	0.12	0.24	356	-0.788	30.8	99.0	304	18	000	0.0
00:48:50	16	-111	0	0	-0.41	0.06	0.22	356	-1.063	34.4	99.0	304	16	000	0.0
00:49:00	16	-113	0	0	-0.42	0.00	0.21	356	-1.309	35.0	99.0	304	22	000	0.0
00:49:10	17	-115	29	0	-0.39	-0.04	0.15	356	-1.192	30.7	99.0	304	19	000	0.0
00:49:20	17	-117	24	0	-0.37	-0.07	0.10	356	-1.048	11.7	99.0	304	16	000	0.0
00:49:30	17	-119	0	0	-0.36	-0.09	0.08	355	-1.093	-7.3	99.0	304	19	000	0.0
00:49:40	17	-120	30	0	-0.31	-0.17	0.10	355	-1.707	-26.3	99.0	304	23	000	0.0
00:49:50	17	-122	25	0	-0.26	-0.27	0.16	355	-2.782	-35.0	99.0	304	19	000	0.0
00:50:00	17	-123	25	0	-0.24	-0.35	0.22	354	-3.603	-34.5	99.0	304	17	000	0.0
00:50:10	17	-124	0	0	-0.22	-0.41	0.22	354	-4.022	-15.5	99.0	358	16	000	0.0
00:50:20	16	-125	32	0	-0.14	-0.44	0.23	353	-4.215	3.5	99.0	358	15	000	0.0
00:50:30	16	-126	32	0	-0.04	-0.42	0.20	352	-3.958	22.5	99.0	358	18	000	0.0
00:50:40	15	-126	32	0	0.04	-0.40	0.12	352	-3.301	26.3	99.0	358	20	000	0.0
00:50:50	14	-126	36	0	0.14	-0.36	0.03	351	-2.479	35.0	99.0	358	19	000	0.0
00:51:00	13	-125	42	0	0.23	-0.33	-0.10	351	-1.414	35.0	99.0	358	20	000	0.0
00:51:10	12	-124	41	0	0.32	-0.30	-0.25	351	-0.314	35.0	99.0	358	23	000	0.0
00:51:20	10	-122	33	0	0.37	-0.22	-0.39	351	1.092	35.0	99.0	096	17	000	0.0
00:51:30	8	-120	25	0	0.36	-0.16	-0.42	351	1.680	35.0	99.0	096	13	000	0.0
00:51:40	7	-119	25	0	0.35	-0.09	-0.45	351	2.287	35.0	99.0	096	14	000	0.0
00:51:50	5	-117	25	0	0.36	-0.04	-0.48	352	2.771	35.0	99.0	096	19	000	0.0
00:52:00	3	-116	27	0	0.33	0.02	-0.51	352	3.351	35.0	99.0	145	19	000	0.0
00:52:10	2	-114	27	0	0.27	0.07	-0.54	353	3.881	35.0	99.0	145	20	000	0.0
00:52:20	1	-113	27	0	0.25	0.09	-0.57	354	4.159	35.0	99.0	145	18	000	0.0
00:52:30	-1	-112	27	0	0.19	0.13	-0.59	354	4.535	35.0	99.0	145	22	000	0.0
00:52:40	-2	-111	27	0	0.16	0.18	-0.61	355	4.971	35.0	99.0	145	22	000	0.0
00:52:50	-3	-110	27	0	0.14	0.22	-0.62	356	5.327	35.0	99.0	089	22	000	0.0
00:53:00	-4	-110	27	0	0.17	0.26	-0.62	357	5.573	35.0	76.0	089	17	000	0.0
00:53:10	-5	-109	27	0	0.17	0.29	-0.63	358	5.861	35.0	76.0	089	21	000	0.0
00:53:20	-6	-108	27	0	0.16	0.32	-0.64	359	6.068	35.0	76.0	089	21	000	0.0
00:53:30	-7	-107	27	0	0.16	0.36	-0.64	360	6.324	35.0	76.0	089	20	000	0.0
00:53:40	-7	-106	27	0	0.17	0.39	-0.64	001	6.580	35.0	76.0	066	15	000	0.0
00:53:50	-8	-105	27	0	0.18	0.43	-0.65	002	6.824	35.0	52.0	066	18	000	0.0
00:54:00	-8	-105	27	0	0.19	0.45	-0.66	003	7.006	34.5	52.0	066	20	000	0.0
00:54:10	-9	-103	27	0	0.19	0.46	-0.64	004	7.012	15.5	52.0	036	22	000	0.0
00:54:20	-9	-102	27	0	0.19	0.45	-0.60	006	6.650	-3.5	52.0	272	15	000	0.0
00:54:30	-10	-101	27	0	0.21	0.42	-0.55	007	6.129	-7.5	52.0	272	15	000	0.0
00:54:40	-10	-100	27	0	0.20	0.37	-0.50	008	5.504	-7.0	52.0	272	16	000	0.0
00:54:50	-10	-99	27	0	0.22	0.32	-0.45	008	4.911	-7.0	52.0	272	19	000	0.0
00:55:00	-10	-98	27	0	0.27	0.31	-0.42	009	4.609	-7.0	52.0	272	15	000	0.0

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 03-Feb-99 Time: 11:27:14

Start Time [hrs:min:sec]: 00:30:00
End Time [hrs:min:sec]: 00:55:10
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 15

Date: 3 February 1999

Start Time: 13:31

Length of run [secs]: 3238

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 20 Direction: 45

Sea State, Significant wave height [m]:.. 3 Direction: 225

Current Speed [knots]:..... 1 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 3.1

Evaluation:

After maneuvering near the approach course the captain turned left to parallel the bow close to the course line (bow was tracking the line). The captain slowed down to experiment with the equilibrium heading for near zero speed – approximately 36 degrees. Then he speeded up a little to approach the buoy and altered the heading to the left for increased speed, and then decelerated again and altered heading to come close to equilibrium. At the final closure to the buoy he altered heading to the left to increase wind and wave forces on the starboard side to offset the current on the port side. The captain performed a sideways closure from port to center.

Shiphhandling Simulator

Exercise date & time: 03-Feb-99

13:31:11

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Tug file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 15**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:26:40	-31	-309	51	0	0.42	-0.15	0.41	031	-3.559	35.0	100.0	180	17	045	1.0	180
00:26:50	-29	-308	45	0	0.42	-0.05	0.20	031	-1.617	35.0	100.0	180	18	045	1.0	180
00:27:00	-28	-306	45	0	0.43	0.01	0.02	031	-0.010	35.0	100.0	180	19	045	1.0	180
00:27:10	-27	-304	39	0	0.40	0.12	-0.15	031	1.713	35.0	100.0	180	19	045	1.0	180
00:27:20	-26	-302	30	0	0.36	0.10	-0.23	031	2.091	35.0	100.0	180	17	045	1.0	180
00:27:30	-25	-301	30	0	0.32	0.12	-0.29	032	2.568	34.7	100.0	180	18	045	1.0	180
00:27:40	-25	-299	30	0	0.28	0.11	-0.33	032	2.797	25.1	100.0	180	17	045	1.0	180
00:27:50	-25	-298	30	0	0.21	0.15	-0.35	033	3.125	11.3	100.0	180	18	045	1.0	180
00:28:00	-25	-296	30	0	0.18	0.09	-0.33	033	2.633	3.6	100.0	180	22	045	1.0	180
00:28:10	-25	-295	30	0	0.12	0.03	-0.30	033	2.102	-3.2	100.0	180	22	045	1.0	180
00:28:20	-25	-295	30	0	0.04	0.02	-0.26	034	1.720	-10.7	100.0	180	18	045	1.0	180
00:28:30	-25	-294	30	0	0.00	0.00	-0.20	034	1.222	-14.1	100.0	180	17	045	1.0	180
00:28:40	-26	-294	30	0	-0.04	-0.01	-0.14	034	0.800	-13.2	100.0	180	17	045	1.0	180
00:28:50	-26	-294	30	0	-0.07	-0.02	-0.09	034	0.469	-10.1	100.0	180	13	045	1.0	180
00:29:00	-27	-295	30	0	-0.10	-0.02	-0.05	034	0.189	-7.3	100.0	180	17	045	1.0	180
00:29:10	-27	-295	35	0	-0.14	-0.06	-0.02	034	-0.242	-3.2	100.0	180	20	045	1.0	180
00:29:20	-28	-295	38	0	-0.15	-0.07	0.01	034	-0.454	-0.5	100.0	180	20	045	1.0	180
00:29:30	-28	-296	38	0	-0.16	-0.12	0.02	034	-0.881	4.0	100.0	180	19	045	1.0	180
00:29:40	-29	-297	38	0	-0.17	-0.12	0.01	034	-0.838	6.3	100.0	180	23	045	1.0	180
00:29:50	-30	-297	37	0	-0.16	-0.10	0.01	034	-0.661	7.3	51.0	180	19	045	1.0	180
00:30:00	-30	-298	38	0	-0.13	-0.12	-0.01	034	-0.692	5.1	51.0	180	20	045	1.0	180
00:30:10	-31	-298	38	0	-0.10	-0.18	0.03	034	-1.332	-13.9	51.0	180	20	045	1.0	180
00:30:20	-32	-298	38	0	-0.09	-0.23	0.08	033	-1.970	-3.8	51.0	180	20	045	1.0	180
00:30:30	-32	-298	38	0	-0.10	-0.24	0.09	033	-2.089	2.8	51.0	180	16	045	1.0	180
00:30:40	-33	-298	37	0	-0.06	-0.24	0.08	033	-2.017	1.0	51.0	180	21	045	1.0	180
00:30:50	-33	-298	38	0	-0.04	-0.26	0.11	032	-2.381	-7.5	51.0	180	18	045	1.0	180
00:31:00	-34	-298	48	0	-0.01	-0.20	0.10	032	-1.915	10.4	51.0	180	18	045	1.0	180
00:31:10	-34	-298	48	0	0.07	-0.18	0.08	032	-1.661	-4.8	51.0	180	22	045	1.0	180
00:31:20	-34	-297	55	0	0.15	-0.24	0.13	031	-2.377	-5.5	51.0	180	25	045	1.0	180
00:31:30	-33	-296	60	0	0.27	-0.28	0.18	031	-2.886	-1.9	51.0	180	16	045	1.0	180
00:31:40	-33	-295	61	0	0.39	-0.28	0.18	030	-2.951	2.7	51.0	180	17	045	1.0	180
00:31:50	-32	-293	61	0	0.54	-0.26	0.13	030	-2.495	7.8	51.0	180	15	045	1.0	180
00:32:00	-31	-290	61	0	0.67	-0.18	0.04	030	-1.402	10.9	51.0	180	15	045	1.0	180
00:32:10	-29	-286	61	0	0.83	-0.18	-0.06	029	-0.716	12.8	51.0	180	14	045	1.0	180
00:32:20	-28	-282	61	0	0.90	-0.13	-0.17	029	0.262	12.1	98.0	180	19	045	1.0	180
00:32:30	-26	-277	62	0	0.98	-0.11	-0.25	029	0.904	9.6	98.0	180	15	045	1.0	180
00:32:40	-24	-272	34	0	1.00	-0.14	-0.28	030	0.882	6.4	98.0	180	19	045	1.0	180
00:32:50	-23	-267	29	0	0.94	-0.17	-0.29	030	0.770	4.1	98.0	180	20	045	1.0	180
00:33:00	-21	-263	29	0	0.88	-0.10	-0.29	030	1.185	0.7	98.0	180	17	045	1.0	180
00:33:10	-20	-258	29	0	0.82	-0.09	-0.28	030	1.204	-2.8	98.0	180	13	045	1.0	180
00:33:20	-19	-254	25	0	0.79	-0.09	-0.26	030	1.047	-6.0	98.0	180	23	045	1.0	180
00:33:30	-18	-250	25	0	0.72	-0.11	-0.24	030	0.811	-8.6	98.0	180	23	045	1.0	180
00:33:40	-17	-247	25	0	0.65	-0.12	-0.21	031	0.561	-10.6	98.0	180	20	045	1.0	180
00:33:50	-16	-244	25	0	0.60	-0.12	-0.18	031	0.426	-15.4	98.0	180	19	045	1.0	180
00:34:00	-15	-241	25	0	0.55	-0.19	-0.13	031	-0.407	-34.4	98.0	180	21	045	1.0	180
00:34:10	-14	-238	25	0	0.50	-0.19	-0.06	031	-0.782	-35.0	98.0	180	19	045	1.0	180
00:34:20	-13	-236	25	0	0.46	-0.25	0.00	030	-1.575	-35.0	98.0	180	22	045	1.0	180
00:34:30	-13	-233	25	0	0.41	-0.31	0.06	030	-2.373	-29.7	98.0	180	20	045	1.0	180
00:34:40	-12	-231	25	0	0.35	-0.38	0.10	030	-3.046	-18.6	98.0	180	18	045	1.0	180
00:34:50	-12	-230	25	0	0.29	-0.46	0.12	029	-3.684	-16.1	98.0	180	21	045	1.0	180
00:35:00	-13	-228	25	0	0.21	-0.50	0.14	028	-4.087	-25.1	98.0	180	23	045	1.0	180
00:35:10	-13	-227	25	0	0.16	-0.46	0.15	028	-3.897	-9.7	98.0	180	17	045	1.0	180
00:35:20	-13	-226	25	0	0.12	-0.48	0.14	027	-3.882	3.7	98.0	180	15	045	1.0	180
00:35:30	-14	-225	25	0	0.07	-0.47	0.10	026	-3.638	14.6	98.0	180	20	045	1.0	180
00:35:40	-15	-224	25	0	0.01	-0.40	0.06	026	-2.923	3.9	98.0	180	19	045	1.0	180
00:35:50	-15	-224	25	0	-0.05	-0.43	0.06	025	-3.127	-4.9	98.0	180	15	045	1.0	180
00:36:00	-17	-224	25	0	-0.08	-0.47	0.06	025	-3.364	3.1	98.0	180	13	045	1.0	180
00:36:10	-18	-224	33	0	-0.12	-0.42	0.03	024	-2.892	9.8	98.0	180	14	045	1.0	180
00:36:20	-19	-224	46	0	-0.12	-0.38	-0.02	024	-2.261	14.3	98.0	180	16	045	1.0	180
00:36:30	-20	-224	57	0	-0.05	-0.31	-0.12	024	-1.229	14.6	98.0	180	21	045	1.0	180
00:36:40	-21	-224	60	0	0.05	-0.35	-0.24	023	-0.733	14.3	98.0	180	19	045	1.0	180
00:36:50	-23	-223	61	0	0.12	-0.33	-0.33	023	-0.030	11.9	98.0	180	20	045	1.0	180
00:37:00	-24	-221	61	0	0.21	-0.36	-0.41	023	0.300	11.0	98.0	180	22	045	1.0	180
00:37:10	-25	-219	61	0	0.28	-0.39	-0.47	023	0.501	9.5	98.0	180	22	045	1.0	180
00:37:20	-27	-217	61	0	0.37	-0.37	-0.50	024	0.820	6.7	98.0	180	14	045	1.0	180
00:37:30	-28	-214	61	0	0.45	-0.39	-0.45	024	0.347	-10.4	98.0	180	15	045	1.0	180
00:37:40	-29	-211	61	0	0.52	-0.53	-0.21	024	-2.063	-23.9	98.0	180	18	045	1.0	180
00:37:50	-29	-207	61	0	0.60	-0.62	-0.02	023	-3.863	-11.9	98.0	180	23	045	1.0	180
00:38:00	-30	-204	28	0	0.63	-0.70	0.02	022	-4.521	1.7	98.0	180	20	045	1.0	180
00:38:10	-30	-200	26	0	0.57	-0.69	-0.03	022	-4.179	16.5	98.0	180	20	045	1.0	180
00:38:20	-31	-197	26	0	0.51	-0.54	-0.10	021	-2.746	35.0	980					

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg
00:38:50	-33	-189	26	0	0.40	-0.44	-0.34	020	-0.627	35.0	98.0	180	18	045	1.0
00:39:00	-35	-186	26	0	0.33	-0.43	-0.41	020	-0.125	35.0	98.0	180	16	045	1.0
00:39:10	-36	-184	26	0	0.29	-0.52	-0.48	020	-0.203	35.0	98.0	180	21	045	1.0
00:39:20	-38	-182	39	0	0.24	-0.50	-0.58	020	0.521	35.0	98.0	180	18	045	1.0
00:39:30	-41	-179	53	0	0.23	-0.43	-0.76	020	2.109	35.0	98.0	180	18	045	1.0
00:39:40	-43	-177	58	0	0.26	-0.26	-0.96	021	4.498	35.0	98.0	180	16	045	1.0
00:39:50	-46	-175	60	0	0.30	-0.13	-1.18	022	6.658	35.0	98.0	180	22	045	1.0
00:40:00	-48	-172	61	0	0.33	-0.02	-1.37	023	8.610	35.0	98.0	180	22	045	1.0
00:40:10	-51	-169	61	0	0.36	0.10	-1.52	025	10.307	35.0	98.0	180	22	045	1.0
00:40:20	-53	-166	47	0	0.34	0.19	-1.58	026	11.220	35.0	98.0	180	16	045	1.0
00:40:30	-56	-162	45	0	0.31	0.26	-1.53	028	11.338	22.6	98.0	180	19	045	1.0
00:40:40	-58	-160	45	0	0.30	0.25	-1.43	030	10.687	29.7	98.0	180	19	045	1.0
00:40:50	-59	-157	45	0	0.28	0.32	-1.41	032	11.001	35.0	98.0	180	20	045	1.0
00:41:00	-61	-154	45	0	0.25	0.40	-1.37	034	11.206	24.5	98.0	180	17	045	1.0
00:41:10	-62	-152	45	0	0.27	0.33	-1.23	036	9.898	5.5	98.0	180	19	045	1.0
00:41:20	-63	-149	44	0	0.25	0.23	-1.02	037	7.968	-13.5	98.0	180	16	045	1.0
00:41:30	-64	-147	44	0	0.24	0.11	-0.76	038	5.508	-32.5	98.0	180	18	045	1.0
00:41:40	-64	-145	45	0	0.22	-0.02	-0.47	039	2.885	-35.0	98.0	180	15	045	1.0
00:41:50	-64	-144	45	0	0.24	-0.15	-0.22	039	0.465	-35.0	98.0	180	14	045	1.0
00:42:00	-64	-142	45	0	0.23	-0.25	0.00	039	-1.558	-35.0	98.0	180	18	045	1.0
00:42:10	-64	-141	45	0	0.21	-0.34	0.20	039	-3.436	-31.2	98.0	180	23	045	1.0
00:42:20	-63	-140	45	0	0.21	-0.39	0.31	038	-4.481	-12.2	98.0	180	20	045	1.0
00:42:30	-63	-139	44	0	0.21	-0.39	0.32	037	-4.510	2.2	98.0	180	17	045	1.0
00:42:40	-62	-138	44	0	0.20	-0.33	0.27	037	-3.792	11.9	98.0	180	19	045	1.0
00:42:50	-62	-137	45	0	0.22	-0.23	0.19	036	-2.686	13.8	98.0	180	18	045	1.0
00:43:00	-61	-136	45	0	0.24	-0.16	0.12	036	-1.743	14.7	98.0	180	17	045	1.0
00:43:10	-60	-135	45	0	0.26	-0.09	0.05	035	-0.888	14.2	98.0	180	20	045	1.0
00:43:20	-60	-134	45	0	0.29	-0.08	0.00	035	-0.496	14.4	98.0	180	21	045	1.0
00:43:30	-59	-132	45	0	0.28	-0.06	-0.06	035	0.005	13.0	98.0	180	21	045	1.0
00:43:40	-58	-131	45	0	0.29	-0.02	-0.10	035	0.481	10.5	98.0	180	25	045	1.0
00:43:50	-58	-130	38	0	0.30	-0.03	-0.12	035	0.582	8.5	98.0	180	22	045	1.0
00:44:00	-57	-128	38	0	0.29	-0.03	-0.13	036	0.629	6.6	98.0	180	19	045	1.0
00:44:10	-57	-127	38	0	0.26	0.00	-0.14	036	0.863	3.0	98.0	180	20	045	1.0
00:44:20	-56	-126	38	0	0.25	-0.03	-0.12	036	0.582	1.2	98.0	180	22	045	1.0
00:44:30	-56	-124	38	0	0.22	-0.05	-0.11	036	0.342	1.1	98.0	180	15	045	1.0
00:44:40	-56	-123	38	0	0.19	-0.06	-0.09	036	0.190	1.1	98.0	180	16	045	1.0
00:44:50	-55	-122	45	0	0.16	-0.05	-0.08	036	0.157	0.6	98.0	180	16	045	1.0
00:45:00	-55	-121	50	0	0.19	-0.03	-0.05	036	0.141	0.3	98.0	180	15	045	1.0
00:45:10	-55	-120	53	0	0.26	-0.02	-0.03	036	0.041	0.9	98.0	180	15	045	1.0
00:45:20	-54	-119	38	0	0.28	-0.02	-0.01	036	-0.052	1.3	98.0	180	22	045	1.0
00:45:30	-53	-118	36	0	0.27	-0.02	0.00	036	-0.127	1.7	98.0	180	18	045	1.0
00:45:40	-52	-117	36	0	0.25	-0.03	0.01	036	-0.276	3.0	98.0	180	18	045	1.0
00:45:50	-52	-116	29	0	0.21	-0.04	0.02	036	-0.359	4.8	98.0	180	17	045	1.0
00:46:00	-51	-115	29	0	0.20	-0.05	0.01	036	-0.342	6.0	98.0	180	17	045	1.0
00:46:10	-51	-114	29	0	0.14	-0.02	0.00	036	-0.143	5.7	98.0	180	13	045	1.0
00:46:20	-50	-114	29	0	0.12	-0.01	-0.01	036	-0.041	5.5	98.0	180	21	045	1.0
00:46:30	-50	-113	29	0	0.09	-0.04	-0.01	036	-0.186	7.4	98.0	180	20	045	1.0
00:46:40	-50	-113	29	0	0.03	-0.08	0.01	036	-0.570	-11.0	98.0	180	20	045	1.0
00:46:50	-50	-113	29	0	-0.05	-0.08	0.04	036	-0.711	-11.5	98.0	180	21	045	1.0
00:47:00	-50	-113	29	0	-0.09	-0.13	0.07	035	-1.254	-9.6	98.0	180	23	045	1.0
00:47:10	-51	-113	29	0	-0.13	-0.14	0.10	035	-1.495	-7.5	98.0	180	16	045	1.0
00:47:20	-51	-114	41	0	-0.17	-0.11	0.12	035	-1.470	-6.0	98.0	180	20	045	1.0
00:47:30	-52	-115	55	0	-0.13	-0.12	0.15	035	-1.704	3.3	98.0	180	22	045	1.0
00:47:40	-52	-115	60	0	-0.04	-0.07	0.08	034	-0.947	16.3	98.0	180	21	045	1.0
00:47:50	-52	-115	61	0	0.04	0.00	-0.07	034	0.434	12.4	98.0	180	18	045	1.0
00:48:00	-52	-115	64	0	0.14	-0.01	-0.05	034	0.305	-6.6	98.0	180	22	045	1.0
00:48:10	-51	-114	62	0	0.25	-0.07	0.05	034	-0.770	-3.7	98.0	180	16	045	1.0
00:48:20	-51	-112	62	0	0.36	-0.09	0.10	034	-1.204	-1.0	98.0	180	17	045	1.0
00:48:30	-49	-111	62	0	0.47	-0.18	0.21	034	-2.525	-11.1	98.0	180	18	045	1.0
00:48:40	-48	-109	62	0	0.57	-0.23	0.28	033	-3.254	-1.7	98.0	180	18	045	1.0
00:48:50	-46	-106	62	0	0.65	-0.24	0.25	033	-3.108	7.3	98.0	180	16	045	1.0
00:49:00	-44	-103	54	0	0.72	-0.19	0.14	032	-2.110	13.1	98.0	180	22	045	1.0
00:49:10	-42	-100	25	0	0.69	-0.19	0.08	032	-1.757	18.2	98.0	180	19	045	1.0
00:49:20	-41	-97	-25	0	0.59	-0.17	0.06	032	-1.442	23.2	98.0	180	16	045	1.0
00:49:30	-40	-94	-50	0	0.46	-0.10	0.04	032	-0.854	25.8	98.0	180	19	045	1.0
00:49:40	-39	-93	-35	0	0.32	-0.11	0.04	032	-0.937	29.3	98.0	180	23	045	1.0
00:49:50	-38	-91	26	0	0.23	-0.13	0.02	031	-0.938	34.0	98.0	180	19	045	1.0
00:50:00	-38	-90	29	0	0.17	-0.05	-0.05	031	-0.010	30.5	98.0	180	17	045	1.0
00:50:10	-38	-89	26	0	0.12	-0.04	-0.10	031	0.383	26.6	98.0	180	16	045	1.0
00:50:20	-38	-89	25	0	0.08	-0.03	-0.14	031	0.693	21.1	98.0	180	15	045	1.0
00:50:30	-38	-88	0	0	0.03	-0.01	-0.16	032	0.955	13.4	98.0	180	18	045	1.0
00:50:40	-38	-88	0	0	-0.04	-0.01	-0.17	032	0.965	11.5	98.0	180	20	045	1.0
00:50:50	-39	-88	29	0	-0.09	-0.02	-0.17	032	0.962	11.3	98.0	180	19	045	1.0
00:51:00	-40	-88	29	0	-0.13	-0.06	-0.17	032	0.655	0.6	98.0	180	20	045	1.0
00:51:10	-41	-89	39	0	-0.17	-0.17	-0.11	032	-0.369	-18.4	83.0	180	23	045	1.0
00:51:20	-42	-89	42	0	-0.16	-0.26	0.03	032	-1.854	-23.2	47.0	180	17	045	1.0
00:51:30	-43	-89	45	0	-0.12	-0.32	0.11	031	-2.717	-7.1	47.0	180	13	045	1.0
00:51:40	-43	-89	45	0	-0.06	-0.30	0.11	031	-2.637	8.6	27.0	180	14	045	1.0
00:51:50	-44	-89	45	0	0.02	-0.28	0.06	031	-2.109	10.8	27.0	180	19	045	1.0
00:52:00	-44	-89	45	0	0.06	-0.24	0.01	030	-1.562	8.4	27.0	180	19	045	1.0
00:52:10	-44	-88	44	0	0.11	-0.20	-0.02	030	-1.104	6.3	27.0	180	20	045	1.0
00:52:20	-45	-87	28	0	0.16	-0.23	-0.04	030	-1.178	7.7	27.0	180	18	045	1.0
00:52:30	-45	-86	28	0	0.14	-0.21	-0.06	030	-0.922	10.1	74.0	180	22	045	1.0

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:52:40	-45	-85	28	0	0.11	-0.16	-0.09	030	-0.441	9.9	100.0	180	22	045	1.0	180
00:52:50	-45	-85	0	0	0.08	-0.13	-0.11	030	-0.163	8.7	100.0	180	22	045	1.0	180
00:53:00	-46	-84	0	0	0.02	-0.19	-0.12	030	-0.481	12.0	100.0	180	17	045	1.0	180
00:53:10	-47	-84	-28	0	-0.07	-0.19	-0.13	029	-0.336	11.8	100.0	180	21	045	1.0	180
00:53:20	-48	-84	-51	0	-0.21	-0.27	-0.14	029	-0.854	14.7	100.0	180	21	045	1.0	180
00:53:30	-50	-85	-38	0	-0.38	-0.30	-0.13	029	-1.066	17.0	100.0	180	20	045	1.0	180
00:53:40	-52	-86	0	0	-0.47	-0.32	-0.13	029	-1.221	20.2	100.0	180	15	045	1.0	180
00:53:50	-54	-88	0	0	-0.55	-0.35	-0.13	029	-1.402	24.6	100.0	180	18	045	1.0	180

Simulation Track Plot

Open Ocean
Ship: 150,000 ton, Tanker, partial load

Date: 03-Feb-99 Time: 13:31:11

Start Time [hrs:min:sec]: 00:26:40
End Time [hrs:min:sec]: 00:53:58
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 16

Date: 3 February 1999

Start Time: 14:36

Length of run [secs]: 2940

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 20 Direction: 45

Sea State, Significant wave height [m]:.. 3 Direction: 225

Current Speed [knots]:..... 1 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 0.4

Evaluation:

The final mating was nearly perfect.

It was easier to find the equilibrium because of the experience with the previous exercise, run # 15.

Shiphhandling Simulator

Exercise date & time: 03-Feb-99
14:36:21

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #16**

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North		Stbd	Long	Bow	Stern						Deg	Knots	Deg	Knots
00:23:20	-90	-453	40	0	1.30	-0.02	-0.72		034	4.458	-19.0	27.0	180	10	045	1.0
00:23:30	-88	-447	40	0	1.32	-0.08	-0.55		034	2.977	-29.0	27.0	180	17	045	1.0
00:23:40	-85	-440	40	0	1.32	-0.19	-0.36		035	1.093	-35.0	27.0	180	19	045	1.0
00:23:50	-82	-434	40	0	1.32	-0.26	-0.18		035	-0.499	-35.0	27.0	180	23	045	1.0
00:24:00	-79	-428	40	0	1.31	-0.31	-0.02		035	-1.799	-35.0	50.0	180	20	045	1.0
00:24:10	-76	-422	35	0	1.32	-0.35	0.12		034	-2.977	-35.0	50.0	180	21	045	1.0
00:24:20	-72	-416	25	0	1.31	-0.33	0.17		034	-3.203	-35.0	100.0	180	20	045	1.0
00:24:30	-69	-410	25	0	1.25	-0.29	0.21		033	-3.158	-35.0	100.0	180	23	045	1.0
00:24:40	-66	-405	25	0	1.19	-0.29	0.25		033	-3.460	-35.0	100.0	180	19	045	1.0
00:24:50	-63	-400	25	0	1.14	-0.34	0.29		032	-4.001	-35.0	100.0	180	20	045	1.0
00:25:00	-60	-395	25	0	1.08	-0.40	0.33		031	-4.611	-35.0	100.0	180	19	045	1.0
00:25:10	-57	-390	25	0	0.99	-0.39	0.36		031	-4.797	-35.0	100.0	180	21	045	1.0
00:25:20	-55	-386	25	0	0.94	-0.41	0.40		030	-5.146	-35.0	100.0	180	18	045	1.0
00:25:30	-52	-382	25	0	0.89	-0.46	0.43		029	-5.660	-35.0	100.0	180	19	045	1.0
00:25:40	-50	-378	25	0	0.81	-0.47	0.46		028	-5.909	-35.0	100.0	180	18	045	1.0
00:25:50	-49	-374	25	0	0.75	-0.49	0.48		027	-6.211	-35.0	100.0	180	22	045	1.0
00:26:00	-47	-371	25	0	0.66	-0.56	0.51		026	-6.817	-35.0	100.0	180	19	045	1.0
00:26:10	-46	-368	25	0	0.61	-0.58	0.53		025	-7.053	-35.0	52.0	180	18	045	1.0
00:26:20	-45	-365	25	0	0.60	-0.58	0.55		023	-7.190	-35.0	28.0	180	15	045	1.0
00:26:30	-43	-362	25	0	0.59	-0.54	0.57		022	-7.052	-27.1	28.0	180	18	045	1.0
00:26:40	-42	-359	25	0	0.61	-0.48	0.56		021	-6.555	-8.1	28.0	180	17	045	1.0
00:26:50	-41	-356	25	0	0.62	-0.51	0.51		020	-6.433	10.9	28.0	180	18	045	1.0
00:27:00	-40	-353	25	0	0.63	-0.54	0.42		019	-6.113	29.9	28.0	180	19	045	1.0
00:27:10	-39	-350	25	0	0.61	-0.49	0.31		018	-5.087	35.0	28.0	180	19	045	1.0
00:27:20	-39	-347	27	0	0.61	-0.53	0.21		017	-4.712	35.0	28.0	180	17	045	1.0
00:27:30	-39	-344	38	0	0.63	-0.51	0.07		016	-3.700	35.0	28.0	180	18	045	1.0
00:27:40	-39	-340	38	0	0.67	-0.49	-0.09		016	-2.495	35.0	28.0	180	17	045	1.0
00:27:50	-40	-336	29	0	0.66	-0.38	-0.23		016	-0.991	35.0	28.0	180	18	045	1.0
00:28:00	-41	-333	29	0	0.68	-0.47	-0.33		016	-0.898	35.0	0.0	180	22	045	1.0
00:28:10	-42	-329	29	0	0.67	-0.53	-0.43		015	-0.609	35.0	0.0	180	22	045	1.0
00:28:20	-43	-325	42	0	0.65	-0.46	-0.56		015	0.617	35.0	0.0	180	18	045	1.0
00:28:30	-45	-321	51	0	0.71	-0.33	-0.75		016	2.663	35.0	0.0	180	17	045	1.0
00:28:40	-47	-316	51	0	0.77	-0.19	-0.94		016	4.753	35.0	0.0	180	17	045	1.0
00:28:50	-48	-311	51	0	0.83	-0.05	-1.10		017	6.622	35.0	0.0	180	13	045	1.0
00:29:00	-50	-306	50	0	0.88	0.05	-1.23		018	8.153	35.0	0.0	180	17	045	1.0
00:29:10	-51	-301	27	0	0.87	0.01	-1.25		020	7.976	35.0	0.0	180	20	045	1.0
00:29:20	-53	-296	27	0	0.85	0.02	-1.24		021	7.972	35.0	0.0	180	20	045	1.0
00:29:30	-54	-291	27	0	0.83	-0.07	-1.24		022	7.372	35.0	26.0	180	19	045	1.0
00:29:40	-56	-285	27	0	0.79	-0.05	-1.25		024	7.622	33.7	52.0	180	23	045	1.0
00:29:50	-57	-280	27	0	0.76	-0.01	-1.23		025	7.758	19.4	52.0	180	19	045	1.0
00:30:00	-58	-276	27	0	0.73	-0.04	-1.21		026	7.469	24.1	52.0	180	20	045	1.0
00:30:10	-60	-271	27	0	0.69	-0.10	-1.17		027	6.790	5.1	98.0	180	20	045	1.0
00:30:20	-61	-266	27	0	0.59	-0.15	-1.08		029	5.932	-13.9	98.0	180	20	045	1.0
00:30:30	-62	-263	27	0	0.49	-0.18	-0.96		029	4.967	-32.9	98.0	180	16	045	1.0
00:30:40	-63	-259	27	0	0.43	-0.23	-0.83		030	3.796	-35.0	98.0	180	21	045	1.0
00:30:50	-65	-256	27	0	0.37	-0.27	-0.71		031	2.787	-35.0	98.0	180	18	045	1.0
00:31:00	-66	-253	27	0	0.32	-0.23	-0.60		031	2.327	-35.0	49.0	180	18	045	1.0
00:31:10	-67	-251	38	0	0.33	-0.28	-0.46		031	1.179	-35.0	49.0	180	22	045	1.0
00:31:20	-67	-248	48	0	0.36	-0.41	-0.24		031	-1.075	-35.0	49.0	180	25	045	1.0
00:31:30	-68	-246	48	0	0.42	-0.53	-0.01		031	-3.290	-35.0	26.0	180	16	045	1.0
00:31:40	-67	-243	48	0	0.48	-0.64	0.20		030	-5.334	-35.0	26.0	180	17	045	1.0
00:31:50	-67	-240	47	0	0.55	-0.75	0.40		029	-7.306	-35.0	26.0	180	15	045	1.0
00:32:00	-66	-237	48	0	0.63	-0.79	0.56		028	-8.572	-23.6	26.0	180	15	045	1.0
00:32:10	-65	-234	48	0	0.74	-0.85	0.59		026	-9.194	-4.6	26.0	180	14	045	1.0
00:32:20	-64	-230	45	0	0.80	-0.80	0.50		025	-8.257	14.4	26.0	180	19	045	1.0
00:32:30	-63	-226	36	0	0.80	-0.73	0.36		024	-6.925	33.4	100.0	180	15	045	1.0
00:32:40	-63	-222	36	0	0.75	-0.70	0.19		023	-5.660	35.0	100.0	180	19	045	1.0
00:32:50	-63	-218	36	0	0.72	-0.65	0.03		022	-4.315	35.0	100.0	180	20	045	1.0
00:33:00	-63	-214	36	0	0.67	-0.48	-0.12		021	-2.272	35.0	100.0	180	17	045	1.0
00:33:10	-63	-210	36	0	0.67	-0.37	-0.25		021	-0.761	35.0	28.0	180	13	045	1.0
00:33:20	-63	-206	36	0	0.70	-0.30	-0.38		021	0.488	35.0	28.0	180	23	045	1.0
00:33:30	-64	-202	42	0	0.71	-0.25	-0.51		021	1.626	35.0	28.0	180	23	045	1.0
00:33:40	-64	-198	55	0	0.74	-0.15	-0.70		022	3.490	35.0	28.0	180	20	045	1.0
00:33:50	-65	-193	60	0	0.83	0.02	-0.94		022	6.094	35.0	28.0	180	19	045	1.0
00:34:00	-65	-188	62	0	0.93	0.09	-1.17		024	7.985	35.0	28.0	180	21	045	1.0
00:34:10	-66	-183	62	0	1.01	0.27	-1.36		025	10.402	35.0	51.0	180	19	045	1.0
00:34:20	-66	-176	62	0	1.08	0.35	-1.52		027	11.855	35.0	100.0	180	22	045	1.0
00:34:30	-66	-170	63	0	1.10	0.40	-1.64		029	12.951	35.0	100.0	180	20	045	1.0
00:34:40	-66	-164	39	0	1.07	0.42	-1.68		031	13.310	35.0	100.0	180	18	045	1.0
00:34:50	-66	-157	29	0	0.97	0.37	-1.60		033	12.471	35.0	100.0	180	21	045	1.0
00:35:00	-66	-152	25	0	0.84	0.36	-1.51		035	11.843	24.6	100.0	180	23	045	1.0
00:35:10	-66	-147	0	0	0.73	0.39	-1.40		037	11.357	5.6	100.0	180	17	045	1.0
00:35:20	-66	-143	0	0	0.63	0.39	-1.31		039	10.783	-13.4	100.0	180	15	045	1.0

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North		Stbd	Long	Bow	Stern	Knots					Deg	Knots	Deg	
00:35:30	-65	-139	31	0	0.54	0.37	-1.16	041	9.694	-32.4	100.0	180	20	045	1.0	180
00:35:40	-65	-136	47	0	0.48	0.26	-0.85	042	7.019	-35.0	100.0	180	19	045	1.0	180
00:35:50	-64	-133	56	0	0.48	0.08	-0.48	043	3.524	-35.0	100.0	180	15	045	1.0	180
00:36:00	-63	-131	46	0	0.53	-0.09	-0.12	044	0.170	-35.0	100.0	180	13	045	1.0	180
00:36:10	-61	-128	29	0	0.49	-0.12	0.02	043	-0.882	-35.0	100.0	180	14	045	1.0	180
00:36:20	-60	-127	26	0	0.43	-0.12	0.08	043	-1.265	-35.0	100.0	180	16	045	1.0	180
00:36:30	-59	-125	26	0	0.41	-0.11	0.15	043	-1.640	-35.0	100.0	180	21	045	1.0	180
00:36:40	-57	-124	26	0	0.37	-0.12	0.21	043	-2.095	-35.0	100.0	180	19	045	1.0	180
00:36:50	-56	-123	26	0	0.29	-0.13	0.26	042	-2.516	-35.0	100.0	180	20	045	1.0	180
00:37:00	-54	-122	26	0	0.23	-0.15	0.32	042	-2.982	-35.0	100.0	180	22	045	1.0	180
00:37:10	-53	-121	26	0	0.16	-0.17	0.38	041	-3.465	-35.0	100.0	180	22	045	1.0	180
00:37:20	-53	-121	26	0	0.10	-0.18	0.43	041	-3.903	-35.0	100.0	180	14	045	1.0	180
00:37:30	-52	-121	36	0	0.05	-0.21	0.51	040	-4.533	-35.0	100.0	180	15	045	1.0	180
00:37:40	-51	-122	41	0	0.03	-0.28	0.65	039	-5.903	-35.0	100.0	180	18	045	1.0	180
00:37:50	-50	-122	41	0	0.01	-0.33	0.76	038	-6.876	-19.2	100.0	180	23	045	1.0	180
00:38:00	-49	-123	41	0	-0.01	-0.35	0.77	037	-7.137	-0.2	100.0	180	20	045	1.0	180
00:38:10	-48	-124	41	0	-0.03	-0.31	0.70	036	-6.454	18.8	100.0	180	20	045	1.0	180
00:38:20	-48	-125	41	0	-0.05	-0.20	0.59	035	-4.956	15.0	100.0	180	18	045	1.0	180
00:38:30	-47	-125	50	0	-0.02	-0.18	0.55	034	-4.639	-4.0	100.0	180	22	045	1.0	180
00:38:40	-46	-126	43	0	0.02	-0.18	0.53	033	-4.464	7.3	100.0	180	19	045	1.0	180
00:38:50	-45	-126	35	0	0.02	-0.15	0.46	033	-3.915	19.0	100.0	180	18	045	1.0	180
00:39:00	-45	-127	35	0	-0.01	-0.12	0.37	032	-3.122	30.2	74.0	180	16	045	1.0	180
00:39:10	-44	-127	29	0	-0.02	-0.15	0.28	031	-2.762	35.0	74.0	180	21	045	1.0	180
00:39:20	-44	-127	29	0	-0.05	-0.14	0.20	031	-2.139	35.0	100.0	180	18	045	1.0	180
00:39:30	-45	-127	29	0	-0.11	-0.12	0.12	031	-1.520	35.0	100.0	180	18	045	1.0	180
00:39:40	-45	-128	29	0	-0.15	-0.07	0.04	031	-0.679	35.0	100.0	180	16	045	1.0	180
00:39:50	-46	-129	29	0	-0.20	-0.06	-0.03	031	-0.143	35.0	100.0	180	22	045	1.0	180
00:40:00	-46	-130	29	0	-0.26	-0.05	-0.10	031	0.324	35.0	100.0	180	22	045	1.0	180
00:40:10	-47	-131	42	0	-0.27	-0.01	-0.19	031	1.173	35.0	28.0	180	22	045	1.0	180
00:40:20	-49	-131	42	0	-0.26	0.05	-0.32	031	2.356	35.0	0.0	180	16	045	1.0	180
00:40:30	-50	-132	47	0	-0.21	0.16	-0.43	031	3.727	29.3	0.0	180	19	045	1.0	180
00:40:40	-51	-132	48	0	-0.11	0.19	-0.47	032	4.170	10.3	0.0	180	19	045	1.0	180
00:40:50	-52	-132	48	0	-0.03	0.17	-0.40	033	3.606	-8.7	0.0	180	20	045	1.0	180
00:41:00	-52	-132	48	0	0.05	0.11	-0.23	033	2.148	-21.7	0.0	180	17	045	1.0	180
00:41:10	-52	-132	39	0	0.14	-0.01	-0.12	034	0.712	-2.7	30.0	180	19	045	1.0	180
00:41:20	-52	-131	29	0	0.10	-0.05	-0.11	034	0.396	3.7	99.0	180	16	045	1.0	180
00:41:30	-52	-130	29	0	0.05	-0.06	-0.11	034	0.286	0.7	99.0	180	18	045	1.0	180
00:41:40	-52	-130	29	0	0.02	-0.08	-0.07	034	-0.032	-18.3	23.0	180	15	045	1.0	180
00:41:50	-53	-129	29	0	0.06	-0.15	-0.01	034	-0.868	-18.3	0.0	180	14	045	1.0	180
00:42:00	-53	-129	29	0	0.06	-0.16	0.03	033	-1.216	-10.5	50.0	180	18	045	1.0	180
00:42:10	-53	-129	29	0	0.04	-0.18	0.04	033	-1.422	-0.6	50.0	180	23	045	1.0	180
00:42:20	-53	-128	29	0	0.03	-0.20	0.04	033	-1.508	3.8	50.0	180	20	045	1.0	180
00:42:30	-53	-128	29	0	0.02	-0.21	0.03	033	-1.499	6.6	26.0	180	17	045	1.0	180
00:42:40	-54	-128	29	0	0.01	-0.19	0.01	032	-1.286	8.8	26.0	180	19	045	1.0	180
00:42:50	-54	-127	31	0	0.03	-0.13	-0.01	032	-0.823	7.8	26.0	180	18	045	1.0	180
00:43:00	-54	-127	37	0	0.07	-0.11	-0.02	032	-0.587	4.4	26.0	180	17	045	1.0	180
00:43:10	-54	-126	38	0	0.12	-0.08	-0.02	032	-0.401	2.0	26.0	180	20	045	1.0	180
00:43:20	-54	-125	38	0	0.18	-0.13	-0.02	032	-0.696	4.2	49.0	180	21	045	1.0	180
00:43:30	-54	-124	38	0	0.19	-0.14	-0.03	032	-0.649	6.0	49.0	180	21	045	1.0	180
00:43:40	-54	-123	38	0	0.21	-0.13	-0.05	032	-0.526	6.6	49.0	180	25	045	1.0	180
00:43:50	-54	-122	38	0	0.24	-0.16	-0.07	032	-0.571	8.1	76.0	180	22	045	1.0	180
00:44:00	-53	-121	36	0	0.24	-0.17	-0.10	032	-0.492	9.5	99.0	180	19	045	1.0	180
00:44:10	-53	-119	33	0	0.20	-0.13	-0.12	032	-0.042	8.1	99.0	180	20	045	1.0	180
00:44:20	-54	-118	43	0	0.19	-0.16	-0.13	032	-0.158	8.6	51.0	180	22	045	1.0	180
00:44:30	-54	-117	44	0	0.23	-0.18	-0.16	032	-0.097	8.9	77.0	180	15	045	1.0	180
00:44:40	-54	-115	44	0	0.23	-0.18	-0.19	032	0.066	8.2	77.0	180	16	045	1.0	180
00:44:50	-54	-114	44	0	0.24	-0.14	-0.20	032	0.372	6.4	77.0	180	16	045	1.0	180
00:45:00	-54	-112	43	0	0.27	-0.10	-0.21	032	0.684	4.2	77.0	180	15	045	1.0	180
00:45:10	-54	-111	43	0	0.31	-0.09	-0.20	032	0.717	2.0	77.0	180	15	045	1.0	180
00:45:20	-54	-109	38	0	0.33	-0.08	-0.18	032	0.603	0.2	77.0	180	22	045	1.0	180
00:45:30	-53	-107	38	0	0.32	-0.09	-0.15	032	0.370	-0.8	100.0	180	18	045	1.0	180
00:45:40	-53	-105	38	0	0.31	-0.13	-0.13	032	-0.002	0.0	100.0	180	18	045	1.0	180
00:45:50	-53	-104	38	0	0.28	-0.15	-0.11	032	-0.260	1.5	100.0	180	17	045	1.0	180
00:46:00	-52	-102	38	0	0.31	-0.17	-0.11	032	-0.397	3.1	76.0	180	17	045	1.0	180
00:46:10	-52	-100	38	0	0.30	-0.16	-0.11	032	-0.349	4.1	100.0	180	13	045	1.0	180
00:46:20	-52	-99	29	0	0.28	-0.15	-0.11	032	-0.242	4.9	100.0	180	21	045	1.0	180
00:46:30	-52	-97	29	0	0.24	-0.19	-0.12	032	-0.452	6.3	100.0	180	20	045	1.0	180
00:46:40	-52	-96	29	0	0.18	-0.24	-0.13	032	-0.663	9.2	100.0	180	20	045	1.0	180
00:46:50	-53	-95	29	0	0.15	-0.19	-0.15	032	-0.251	9.2	0.0	180	21	045	1.0	180
00:47:00	-53	-93	41	0	0.17	-0.22	-0.17	032	-0.310	9.9	0.0	180	23	045	1.0	180
00:47:10	-53	-92	56	0	0.26	-0.19	-0.21	032	0.151	8.5	0.0	180	16	045	1.0	180
00:47:20	-53	-90	34	0	0.32	-0.10	-0.23	032	0.805	5.3	0.0	180	20	045	1.0	180
00:47:30	-53	-88	34	0	0.35	-0.10	-0.22	032	0.783	2.6	0.0	180	22	045	1.0	180
00:47:40	-53	-86	34	0	0.38	-0.09	-0.21	032	0.713	0.7	0.0	180	21	045	1.0	180
00:47:50	-52	-84	34	0	0.41	-0.14	-0.19	032	0.296	0.3	0.0	180	18	045	1.0	180
00:48:00	-52	-82	34	0	0.42	-0.15	-0.16	032	0.066	-9.4	0.0	180	22	045	1.0	180
00:48:10	-51	-80	34	0	0.46	-0.20	-0.08	032	-0.743	-28.4	0.0	180	16	045	1.0	180
00:48:20	-51	-77	34	0	0.48	-0.25	0.04	032	-1.834	-35.0	0.0	180	17	045	1.0	180
00:48:30	-50	-75	34	0	0.52	-0.35	0.15	031	-3.144	-35.0	0.0	180	18	045	1.0	180
00:48:40	-49	-72	34	0	0.55	-0.42	0.25	031	-4.250	-35.0	0.0	180	18	045	1.0	180
00:48:50	-48	-69	34	0	0.55	-0.52	0.35	030	-5.472	-35.0	0.0	180				

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 03-Feb-99

Time: 14:36:21

Start Time [hrs:min:sec]: 00:23:20
End Time [hrs:min:sec]: 00:49:00
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 17

Date: 3 February 1999

Start Time: 15:38

Length of run [secs]: 2872

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 20 Direction: 90

Sea State, Significant wave height [m]:.. 3 Direction: 270

Current Speed [knots]:..... 1 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 1.1

Evaluation:

On the final closure at very slow speed (to stop) on 070 degrees heading the ship closed with the buoy at a very slow rate. This seems to indicate that the equilibrium heading was probably between 072 to 075 degrees. The ship behaved very well. The buoy closed from beam on port side.

Shiphandling Simulator

Exercise date & time: 03-Feb-99
15:38:37

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #17**

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Stbd	Long	Bow	Stern					%	Deg	Knots	Deg	Knots	Deg
00:23:20	-41	-438	29	0	1.23	-0.79	-0.77		036	-0.147	-35.0	100.0	180	10	090	1.0	180
00:23:30	-41	-431	29	0	1.18	-0.75	-0.71		036	-0.254	-35.0	100.0	180	17	090	1.0	180
00:23:40	-40	-424	29	0	1.12	-0.82	-0.70		036	-0.812	-35.0	100.0	180	19	090	1.0	180
00:23:50	-40	-417	29	0	1.06	-0.82	-0.66		036	-1.011	-35.0	100.0	180	23	090	1.0	180
00:24:00	-40	-411	29	0	1.00	-0.76	-0.61		035	-0.953	-35.0	100.0	180	20	090	1.0	180
00:24:10	-40	-405	29	0	0.95	-0.73	-0.57		035	-1.053	-35.0	100.0	180	21	090	1.0	180
00:24:20	-40	-399	29	0	0.92	-0.71	-0.52		035	-1.237	-35.0	100.0	180	20	090	1.0	180
00:24:30	-40	-393	29	0	0.87	-0.62	-0.45		035	-1.051	-35.0	100.0	180	23	090	1.0	180
00:24:40	-39	-388	26	0	0.82	-0.65	-0.43		035	-1.370	-35.0	100.0	180	19	090	1.0	180
00:24:50	-40	-383	26	0	0.78	-0.77	-0.45		034	-2.022	-35.0	100.0	180	20	090	1.0	180
00:25:00	-40	-378	26	0	0.74	-0.91	-0.48		034	-2.718	-35.0	100.0	180	19	090	1.0	180
00:25:10	-41	-373	26	0	0.68	-0.89	-0.46		034	-2.686	-35.0	100.0	180	21	090	1.0	180
00:25:20	-42	-368	26	0	0.64	-0.91	-0.45		033	-2.910	-35.0	100.0	180	18	090	1.0	180
00:25:30	-43	-363	39	0	0.61	-1.01	-0.44		033	-3.657	-35.0	100.0	180	19	090	1.0	180
00:25:40	-45	-359	52	0	0.62	-1.09	-0.27		032	-5.240	-35.0	100.0	180	18	090	1.0	180
00:25:50	-46	-354	58	0	0.68	-1.23	-0.04		031	-7.549	-26.0	100.0	180	22	090	1.0	180
00:26:00	-47	-349	55	0	0.75	-1.33	-0.01		029	-8.367	-7.0	100.0	180	19	090	1.0	180
00:26:10	-48	-344	48	0	0.80	-1.22	-0.12		028	-7.027	12.0	100.0	180	18	090	1.0	180
00:26:20	-49	-339	29	0	0.80	-1.06	-0.27		027	-5.037	31.0	100.0	180	15	090	1.0	180
00:26:30	-50	-334	29	0	0.76	-0.85	-0.40		026	-2.903	35.0	100.0	180	18	090	1.0	180
00:26:40	-51	-329	29	0	0.73	-0.65	-0.50		026	-0.938	35.0	100.0	180	17	090	1.0	180
00:26:50	-53	-324	29	0	0.69	-0.63	-0.68		026	0.338	35.0	100.0	180	18	090	1.0	180
00:27:00	-54	-320	31	0	0.65	-0.64	-0.86		026	1.406	35.0	100.0	180	19	090	1.0	180
00:27:10	-56	-315	43	0	0.63	-0.52	-1.00		027	3.058	35.0	53.0	180	19	090	1.0	180
00:27:20	-59	-310	47	0	0.67	-0.52	-1.22		027	4.481	26.4	53.0	180	17	090	1.0	180
00:27:30	-61	-305	55	0	0.73	-0.50	-1.31		028	5.166	12.2	53.0	180	18	090	1.0	180
00:27:40	-63	-299	58	0	0.82	-0.46	-1.45		029	6.255	31.2	53.0	180	17	090	1.0	180
00:27:50	-65	-293	57	0	0.86	-0.24	-1.62		030	8.761	35.0	53.0	180	18	090	1.0	180
00:28:00	-67	-286	54	0	0.91	-0.25	-1.82		032	9.986	35.0	53.0	180	22	090	1.0	180
00:28:10	-69	-280	29	0	0.86	-0.30	-1.87		034	9.933	35.0	53.0	180	22	090	1.0	180
00:28:20	-72	-273	29	0	0.79	-0.24	-1.83		035	10.095	35.0	53.0	180	18	090	1.0	180
00:28:30	-73	-267	29	0	0.74	-0.16	-1.76		037	10.159	35.0	77.0	180	17	090	1.0	180
00:28:40	-75	-261	29	0	0.67	-0.08	-1.67		039	10.108	23.0	77.0	180	17	090	1.0	180
00:28:50	-76	-256	29	0	0.63	-0.03	-1.54		040	9.575	4.0	48.0	180	13	090	1.0	180
00:29:00	-77	-251	29	0	0.61	-0.03	-1.37		042	8.529	-15.0	48.0	180	17	090	1.0	180
00:29:10	-77	-246	29	0	0.59	-0.17	-1.21		043	6.605	-34.0	27.0	180	20	090	1.0	180
00:29:20	-78	-242	29	0	0.58	-0.22	-1.03		044	5.182	-35.0	27.0	180	20	090	1.0	180
00:29:30	-78	-237	29	0	0.58	-0.42	-0.91		045	3.109	-35.0	27.0	180	19	090	1.0	180
00:29:40	-78	-233	29	0	0.58	-0.47	-0.79		045	2.004	-35.0	0.0	180	23	090	1.0	180
00:29:50	-78	-228	29	0	0.59	-0.47	-0.67		045	1.298	-35.0	0.0	180	19	090	1.0	180
00:30:00	-78	-224	29	0	0.60	-0.58	-0.58		045	0.001	-35.0	0.0	180	20	090	1.0	180
00:30:10	-78	-220	29	0	0.61	-0.73	-0.51		045	-1.401	-35.0	0.0	180	20	090	1.0	180
00:30:20	-78	-215	29	0	0.61	-0.82	-0.44		045	-2.397	-35.0	0.0	180	20	090	1.0	180
00:30:30	-78	-211	29	0	0.60	-0.83	-0.37		045	-2.919	-35.0	0.0	180	16	090	1.0	180
00:30:40	-78	-206	29	0	0.62	-0.86	-0.31		044	-3.508	-35.0	0.0	180	21	090	1.0	180
00:30:50	-78	-202	37	0	0.64	-0.88	-0.23		043	-4.161	-35.0	0.0	180	18	090	1.0	180
00:31:00	-78	-198	44	0	0.69	-0.78	-0.04		043	-4.691	-35.0	0.0	180	18	090	1.0	180
00:31:10	-77	-194	44	0	0.76	-0.81	0.09		042	-5.718	-25.1	0.0	180	22	090	1.0	180
00:31:20	-75	-189	44	0	0.83	-0.88	0.10		041	-6.240	-7.3	0.0	180	25	090	1.0	180
00:31:30	-74	-185	44	0	0.90	-0.84	0.02		040	-5.454	9.4	25.0	180	16	090	1.0	180
00:31:40	-73	-180	44	0	0.95	-0.74	-0.12		039	-3.892	21.3	99.0	180	17	090	1.0	180
00:31:50	-72	-174	44	0	0.96	-0.64	-0.32		039	-2.040	28.8	99.0	180	15	090	1.0	180
00:32:00	-70	-169	44	0	0.96	-0.44	-0.51		038	0.431	35.0	99.0	180	15	090	1.0	180
00:32:10	-69	-163	38	0	0.96	-0.45	-0.74		039	1.819	35.0	99.0	180	14	090	1.0	180
00:32:20	-69	-158	29	0	0.90	-0.42	-0.86		039	2.812	35.0	99.0	180	19	090	1.0	180
00:32:30	-69	-152	29	0	0.84	-0.41	-0.96		040	3.505	35.0	99.0	180	15	090	1.0	180
00:32:40	-69	-146	29	0	0.76	-0.47	-1.06		040	3.741	35.0	99.0	180	19	090	1.0	180
00:32:50	-70	-141	43	0	0.71	-0.46	-1.16		041	4.410	35.0	99.0	180	20	090	1.0	180
00:33:00	-70	-135	56	0	0.69	-0.20	-1.27		042	6.799	35.0	99.0	180	17	090	1.0	180
00:33:10	-71	-130	54	0	0.70	-0.03	-1.40		043	8.655	35.0	99.0	180	13	090	1.0	180
00:33:20	-71	-125	44	0	0.71	0.06	-1.47		045	9.737	35.0	99.0	180	23	090	1.0	180
00:33:30	-71	-120	39	0	0.65	0.09	-1.46		046	9.852	35.0	99.0	180	23	090	1.0	180
00:33:40	-71	-115	39	0	0.59	0.12	-1.44		048	9.847	35.0	99.0	180	20	090	1.0	180
00:33:50	-71	-111	39	0	0.54	0.19	-1.39		050	10.038	35.0	99.0	180	19	090	1.0	180
00:34:00	-71	-107	30	0	0.49	0.10	-1.34		051	9.138	35.0	99.0	180	21	090	1.0	180
00:34:10	-71	-103	30	0	0.43	0.20	-1.26		053	9.307	35.0	99.0	180	19	090	1.0	180
00:34:20	-71	-100	30	0	0.38	0.16	-1.20		054	8.614	35.0	99.0	180	22	090	1.0	180
00:34:30	-71	-96	30	0	0.32	0.10	-1.14		056	7.871	35.0	99.0	180	20	090	1.0	180
00:34:40	-71	-93	40	0	0.27	0.04	-1.11		057	7.268	35.0	99.0	180	18	090	1.0	180
00:34:50	-71	-90	38	0	0.23	-0.05	-1.09		058	6.625	35.0	99.0	180	21	090	1.0	180
00:35:00	-72	-87	38	0	0.17	-0.04	-1.07		059	6.488	35.0	99.0	180	23	090	1.0	180
00:35:10	-73	-85	25	0	0.12	0.06	-1.02		060	6.832	35.0	99.0	180	17	090	1.0	180
00:35:20	-73	-82	25	0	0.07	0.04	-0.94		061	6.219	35.0	99.0	180	15	090	1.0	180

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Stbd	Long	Bow	Stern					%	Deg	Knots	Deg	Knots	Deg
00:35:30	-74	-80	28	0	0.00	0.03	-0.87		062	5.732	35.0	99.0	180	20	090	1.0	180
00:35:40	-75	-79	28	0	-0.06	0.13	-0.81		063	5.922	35.0	99.0	180	19	090	1.0	180
00:35:50	-77	-77	28	0	-0.13	0.10	-0.74		064	5.353	35.0	99.0	180	15	090	1.0	180
00:36:00	-78	-76	28	0	-0.16	0.06	-0.69		065	4.749	35.0	99.0	180	13	090	1.0	180
00:36:10	-79	-75	28	0	-0.21	0.13	-0.63		066	4.825	35.0	99.0	180	14	090	1.0	180
00:36:20	-81	-75	28	0	-0.26	0.16	-0.58		067	4.684	35.0	99.0	180	16	090	1.0	180
00:36:30	-83	-74	28	0	-0.28	0.19	-0.53		067	4.560	35.0	99.0	180	21	090	1.0	180
00:36:40	-84	-74	28	0	-0.31	0.09	-0.49		068	3.678	35.0	99.0	180	19	090	1.0	180
00:36:50	-86	-74	28	0	-0.37	0.06	-0.44		069	3.224	21.7	99.0	180	20	090	1.0	180
00:37:00	-89	-73	28	0	-0.41	0.02	-0.43		069	2.863	8.9	99.0	180	22	090	1.0	180
00:37:10	-91	-73	28	0	-0.47	-0.03	-0.40		070	2.361	3.0	99.0	180	22	090	1.0	180
00:37:20	-94	-73	43	0	-0.45	-0.03	-0.36		070	2.113	-3.3	0.0	180	14	090	1.0	180
00:37:30	-96	-73	49	0	-0.37	-0.02	-0.30		070	1.793	-9.2	0.0	180	15	090	1.0	180
00:37:40	-98	-73	53	0	-0.28	-0.09	-0.15		070	0.352	-9.4	0.0	180	18	090	1.0	180
00:37:50	-99	-73	54	0	-0.18	-0.14	0.00		070	-0.857	-1.8	0.0	180	23	090	1.0	180
00:38:00	-100	-73	59	0	-0.04	-0.19	0.03		070	-1.382	15.0	0.0	180	20	090	1.0	180
00:38:10	-100	-72	62	0	0.09	-0.16	-0.01		070	-0.910	9.4	0.0	180	20	090	1.0	180
00:38:20	-99	-72	52	0	0.22	-0.06	0.01		070	-0.412	4.5	0.0	180	18	090	1.0	180
00:38:30	-98	-71	34	0	0.27	-0.06	0.04		070	-0.621	6.0	50.0	180	22	090	1.0	180
00:38:40	-97	-70	34	0	0.31	-0.05	0.05		070	-0.651	8.2	50.0	180	19	090	1.0	180
00:38:50	-95	-70	34	0	0.34	-0.05	0.06		070	-0.659	9.6	50.0	180	18	090	1.0	180
00:39:00	-93	-69	34	0	0.34	-0.05	0.06		069	-0.708	12.0	50.0	180	16	090	1.0	180
00:39:10	-92	-69	26	0	0.36	-0.14	0.06		069	-1.238	16.4	73.0	180	21	090	1.0	180
00:39:20	-90	-68	26	0	0.33	-0.15	0.05		069	-1.247	20.7	73.0	180	18	090	1.0	180
00:39:30	-89	-67	26	0	0.29	-0.15	0.03		069	-1.177	23.1	73.0	180	18	090	1.0	180
00:39:40	-87	-66	26	0	0.27	-0.11	0.04		069	-0.920	4.1	73.0	180	16	090	1.0	180
00:39:50	-86	-65	26	0	0.24	-0.14	0.07		069	-1.347	-3.2	100.0	180	22	090	1.0	180
00:40:00	-85	-65	26	0	0.19	-0.17	0.10		068	-1.724	5.5	100.0	180	22	090	1.0	180
00:40:10	-85	-64	26	0	0.13	-0.18	0.11		068	-1.818	16.0	100.0	180	22	090	1.0	180
00:40:20	-84	-64	26	0	0.05	-0.17	0.09		068	-1.649	33.4	100.0	180	16	090	1.0	180
00:40:30	-84	-64	26	0	0.00	-0.08	0.06		067	-0.907	35.0	100.0	180	19	090	1.0	180
00:40:40	-84	-64	26	0	-0.03	-0.06	0.03		067	-0.611	35.0	70.0	180	19	090	1.0	180
00:40:50	-84	-64	26	0	-0.03	-0.01	0.02		067	-0.166	22.7	53.0	180	20	090	1.0	180
00:41:00	-85	-64	26	0	-0.03	0.05	0.03		067	0.153	9.1	27.0	180	17	090	1.0	180
00:41:10	-85	-64	26	0	0.00	-0.05	0.04		067	-0.580	26.4	27.0	180	19	090	1.0	180
00:41:20	-85	-64	26	0	0.00	-0.10	0.02		067	-0.772	35.0	27.0	180	16	090	1.0	180
00:41:30	-85	-64	26	0	-0.01	-0.11	0.00		067	-0.663	31.9	51.0	180	18	090	1.0	180
00:41:40	-85	-64	26	0	-0.03	-0.09	-0.01		067	-0.464	28.5	51.0	180	15	090	1.0	180
00:41:50	-85	-63	26	0	-0.01	-0.15	-0.01		067	-0.906	12.7	51.0	180	14	090	1.0	180
00:42:00	-85	-63	26	0	-0.02	-0.15	0.02		067	-1.118	7.5	51.0	180	18	090	1.0	180
00:42:10	-86	-63	26	0	-0.04	-0.18	0.04		066	-1.433	13.4	26.0	180	23	090	1.0	180
00:42:20	-86	-62	26	0	-0.04	-0.21	0.05		066	-1.695	18.3	26.0	180	20	090	1.0	180
00:42:30	-86	-62	26	0	-0.05	-0.24	0.05		066	-1.847	22.6	26.0	180	17	090	1.0	180
00:42:40	-87	-62	26	0	-0.06	-0.23	0.07		066	-1.886	3.6	26.0	180	19	090	1.0	180
00:42:50	-87	-62	29	0	-0.04	-0.16	0.10		065	-1.633	12.2	26.0	180	18	090	1.0	180
00:43:00	-87	-62	34	0	-0.01	-0.11	0.07		065	-1.150	31.2	26.0	180	17	090	1.0	180
00:43:10	-87	-62	34	0	0.02	-0.02	0.01		065	-0.172	28.4	26.0	180	20	090	1.0	180
00:43:20	-87	-61	28	0	0.05	-0.10	0.01		065	-0.671	9.3	26.0	180	21	090	1.0	180
00:43:30	-87	-61	28	0	0.05	-0.14	0.03		065	-1.101	5.1	26.0	180	21	090	1.0	180
00:43:40	-87	-61	28	0	0.06	-0.16	0.05		065	-1.309	10.2	26.0	180	25	090	1.0	180
00:43:50	-87	-60	28	0	0.08	-0.24	0.07		064	-1.944	-3.4	26.0	180	22	090	1.0	180
00:44:00	-87	-60	28	0	0.10	-0.32	0.12		064	-2.793	-10.1	26.0	180	19	090	1.0	180
00:44:10	-86	-59	28	0	0.10	-0.28	0.15		063	-2.711	2.2	26.0	180	20	090	1.0	180
00:44:20	-86	-58	28	0	0.11	-0.36	0.16		063	-3.310	9.7	26.0	180	22	090	1.0	180
00:44:30	-86	-57	25	0	0.11	-0.42	0.15		062	-3.664	19.2	26.0	180	15	090	1.0	180
00:44:40	-86	-57	25	0	0.09	-0.43	0.13		062	-3.592	30.0	50.0	180	16	090	1.0	180
00:44:50	-86	-56	26	0	0.06	-0.37	0.09		061	-2.954	35.0	50.0	180	16	090	1.0	180
00:45:00	-86	-55	33	0	0.07	-0.26	0.03		061	-1.843	35.0	50.0	180	15	090	1.0	180
00:45:10	-86	-54	26	0	0.09	-0.19	-0.03		061	-0.971	35.0	50.0	180	15	090	1.0	180
00:45:20	-86	-54	25	0	0.08	-0.12	-0.07		060	-0.369	32.9	50.0	180	22	090	1.0	180
00:45:30	-86	-53	25	0	0.07	-0.10	-0.09		060	-0.064	29.8	50.0	180	18	090	1.0	180
00:45:40	-85	-52	25	0	0.07	-0.13	-0.11		060	-0.093	30.6	50.0	180	18	090	1.0	180
00:45:50	-86	-52	25	0	0.05	-0.16	-0.13		060	-0.163	31.0	62.0	180	17	090	1.0	180
00:46:00	-86	-51	25	0	0.05	-0.20	-0.16		060	-0.268	32.7	76.0	180	17	090	1.0	180
00:46:10	-86	-50	25	0	0.01	-0.16	-0.17		060	0.094	30.3	76.0	180	13	090	1.0	180
00:46:20	-86	-49	25	0	0.00	-0.15	-0.18		060	0.230	28.7	76.0	180	21	090	1.0	180
00:46:30	-87	-48	25	0	-0.02	-0.23	-0.20		060	-0.215	35.0	76.0	180	20	090	1.0	180
00:46:40	-88	-47	25	0	-0.06	-0.34	-0.22		060	-0.739	35.0	76.0	180	20	090	1.0	180
00:46:50	-89	-46	25	0	-0.12	-0.26	-0.23		060	-0.164	35.0	1.0	180	21	090	1.0	180
00:47:00	-90	-46	25	0	-0.12	-0.33	-0.24		060	-0.558	35.0	0.0	180	23	090	1.0	180
00:47:10	-91	-45	25	0	-0.12	-0.30	-0.25		060	-0.333	35.0	0.0	180	16	090	1.0	180
00:47:20	-93	-44	25	0	-0.12	-0.16	-0.26		060	0.596	35.0	0.0	180	20	090	1.0	180
00:47:30	-94	-43	0	0	-0.12	-0.15	-0.26		060	0.690	35.0	0.0	180	22	090	1.0	180
00:47:40	-95	-43	0	0	-0.13	-0.12	-0.24		060	0.759	35.0	0.0	180	21	090	1.0	180
00:47:50	-96	-42	0	0	-0.15	-0.20	-0.23		060	0.183	17.4	0.0	180	18	090	1.0	180

Simulation Track Plot

Open Ocean
Ship: 150,000 ton, Tanker, partial load

Date: 03-Feb-99 Time: 15:38:37

Start Time [hrs:min:sec]: 00:23:20
End Time [hrs:min:sec]: 00:47:52
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 18

Date: 3 February 1999

Start Time: 16:35

Length of run [secs]: 2812

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 20 Direction: 90

Sea State, Significant wave height [m]:... 3 Direction: 270

Current Speed [knots]:..... 1 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 3.8

Evaluation:

*A little too much throttle to move ahead and we missed by 3.8 m.
The approach was very controlled. The ship handler had a lapse in discipline specifically in forgetting to maintain a balance of the thruster versus propeller. He momentarily forgot about the axial components of all forces, which were at acute angles. J.A. asked for a rerun, which we never made.*

Shiphhandling Simulator

Exercise date & time: 03-Feb-99

16:35:37

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 18**

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Stbd	Long	Bow	Stern					%	Deg	Knots	Deg	Knots	Deg
00:23:20	-68	-276	25	0	0.55	-0.42	-1.29		038	5.521	3.4	50.0	180	10	090	1.0	180
00:23:30	-70	-271	25	0	0.53	-0.38	-1.24		039	5.478	22.4	50.0	180	17	090	1.0	180
00:23:40	-71	-266	25	0	0.48	-0.42	-1.26		040	5.321	35.0	76.0	180	19	090	1.0	180
00:23:50	-73	-262	25	0	0.42	-0.38	-1.26		041	5.555	35.0	76.0	180	23	090	1.0	180
00:24:00	-75	-257	25	0	0.37	-0.30	-1.24		042	6.000	35.0	76.0	180	20	090	1.0	180
00:24:10	-76	-253	25	0	0.32	-0.23	-1.21		043	6.223	35.0	76.0	180	21	090	1.0	180
00:24:20	-78	-250	25	0	0.30	-0.19	-1.18		044	6.322	35.0	0.0	180	20	090	1.0	180
00:24:30	-79	-246	28	0	0.29	-0.06	-1.14		045	6.841	35.0	0.0	180	23	090	1.0	180
00:24:40	-80	-243	41	0	0.30	-0.05	-1.14		046	6.916	35.0	0.0	180	19	090	1.0	180
00:24:50	-81	-240	43	0	0.35	-0.10	-1.19		048	6.912	32.7	0.0	180	20	090	1.0	180
00:25:00	-82	-236	44	0	0.39	-0.21	-1.18		049	6.141	14.5	0.0	180	19	090	1.0	180
00:25:10	-83	-232	44	0	0.42	-0.22	-1.07		050	5.401	-1.6	24.0	180	21	090	1.0	180
00:25:20	-83	-228	44	0	0.48	-0.31	-0.90		050	3.757	-13.8	51.0	180	18	090	1.0	180
00:25:30	-83	-224	44	0	0.52	-0.46	-0.73		051	1.719	-18.4	51.0	180	19	090	1.0	180
00:25:40	-83	-220	44	0	0.55	-0.52	-0.56		051	0.257	-19.6	51.0	180	18	090	1.0	180
00:25:50	-82	-216	44	0	0.59	-0.58	-0.42		051	-1.013	-16.5	76.0	180	22	090	1.0	180
00:26:00	-81	-212	44	0	0.60	-0.70	-0.34		051	-2.275	-9.6	76.0	180	19	090	1.0	180
00:26:10	-81	-208	44	0	0.63	-0.68	-0.29		050	-2.460	-2.0	76.0	180	18	090	1.0	180
00:26:20	-80	-204	44	0	0.65	-0.61	-0.28		050	-2.099	4.8	100.0	180	15	090	1.0	180
00:26:30	-79	-200	33	0	0.62	-0.48	-0.29		050	-1.198	8.7	100.0	180	18	090	1.0	180
00:26:40	-77	-197	33	0	0.61	-0.34	-0.31		050	-0.230	8.9	100.0	180	17	090	1.0	180
00:26:50	-76	-194	33	0	0.58	-0.36	-0.35		050	-0.105	20.5	100.0	180	18	090	1.0	180
00:27:00	-75	-190	33	0	0.56	-0.39	-0.44		050	0.343	35.0	100.0	180	19	090	1.0	180
00:27:10	-74	-187	33	0	0.50	-0.30	-0.53		050	1.455	35.0	100.0	180	19	090	1.0	180
00:27:20	-74	-183	33	0	0.47	-0.34	-0.61		050	1.740	35.0	100.0	180	17	090	1.0	180
00:27:30	-74	-180	33	0	0.43	-0.31	-0.68		050	2.333	35.0	100.0	180	18	090	1.0	180
00:27:40	-74	-177	33	0	0.40	-0.31	-0.74		051	2.708	35.0	100.0	180	17	090	1.0	180
00:27:50	-74	-173	33	0	0.34	-0.19	-0.78		051	3.703	35.0	76.0	180	18	090	1.0	180
00:28:00	-74	-170	33	0	0.33	-0.28	-0.82		052	3.423	35.0	52.0	180	22	090	1.0	180
00:28:10	-75	-167	33	0	0.32	-0.33	-0.86		052	3.374	35.0	27.0	180	22	090	1.0	180
00:28:20	-75	-163	33	0	0.29	-0.26	-0.88		053	3.955	35.0	27.0	180	18	090	1.0	180
00:28:30	-76	-160	33	0	0.30	-0.17	-0.89		054	4.536	35.0	27.0	180	17	090	1.0	180
00:28:40	-76	-157	33	0	0.31	-0.08	-0.89		055	5.137	35.0	27.0	180	17	090	1.0	180
00:28:50	-76	-154	33	0	0.32	0.02	-0.88		055	5.712	35.0	27.0	180	13	090	1.0	180
00:29:00	-76	-152	33	0	0.34	0.08	-0.85		056	5.840	16.5	27.0	180	17	090	1.0	180
00:29:10	-76	-149	33	0	0.35	-0.01	-0.76		057	4.790	-2.5	27.0	180	20	090	1.0	180
00:29:20	-75	-147	33	0	0.36	-0.04	-0.63		058	3.764	-21.5	27.0	180	20	090	1.0	180
00:29:30	-74	-144	33	0	0.38	-0.23	-0.47		058	1.494	-35.0	27.0	180	19	090	1.0	180
00:29:40	-74	-142	33	0	0.36	-0.31	-0.31		059	0.002	-35.0	100.0	180	23	090	1.0	180
00:29:50	-73	-139	26	0	0.31	-0.32	-0.21		059	-0.704	-35.0	100.0	180	19	090	1.0	180
00:30:00	-72	-137	26	0	0.27	-0.43	-0.12		058	-1.954	-35.0	100.0	180	20	090	1.0	180
00:30:10	-72	-136	26	0	0.22	-0.57	-0.03		058	-3.388	-35.0	100.0	180	20	090	1.0	180
00:30:20	-72	-134	26	0	0.16	-0.66	0.04		057	-4.455	-24.4	100.0	180	20	090	1.0	180
00:30:30	-72	-132	26	0	0.09	-0.67	0.09		056	-4.803	-7.1	100.0	180	16	090	1.0	180
00:30:40	-73	-131	26	0	0.05	-0.68	0.10		056	-4.962	9.3	100.0	180	21	090	1.0	180
00:30:50	-74	-129	26	0	0.01	-0.66	0.09		055	-4.737	23.4	100.0	180	18	090	1.0	180
00:31:00	-74	-128	26	0	-0.02	-0.48	0.06		054	-3.402	35.0	35.0	180	18	090	1.0	180
00:31:10	-75	-127	26	0	0.00	-0.42	0.00		054	-2.665	35.0	26.0	180	22	090	1.0	180
00:31:20	-76	-127	26	0	0.01	-0.45	-0.06		053	-2.487	35.0	26.0	180	25	090	1.0	180
00:31:30	-77	-125	26	0	0.01	-0.44	-0.11		053	-2.075	35.0	26.0	180	16	090	1.0	180
00:31:40	-77	-124	26	0	0.01	-0.41	-0.15		052	-1.615	35.0	26.0	180	17	090	1.0	180
00:31:50	-78	-123	26	0	0.03	-0.41	-0.20		052	-1.317	35.0	26.0	180	15	090	1.0	180
00:32:00	-79	-122	26	0	0.04	-0.33	-0.24		052	-0.570	35.0	26.0	180	15	090	1.0	180
00:32:10	-80	-120	26	0	0.06	-0.42	-0.28		052	-0.841	35.0	26.0	180	14	090	1.0	180
00:32:20	-81	-119	26	0	0.05	-0.42	-0.33		052	-0.626	35.0	26.0	180	19	090	1.0	180
00:32:30	-82	-117	26	0	0.05	-0.45	-0.37		052	-0.534	35.0	26.0	180	15	090	1.0	180
00:32:40	-83	-115	26	0	0.04	-0.54	-0.41		052	-0.816	35.0	0.0	180	19	090	1.0	180
00:32:50	-84	-113	26	0	0.05	-0.57	-0.44		051	-0.785	35.0	0.0	180	20	090	1.0	180
00:33:00	-86	-111	32	0	0.04	-0.41	-0.46		051	0.368	35.0	0.0	180	17	090	1.0	180
00:33:10	-87	-109	44	0	0.07	-0.29	-0.54		052	1.583	35.0	50.0	180	13	090	1.0	180
00:33:20	-88	-107	45	0	0.13	-0.20	-0.66		052	2.901	35.0	50.0	180	23	090	1.0	180
00:33:30	-89	-105	51	0	0.17	-0.12	-0.78		053	4.211	35.0	50.0	180	23	090	1.0	180
00:33:40	-89	-102	49	0	0.21	-0.03	-0.89		053	5.480	35.0	50.0	180	20	090	1.0	180
00:33:50	-90	-100	49	0	0.25	0.10	-0.97		054	6.787	35.0	75.0	180	19	090	1.0	180
00:34:00	-90	-97	50	0	0.30	0.08	-1.04		056	7.121	35.0	53.0	180	21	090	1.0	180
00:34:10	-90	-94	49	0	0.35	0.24	-1.09		057	8.438	35.0	53.0	180	19	090	1.0	180
00:34:20	-89	-91	50	0	0.40	0.26	-1.12		058	8.792	35.0	74.0	180	22	090	1.0	180
00:34:30	-89	-88	49	0	0.43	0.27	-1.15		060	8.973	35.0	74.0	180	20	090	1.0	180
00:34:40	-88	-85	50	0	0.45	0.25	-1.17		061	8.996	35.0	74.0	180	18	090	1.0	180
00:34:50	-87	-82	37	0	0.45	0.19	-1.16		063	8.554	35.0	74.0	180	21	090	1.0	180
00:35:00	-86	-79	29	0	0.37	0.17	-1.09		064	8.022	35.0	100.0	180	23	090	1.0	180
00:35:10	-85	-76	29	0	0.30	0.25	-1.01		065	7.985	35.0	100.0	180	17	090	1.0	180
00:35:20	-85	-74	29	0	0.25	0.23	-0.93		067	7.414	35.0	100.0	180	15	090	1.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg	
00:35:30	-84	-72	29	0	0.19	0.22	-0.85	068	6.779	19.0	100.0	180	20	090	1.0	180
00:35:40	-84	-70	25	0	0.13	0.27	-0.73	069	6.294	0.0	100.0	180	19	090	1.0	180
00:35:50	-84	-69	25	0	0.06	0.19	-0.58	070	4.919	-19.0	100.0	180	15	090	1.0	180
00:36:00	-84	-68	25	0	0.02	0.10	-0.42	071	3.301	-35.0	100.0	180	13	090	1.0	180
00:36:10	-84	-67	25	0	-0.04	0.08	-0.27	071	2.276	-35.0	100.0	180	14	090	1.0	180
00:36:20	-85	-67	25	0	-0.09	0.05	-0.14	071	1.179	-35.0	100.0	180	16	090	1.0	180
00:36:30	-85	-67	25	0	-0.11	0.01	-0.02	072	0.187	-35.0	100.0	180	21	090	1.0	180
00:36:40	-86	-67	25	0	-0.14	-0.13	0.10	071	-1.443	-35.0	100.0	180	19	090	1.0	180
00:36:50	-87	-67	25	0	-0.22	-0.21	0.21	071	-2.651	-35.0	100.0	180	20	090	1.0	180
00:37:00	-88	-68	25	0	-0.27	-0.32	0.31	071	-3.995	-28.0	100.0	180	22	090	1.0	180
00:37:10	-90	-68	25	0	-0.33	-0.41	0.39	070	-5.068	-14.1	100.0	180	22	090	1.0	180
00:37:20	-91	-69	29	0	-0.37	-0.42	0.42	069	-5.353	0.5	100.0	180	14	090	1.0	180
00:37:30	-93	-70	44	0	-0.34	-0.39	0.42	068	-5.135	17.0	0.0	180	15	090	1.0	180
00:37:40	-94	-70	32	0	-0.29	-0.33	0.35	067	-4.337	31.7	0.0	180	18	090	1.0	180
00:37:50	-96	-71	29	0	-0.28	-0.27	0.31	067	-3.691	35.0	0.0	180	23	090	1.0	180
00:38:00	-97	-72	43	0	-0.25	-0.29	0.23	066	-3.279	35.0	0.0	180	20	090	1.0	180
00:38:10	-98	-72	57	0	-0.18	-0.19	0.05	066	-1.486	35.0	0.0	180	20	090	1.0	180
00:38:20	-99	-72	61	0	-0.06	0.08	-0.20	066	1.775	30.3	0.0	180	18	090	1.0	180
00:38:30	-99	-71	58	0	0.08	0.13	-0.28	066	2.575	11.2	0.0	180	22	090	1.0	180
00:38:40	-98	-71	53	0	0.21	0.15	-0.29	066	2.759	14.3	0.0	180	19	090	1.0	180
00:38:50	-97	-70	59	0	0.34	0.16	-0.29	067	2.828	10.6	0.0	180	18	090	1.0	180
00:39:00	-96	-69	59	0	0.46	0.13	-0.27	067	2.523	5.9	0.0	180	16	090	1.0	180
00:39:10	-93	-67	40	0	0.59	0.00	-0.22	068	1.394	3.4	0.0	180	21	090	1.0	180
00:39:20	-91	-66	28	0	0.57	-0.04	-0.18	068	0.916	0.9	100.0	180	18	090	1.0	180
00:39:30	-88	-64	28	0	0.50	-0.07	-0.15	068	0.496	0.0	100.0	180	18	090	1.0	180
00:39:40	-86	-63	25	0	0.46	-0.04	-0.12	068	0.483	-1.8	100.0	180	16	090	1.0	180
00:39:50	-84	-62	25	0	0.41	-0.07	-0.08	068	0.089	-2.0	100.0	180	22	090	1.0	180
00:40:00	-82	-60	25	0	0.34	-0.10	-0.05	068	-0.318	-0.1	100.0	180	22	090	1.0	180
00:40:10	-81	-59	0	0	0.26	-0.10	-0.05	068	-0.337	1.5	100.0	180	22	090	1.0	180
00:40:20	-80	-59	0	0	0.16	-0.10	-0.04	068	-0.351	3.6	100.0	180	16	090	1.0	180
00:40:30	-80	-58	0	0	0.08	-0.03	-0.03	068	-0.004	1.9	100.0	180	19	090	1.0	180
00:40:40	-80	-58	0	0	0.02	-0.03	-0.02	068	-0.098	4.8	100.0	180	19	090	1.0	180
00:40:50	-80	-58	0	0	-0.05	0.00	-0.01	068	0.041	1.0	100.0	180	20	090	1.0	180
00:41:00	-80	-58	29	0	-0.09	0.05	0.04	068	0.049	0.4	100.0	180	17	090	1.0	180
00:41:10	-81	-59	29	0	-0.10	-0.07	0.07	068	-0.946	5.2	100.0	180	19	090	1.0	180
00:41:20	-81	-59	29	0	-0.15	-0.18	0.13	068	-1.960	-13.7	77.0	180	16	090	1.0	180
00:41:30	-82	-59	29	0	-0.14	-0.23	0.19	067	-2.686	0.0	26.0	180	18	090	1.0	180
00:41:40	-83	-59	29	0	-0.13	-0.24	0.22	067	-2.919	11.4	26.0	180	15	090	1.0	180
00:41:50	-83	-59	29	0	-0.10	-0.30	0.21	066	-3.239	30.4	26.0	180	14	090	1.0	180
00:42:00	-84	-59	29	0	-0.09	-0.26	0.17	066	-2.727	35.0	0.0	180	18	090	1.0	180
00:42:10	-84	-59	29	0	-0.10	-0.25	0.13	065	-2.411	35.0	0.0	180	23	090	1.0	180
00:42:20	-85	-59	29	0	-0.09	-0.26	0.09	065	-2.188	35.0	0.0	180	20	090	1.0	180
00:42:30	-86	-59	29	0	-0.09	-0.26	0.05	065	-1.963	35.0	0.0	180	17	090	1.0	180
00:42:40	-86	-59	29	0	-0.09	-0.22	0.01	064	-1.474	35.0	0.0	180	19	090	1.0	180
00:42:50	-87	-58	29	0	-0.07	-0.11	-0.02	064	-0.546	35.0	0.0	180	18	090	1.0	180
00:43:00	-87	-58	31	0	-0.05	-0.05	-0.06	064	0.059	34.3	0.0	180	17	090	1.0	180
00:43:10	-87	-58	41	0	0.00	0.03	-0.10	064	0.813	16.0	0.0	180	20	090	1.0	180
00:43:20	-87	-58	42	0	0.08	-0.04	-0.12	064	0.508	26.1	0.0	180	21	090	1.0	180
00:43:30	-87	-57	29	0	0.09	-0.04	-0.15	064	0.705	23.7	0.0	180	21	090	1.0	180
00:43:40	-87	-56	29	0	0.11	-0.06	-0.14	064	0.559	6.8	0.0	180	25	090	1.0	180
00:43:50	-87	-56	25	0	0.12	-0.15	-0.10	065	-0.313	-7.1	51.0	180	22	090	1.0	180
00:44:00	-86	-55	25	0	0.12	-0.22	-0.06	064	-1.038	-0.1	77.0	180	19	090	1.0	180
00:44:10	-86	-54	25	0	0.08	-0.17	-0.03	064	-0.915	4.4	77.0	180	20	090	1.0	180
00:44:20	-86	-53	25	0	0.06	-0.26	-0.01	064	-1.596	12.3	77.0	180	22	090	1.0	180
00:44:30	-86	-52	25	0	0.02	-0.32	0.00	064	-2.045	19.7	77.0	180	15	090	1.0	180
00:44:40	-87	-52	25	0	-0.01	-0.34	0.00	063	-2.147	26.3	52.0	180	16	090	1.0	180
00:44:50	-87	-51	25	0	-0.04	-0.30	-0.02	063	-1.779	30.6	52.0	180	16	090	1.0	180
00:45:00	-88	-50	25	0	-0.05	-0.21	-0.03	063	-1.157	32.5	52.0	180	15	090	1.0	180
00:45:10	-88	-50	25	0	-0.03	-0.17	-0.05	063	-0.747	32.6	0.0	180	15	090	1.0	180
00:45:20	-89	-50	25	0	-0.03	-0.11	-0.07	063	-0.290	30.2	0.0	180	22	090	1.0	180
00:45:30	-89	-49	38	0	0.00	-0.08	-0.10	063	0.084	25.4	0.0	180	18	090	1.0	180
00:45:40	-89	-49	44	0	0.06	-0.08	-0.16	063	0.478	21.8	0.0	180	18	090	1.0	180
00:45:50	-89	-48	45	0	0.13	-0.09	-0.20	063	0.692	19.9	0.0	180	17	090	1.0	180
00:46:00	-88	-47	45	0	0.21	-0.11	-0.24	063	0.813	18.5	0.0	180	17	090	1.0	180
00:46:10	-88	-45	42	0	0.27	-0.06	-0.25	063	1.242	13.9	0.0	180	13	090	1.0	180
00:46:20	-87	-44	-6	0	0.29	-0.06	-0.24	063	1.159	11.0	0.0	180	21	090	1.0	180
00:46:30	-86	-43	-46	0	0.25	-0.14	-0.23	063	0.596	10.0	0.0	180	20	090	1.0	180
00:46:40	-85	-41	-25	0	0.17	-0.24	-0.23	063	-0.090	12.2	0.0	180	20	090	1.0	180
00:46:50	-85	-40	0	0	0.11	-0.17	-0.22	063	0.287	9.8	0.0	180	21	090	1.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 03-Feb-99 Time: 16:35:37

Start Time [hrs:min:sec]: 00:23:20
End Time [hrs:min:sec]: 00:46:52
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 19

Date: 4 February 1999

Start Time: 08:00

Length of run [secs]: 2205

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 0
Sea State, Significant wave height [m]:..	5	Direction: 180
Current Speed [knots]:.....	0	Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.6

Evaluation:

Deceleration and tracking were good up to the point where the buoy came into camera view. When the buoy was in camera view, the ground head speed was about 0.2 knots. At first the buoy was tracking apparently straight aft. Then the buoy began to trend just a little to starboard. The captain started to change the autopilot heading to the right up to 005 degrees but it was not enough. The buoy ended up a little aft and to the starboard, just beyond the limit. It appears that higher rudder rate would help the problem. A high lift rudder would also be very beneficial.

Shiphhandling Simulator

Exercise date & time: 04-Feb-99
08:00:44

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 755 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 595 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #19**

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind Knots	Current	
	East	North			Long	Bow	Stern					Deg	Deg	Deg
00:16:40	0	-590	28	0	1.76	-0.02	0.04	000	-0.351	-6.6	0.0	180	32	000
00:16:50	0	-581	28	0	1.70	-0.02	0.05	000	-0.462	-5.3	0.0	180	21	000
00:17:00	0	-572	28	0	1.74	-0.02	0.06	000	-0.532	-4.1	0.0	180	29	000
00:17:10	0	-563	37	0	1.74	-0.02	0.07	000	-0.597	-2.4	0.0	180	25	000
00:17:20	0	-555	41	0	1.71	-0.02	0.08	000	-0.633	-0.1	0.0	180	22	000
00:17:30	1	-546	42	0	1.79	-0.02	0.07	360	-0.579	1.5	0.0	180	24	000
00:17:40	1	-536	42	0	1.83	-0.01	0.06	360	-0.458	3.1	0.0	180	16	000
00:17:50	1	-527	33	0	1.84	0.00	0.05	360	-0.325	4.1	0.0	180	25	000
00:18:00	1	-517	33	0	1.73	0.00	0.03	360	-0.204	4.6	0.0	180	26	000
00:18:10	1	-509	33	0	1.62	0.01	0.02	360	-0.047	5.1	0.0	180	20	000
00:18:20	1	-501	33	0	1.59	0.01	0.00	360	0.067	5.0	0.0	180	23	000
00:18:30	1	-492	33	0	1.57	0.02	-0.01	360	0.171	1.5	0.0	180	20	000
00:18:40	1	-484	33	0	1.56	0.00	0.02	360	-0.107	-13.0	0.0	180	13	000
00:18:50	1	-477	33	0	1.52	0.00	0.03	360	-0.199	5.2	0.0	180	25	000
00:19:00	1	-469	39	0	1.53	0.01	0.01	360	-0.035	5.7	0.0	180	23	000
00:19:10	1	-461	39	0	1.54	0.02	-0.01	360	0.176	4.9	0.0	180	28	000
00:19:20	1	-453	40	0	1.59	0.00	0.01	360	-0.011	-12.2	0.0	180	27	000
00:19:30	1	-444	40	0	1.59	-0.04	0.06	360	-0.626	-11.9	0.0	180	23	000
00:19:40	1	-436	40	0	1.55	-0.05	0.08	360	-0.804	4.8	0.0	180	28	000
00:19:50	1	-428	40	0	1.58	-0.02	0.04	359	-0.387	9.9	0.0	180	24	000
00:20:00	1	-420	40	0	1.66	0.00	-0.01	359	0.071	10.1	0.0	180	23	000
00:20:10	1	-411	40	0	1.66	0.02	-0.05	359	0.461	9.2	0.0	180	24	000
00:20:20	1	-403	40	0	1.73	0.04	-0.08	360	0.737	7.4	0.0	180	26	000
00:20:30	0	-394	40	0	1.78	0.04	-0.10	360	0.908	4.5	0.0	180	20	000
00:20:40	0	-385	40	0	1.74	0.04	-0.11	360	0.954	1.6	0.0	180	27	000
00:20:50	0	-376	39	0	1.69	0.03	-0.10	000	0.879	-1.2	0.0	180	25	000
00:21:00	0	-367	40	0	1.65	0.02	-0.09	000	0.710	-3.3	0.0	180	19	000
00:21:10	0	-359	40	0	1.67	0.01	-0.07	000	0.482	-4.8	0.0	180	22	000
00:21:20	0	-350	40	0	1.63	0.00	-0.04	000	0.214	-5.8	50.0	180	21	000
00:21:30	0	-342	40	0	1.54	-0.02	-0.01	000	-0.093	-5.6	50.0	180	24	000
00:21:40	0	-334	39	0	1.54	-0.04	0.02	000	-0.344	-4.8	75.0	180	25	000
00:21:50	0	-326	40	0	1.56	-0.04	0.04	000	-0.509	-3.6	75.0	180	19	000
00:22:00	0	-318	40	0	1.54	-0.05	0.05	000	-0.589	-1.8	100.0	180	23	000
00:22:10	0	-311	38	0	1.42	-0.05	0.05	000	-0.599	-0.1	100.0	180	25	000
00:22:20	0	-303	35	0	1.37	-0.04	0.04	360	-0.540	1.6	100.0	180	19	000
00:22:30	0	-297	35	0	1.28	-0.03	0.04	360	-0.438	3.2	100.0	180	33	000
00:22:40	0	-290	35	0	1.25	-0.03	0.02	360	-0.306	4.2	100.0	180	23	000
00:22:50	-1	-284	35	0	1.25	-0.02	0.01	360	-0.157	4.7	100.0	180	19	000
00:23:00	-1	-277	35	0	1.22	-0.01	-0.01	360	0.007	5.1	100.0	180	22	000
00:23:10	-1	-271	33	0	1.16	0.00	-0.02	360	0.121	4.4	100.0	180	19	000
00:23:20	-1	-265	33	0	1.16	0.00	-0.03	360	0.220	3.7	100.0	180	25	000
00:23:30	-1	-259	33	0	1.08	0.01	-0.05	360	0.342	11.3	100.0	180	24	000
00:23:40	-1	-254	33	0	0.99	0.03	-0.10	360	0.830	18.7	100.0	180	25	000
00:23:50	-1	-249	29	0	0.87	0.05	-0.13	000	1.180	15.3	100.0	180	27	000
00:24:00	-1	-245	29	0	0.76	0.07	-0.15	000	1.417	10.8	52.0	180	25	000
00:24:10	-2	-241	29	0	0.70	0.08	-0.17	001	1.545	5.8	27.0	180	21	000
00:24:20	-2	-238	27	0	0.63	0.08	-0.17	001	1.543	0.6	27.0	180	28	000
00:24:30	-2	-235	25	0	0.64	0.07	-0.16	001	1.467	-4.3	27.0	180	21	000
00:24:40	-2	-231	25	0	0.64	0.07	-0.13	001	1.229	-23.3	27.0	180	23	000
00:24:50	-2	-228	25	0	0.54	0.04	-0.08	001	0.736	-27.5	27.0	180	27	000
00:25:00	-2	-226	25	0	0.44	0.01	-0.03	002	0.215	-28.2	27.0	180	28	000
00:25:10	-2	-223	37	0	0.42	-0.03	0.05	002	-0.475	-26.3	27.0	180	24	000
00:25:20	-2	-221	37	0	0.48	-0.05	0.13	001	-1.173	-21.9	27.0	180	21	000
00:25:30	-2	-219	37	0	0.43	-0.09	0.19	001	-1.779	-15.5	27.0	180	19	000
00:25:40	-1	-217	37	0	0.47	-0.11	0.23	001	-2.148	-9.2	27.0	180	17	000
00:25:50	-1	-214	37	0	0.51	-0.11	0.24	000	-2.242	-2.7	27.0	180	23	000
00:26:00	-1	-211	37	0	0.58	-0.10	0.23	000	-2.094	3.1	27.0	180	19	000
00:26:10	0	-208	37	0	0.64	-0.08	0.20	360	-1.784	7.8	27.0	180	27	000
00:26:20	0	-205	37	0	0.64	-0.06	0.15	359	-1.329	11.9	40.0	180	20	000
00:26:30	0	-202	37	0	0.59	-0.03	0.10	359	-0.862	14.1	40.0	180	19	000
00:26:40	0	-199	37	0	0.57	-0.01	0.05	359	-0.357	15.4	40.0	180	29	000
00:26:50	0	-196	37	0	0.52	0.01	-0.01	359	0.141	14.3	40.0	180	25	000
00:27:00	0	-193	37	0	0.52	0.03	-0.05	359	0.566	12.3	40.0	180	25	000
00:27:10	0	-190	37	0	0.50	0.05	-0.09	359	0.864	9.8	40.0	180	27	000
00:27:20	0	-188	37	0	0.47	0.06	-0.11	360	1.074	5.8	40.0	180	23	000
00:27:30	0	-185	37	0	0.48	0.06	-0.12	360	1.145	2.8	40.0	180	25	000
00:27:40	0	-183	37	0	0.44	0.05	-0.12	360	1.083	-0.7	40.0	180	26	000
00:27:50	-1	-181	37	0	0.40	0.04	-0.10	000	0.912	-3.8	40.0	180	23	000
00:28:00	-1	-179	37	0	0.40	0.03	-0.08	000	0.681	-5.4	15.0	180	29	000
00:28:10	-1	-177	37	0	0.39	0.02	-0.05	000	0.416	-6.4	15.0	180	19	000
00:28:20	-1	-175	37	0	0.34	0.00	-0.02	000	0.133	-6.7	15.0	180	24	000
00:28:30	-1	-173	40	0	0.35	-0.02	0.00	000	-0.149	-5.7	15.0	180	24	000
00:28:40	-1	-171	40	0	0.52	-0.03	0.03	000	-0.355	-4.3	25.0	180	19	000

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:28:50	-1	-168	38	0	0.55	-0.04	0.04	000	-0.492	-2.9	39.0	180	18	000	0.0	180
00:29:00	-1	-165	36	0	0.57	-0.04	0.05	000	-0.544	-1.1	39.0	180	19	000	0.0	180
00:29:10	-1	-162	36	0	0.55	-0.03	0.04	000	-0.413	11.3	39.0	180	24	000	0.0	180
00:29:20	-1	-160	36	0	0.56	0.01	-0.02	000	0.176	17.1	39.0	180	24	000	0.0	180
00:29:30	-1	-157	36	0	0.57	0.04	-0.07	000	0.726	14.8	39.0	180	28	000	0.0	180
00:29:40	-1	-154	36	0	0.52	0.06	-0.11	000	1.127	11.0	51.0	180	24	000	0.0	180
00:29:50	-1	-151	36	0	0.47	0.08	-0.14	000	1.371	6.2	51.0	180	22	000	0.0	180
00:30:00	-1	-149	36	0	0.47	0.09	-0.14	001	1.449	2.0	51.0	180	19	000	0.0	180
00:30:10	-1	-146	36	0	0.45	0.09	-0.13	001	1.389	-2.5	51.0	180	23	000	0.0	180
00:30:20	-1	-144	36	0	0.44	0.07	-0.11	001	1.175	-6.0	51.0	180	27	000	0.0	180
00:30:30	-1	-142	36	0	0.43	0.07	-0.08	001	0.954	-8.7	51.0	180	26	000	0.0	180
00:30:40	-1	-140	36	0	0.35	0.06	-0.04	001	0.670	-10.7	35.0	180	22	000	0.0	180
00:30:50	-1	-138	36	0	0.30	0.05	0.00	002	0.313	-11.4	25.0	180	27	000	0.0	180
00:31:00	-1	-137	36	0	0.27	0.03	0.04	002	-0.056	-9.9	25.0	180	22	000	0.0	180
00:31:10	-1	-135	36	0	0.26	0.00	0.09	002	-0.515	-22.8	25.0	180	21	000	0.0	180
00:31:20	0	-134	36	0	0.28	-0.03	0.16	001	-1.218	-19.8	0.0	180	26	000	0.0	180
00:31:30	0	-132	39	0	0.36	-0.07	0.22	001	-1.808	-14.5	0.0	180	19	000	0.0	180
00:31:40	0	-130	39	0	0.40	-0.09	0.25	001	-2.184	-8.4	0.0	180	26	000	0.0	180
00:31:50	1	-128	39	0	0.39	-0.09	0.26	000	-2.217	-1.3	0.0	180	22	000	0.0	180
00:32:00	1	-126	39	0	0.49	-0.08	0.25	000	-2.104	-6.9	0.0	180	28	000	0.0	180
00:32:10	2	-124	36	0	0.51	-0.10	0.28	360	-2.377	-7.0	47.0	180	27	000	0.0	180
00:32:20	2	-121	33	0	0.49	-0.10	0.28	359	-2.414	0.1	47.0	180	20	000	0.0	180
00:32:30	3	-119	33	0	0.40	-0.10	0.25	359	-2.208	8.1	47.0	180	23	000	0.0	180
00:32:40	3	-117	33	0	0.37	-0.07	0.21	359	-1.761	13.3	47.0	180	24	000	0.0	180
00:32:50	3	-115	33	0	0.43	-0.07	0.16	358	-1.459	16.4	47.0	180	22	000	0.0	180
00:33:00	3	-113	33	0	0.40	-0.05	0.10	358	-0.980	19.3	77.0	180	22	000	0.0	180
00:33:10	3	-111	33	0	0.31	-0.03	0.05	358	-0.456	20.3	77.0	180	21	000	0.0	180
00:33:20	3	-109	33	0	0.25	0.00	-0.01	358	0.062	18.9	77.0	180	18	000	0.0	180
00:33:30	3	-108	33	0	0.18	0.00	-0.06	358	0.339	16.4	77.0	180	21	000	0.0	180
00:33:40	3	-108	33	0	0.08	0.00	-0.09	358	0.551	9.9	77.0	180	22	000	0.0	180
00:33:50	3	-107	33	0	0.04	-0.01	-0.10	358	0.613	4.4	27.0	180	29	000	0.0	180
00:34:00	2	-107	37	0	0.01	-0.01	-0.11	358	0.593	2.2	27.0	180	22	000	0.0	180
00:34:10	2	-107	37	0	0.01	-0.02	-0.11	358	0.569	1.2	27.0	180	23	000	0.0	180
00:34:20	2	-107	36	0	0.04	-0.02	-0.10	358	0.544	0.8	15.0	180	22	000	0.0	180
00:34:30	1	-107	37	0	0.11	-0.01	-0.10	359	0.588	2.9	15.0	180	24	000	0.0	180
00:34:40	1	-106	37	0	0.14	-0.02	-0.11	359	0.535	2.6	15.0	180	26	000	0.0	180
00:34:50	1	-105	37	0	0.18	-0.04	-0.11	359	0.410	3.9	24.0	180	25	000	0.0	180
00:35:00	0	-104	37	0	0.19	-0.03	-0.15	359	0.765	17.4	24.0	180	32	000	0.0	180
00:35:10	0	-103	37	0	0.13	0.00	-0.21	359	1.338	27.0	24.0	180	24	000	0.0	180
00:35:20	-1	-103	37	0	0.16	0.03	-0.28	359	1.965	20.2	24.0	180	26	000	0.0	180
00:35:30	-2	-102	36	0	0.18	0.07	-0.34	360	2.605	31.6	24.0	180	24	000	0.0	180
00:35:40	-2	-101	37	0	0.24	0.13	-0.44	000	3.632	35.0	24.0	180	21	000	0.0	180
00:35:50	-3	-99	37	0	0.21	0.20	-0.54	001	4.666	35.0	24.0	180	17	000	0.0	180
00:36:00	-4	-99	37	0	0.10	0.30	-0.62	002	5.828	28.5	24.0	180	19	000	0.0	180
00:36:10	-5	-98	37	0	0.07	0.45	-0.64	003	6.900	9.5	24.0	180	23	000	0.0	180
00:36:20	-5	-98	37	0	0.00	0.60	-0.59	004	7.533	-9.5	24.0	180	25	000	0.0	180
00:36:30	-5	-98	37	0	-0.14	0.74	-0.57	005	8.302	-28.5	24.0	180	21	000	0.0	180
00:36:40	-4	-99	36	0	-0.24	0.74	-0.48	007	7.740	-35.0	24.0	180	22	000	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

00:23:10
00:22:40
00:22:10
00:21:40
00:21:10
00:20:40
00:20:10
00:19:40
00:19:10
00:18:40
00:18:10

00:1 Start Time [hrs:min:sec]: 00:16:40
00:1 End Time [hrs:min:sec]: 00:36:45
00:1 Delta Plot Time [sec]: 30
00:16 East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

Date: 04-Feb-99 Time: 08:00:44

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 20
Start Time: 08:50
Length of run [secs]: 2280

Date: 4 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 0
Sea State, Significant wave height [m]:..	5.1	Direction: 180
Current Speed [knots]:.....	0	Direction: 0

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 1.8

Evaluation:

The approach – deceleration and tracking along the course line was no problem. The plan was to bring the ship to a stop over the buoy and hover there by balancing forces, thruster against propeller and achieving lateral motion control by autopilot change of 1 to 2 degrees. The captain believes that this is better than the case of the previous run, where the ship was kept moving ahead over the buoy. The last approach will allow for more mating operations if needed with no difficulty.

Shiphandling Simulator

Exercise date & time: 04-Feb-99
08:50:07

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 755 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 595 150k tanker in partial load - Suction Mooring
 Exercise identification: Run # 20

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Deg	Knots	Deg	Knots
00:16:40	-2	-399	27	0	2.15	0.01	-0.06	001	0.441	-24.4	25.0	180	32	000	0.0	180
00:16:50	-2	-388	27	0	2.12	-0.01	-0.01	001	-0.055	-24.7	25.0	180	21	000	0.0	180
00:17:00	-2	-377	27	0	2.03	-0.03	0.05	001	-0.529	-23.9	25.0	180	29	000	0.0	180
00:17:10	-2	-367	27	0	2.04	-0.04	0.10	001	-0.900	-21.4	25.0	180	25	000	0.0	180
00:17:20	-1	-356	27	0	2.05	-0.05	0.14	001	-1.238	-17.9	25.0	180	22	000	0.0	180
00:17:30	-1	-346	27	0	1.96	-0.06	0.18	001	-1.528	-13.7	25.0	180	24	000	0.0	180
00:17:40	0	-336	27	0	1.97	-0.07	0.20	001	-1.681	-8.6	25.0	180	16	000	0.0	180
00:17:50	0	-325	27	0	1.97	-0.06	0.21	000	-1.720	-3.5	25.0	180	25	000	0.0	180
00:18:00	1	-315	27	0	1.95	-0.05	0.21	360	-1.665	-3.8	25.0	180	26	000	0.0	180
00:18:10	1	-306	27	0	1.85	-0.06	0.23	360	-1.858	-11.2	25.0	180	20	000	0.0	180
00:18:20	1	-296	27	0	1.69	-0.07	0.24	359	-1.955	-5.4	25.0	180	23	000	0.0	180
00:18:30	2	-288	27	0	1.62	-0.07	0.24	359	-1.974	0.9	25.0	180	20	000	0.0	180
00:18:40	2	-280	27	0	1.57	-0.07	0.22	359	-1.865	14.1	25.0	180	13	000	0.0	180
00:18:50	2	-272	27	0	1.54	-0.04	0.17	358	-1.322	29.1	25.0	180	25	000	0.0	180
00:19:00	2	-264	27	0	1.47	0.01	0.10	358	-0.548	31.4	25.0	180	23	000	0.0	180
00:19:10	2	-256	27	0	1.44	0.05	0.03	358	0.148	31.4	25.0	180	28	000	0.0	180
00:19:20	2	-249	27	0	1.39	0.08	-0.03	358	0.690	29.8	25.0	180	27	000	0.0	180
00:19:30	2	-242	27	0	1.40	0.10	-0.09	358	1.202	26.6	51.0	180	23	000	0.0	180
00:19:40	2	-235	27	0	1.33	0.10	-0.13	359	1.493	22.3	100.0	180	28	000	0.0	180
00:19:50	2	-228	27	0	1.21	0.11	-0.17	359	1.745	16.9	100.0	180	24	000	0.0	180
00:20:00	1	-222	27	0	1.09	0.11	-0.19	359	1.887	11.0	100.0	180	23	000	0.0	180
00:20:10	1	-217	27	0	1.09	0.11	-0.20	360	1.919	5.2	100.0	180	24	000	0.0	180
00:20:20	1	-211	27	0	1.02	0.10	-0.19	360	1.853	-0.4	100.0	180	26	000	0.0	180
00:20:30	1	-206	27	0	0.96	0.09	-0.18	000	1.690	-5.9	100.0	180	20	000	0.0	180
00:20:40	0	-201	27	0	0.96	0.07	-0.16	000	1.464	-10.3	100.0	180	27	000	0.0	180
00:20:50	0	-197	27	0	0.85	0.05	-0.11	001	1.034	-27.9	100.0	180	25	000	0.0	180
00:21:00	0	-193	27	0	0.71	0.02	-0.04	001	0.412	-33.3	100.0	180	19	000	0.0	180
00:21:10	0	-189	27	0	0.57	-0.01	0.02	001	-0.208	-32.2	100.0	180	22	000	0.0	180
00:21:20	0	-187	27	0	0.46	-0.04	0.08	001	-0.744	-29.6	100.0	180	21	000	0.0	180
00:21:30	0	-185	27	0	0.38	-0.05	0.13	001	-1.185	-25.1	100.0	180	24	000	0.0	180
00:21:40	1	-183	27	0	0.22	-0.07	0.17	000	-1.538	-16.5	100.0	180	25	000	0.0	180
00:21:50	1	-182	27	0	0.10	-0.08	0.18	000	-1.671	-2.6	100.0	180	19	000	0.0	180
00:22:00	1	-182	27	0	0.06	-0.08	0.17	360	-1.534	9.4	100.0	180	23	000	0.0	180
00:22:10	1	-182	27	0	0.04	-0.06	0.13	360	-1.220	18.0	100.0	180	25	000	0.0	180
00:22:20	2	-182	27	0	-0.08	-0.03	0.08	359	-0.712	28.5	100.0	180	19	000	0.0	180
00:22:30	2	-182	37	0	-0.18	0.00	0.03	359	-0.227	13.4	100.0	180	33	000	0.0	180
00:22:40	2	-183	37	0	-0.20	0.02	-0.01	359	0.155	11.0	25.0	180	23	000	0.0	180
00:22:50	2	-184	37	0	-0.20	0.03	-0.04	359	0.483	8.5	0.0	180	19	000	0.0	180
00:23:00	2	-185	37	0	-0.14	0.04	-0.06	359	0.669	3.9	0.0	180	22	000	0.0	180
00:23:10	2	-186	37	0	-0.06	0.03	-0.05	360	0.560	-11.4	0.0	180	19	000	0.0	180
00:23:20	2	-186	36	0	-0.06	0.00	0.00	360	-0.012	-11.4	0.0	180	25	000	0.0	180
00:23:30	2	-186	37	0	-0.01	-0.01	0.01	360	-0.127	7.6	27.0	180	24	000	0.0	180
00:23:40	2	-186	37	0	0.04	0.00	-0.02	360	0.119	3.6	0.0	180	25	000	0.0	180
00:23:50	2	-186	37	0	0.02	0.00	-0.02	360	0.122	-0.2	26.0	180	27	000	0.0	180
00:24:00	1	-186	36	0	0.01	-0.01	-0.02	360	0.068	1.7	26.0	180	25	000	0.0	180
00:24:10	1	-186	37	0	-0.04	-0.01	-0.03	360	0.102	2.8	26.0	180	21	000	0.0	180
00:24:20	1	-186	37	0	-0.08	-0.02	-0.01	360	-0.100	-11.0	26.0	180	28	000	0.0	180
00:24:30	1	-187	37	0	-0.11	-0.05	0.02	360	-0.441	-6.4	26.0	180	21	000	0.0	180
00:24:40	1	-187	42	0	-0.13	-0.06	0.05	360	-0.693	-3.1	0.0	180	23	000	0.0	180
00:24:50	1	-188	42	0	-0.05	-0.06	0.04	359	-0.681	8.3	0.0	180	27	000	0.0	180
00:25:00	1	-188	41	0	-0.01	-0.04	-0.01	359	-0.158	7.2	0.0	180	28	000	0.0	180
00:25:10	1	-188	42	0	-0.06	-0.04	-0.01	359	-0.189	-2.1	0.0	180	24	000	0.0	180
00:25:20	1	-188	45	0	-0.08	-0.05	0.00	359	-0.296	-0.7	0.0	180	21	000	0.0	180
00:25:30	1	-189	45	0	-0.01	-0.05	-0.01	359	-0.266	6.4	0.0	180	19	000	0.0	180
00:25:40	1	-189	44	0	0.08	-0.06	-0.01	359	-0.283	0.6	0.0	180	17	000	0.0	180
00:25:50	0	-188	44	0	0.06	-0.05	-0.02	359	-0.237	1.3	0.0	180	23	000	0.0	180
00:26:00	0	-188	44	0	0.15	-0.03	-0.05	359	0.143	14.8	0.0	180	19	000	0.0	180
00:26:10	0	-187	45	0	0.22	0.01	-0.11	359	0.754	10.3	0.0	180	27	000	0.0	180
00:26:20	0	-185	45	0	0.32	0.02	-0.15	359	1.090	7.4	51.0	180	20	000	0.0	180
00:26:30	-1	-183	42	0	0.39	0.02	-0.17	360	1.224	4.2	75.0	180	19	000	0.0	180
00:26:40	-1	-181	41	0	0.38	0.02	-0.17	360	1.216	0.8	75.0	180	29	000	0.0	180
00:26:50	-2	-180	42	0	0.32	0.02	-0.17	360	1.182	9.0	75.0	180	25	000	0.0	180
00:27:00	-2	-178	42	0	0.29	0.04	-0.21	000	1.587	8.5	75.0	180	25	000	0.0	180
00:27:10	-2	-177	42	0	0.24	0.05	-0.22	000	1.706	1.8	75.0	180	27	000	0.0	180
00:27:20	-3	-175	42	0	0.25	0.05	-0.20	001	1.571	-2.5	27.0	180	23	000	0.0	180
00:27:30	-3	-174	42	0	0.26	0.04	-0.17	001	1.328	-5.3	27.0	180	25	000	0.0	180
00:27:40	-3	-173	42	0	0.25	0.02	-0.13	001	0.913	-7.6	27.0	180	26	000	0.0	180
00:27:50	-4	-171	42	0	0.28	-0.01	-0.09	001	0.502	-7.2	27.0	180	23	000	0.0	180
00:28:00	-4	-170	41	0	0.26	-0.02	-0.05	001	0.156	-6.9	27.0	180	29	000	0.0	180
00:28:10	-4	-169	42	0	0.25	-0.03	-0.01	001	-0.080	-5.8	27.0	180	19	000	0.0	180
00:28:20	-4	-167	42	0	0.27	-0.03	0.01	001	-0.249	-4.5	0.0	180	24	000	0.0	180
00:28:30	-4	-166	41	0	0.28	-0.03	0.03	001	-0.378	-3.5	0.0	180	24	000	0.0	180
00:28:40	-4	-165	42	0	0.25	-0.04	0.04	001	-0.501	-1.0	0.0	180	19	000	0.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Deg	%	Deg	Knots	Deg	Knots
00:28:50	-4	-163.	42	0	0.27	-0.04	0.04	001	-0.533	0.1	0.0	180	18	000	0.0	180
00:29:00	-4	-161	42	0	0.45	-0.03	0.04	001	-0.450	0.6	0.0	180	19	000	0.0	180
00:29:10	-4	-159	42	0	0.51	-0.02	0.03	001	-0.335	1.3	0.0	180	24	000	0.0	180
00:29:20	-4	-156	39	0	0.53	-0.01	0.03	001	-0.202	2.1	75.0	180	24	000	0.0	180
00:29:30	-4	-154	37	0	0.50	0.01	0.02	001	-0.086	1.9	75.0	180	28	000	0.0	180
00:29:40	-3	-151	37	0	0.48	0.02	0.01	001	0.042	2.2	75.0	180	24	000	0.0	180
00:29:50	-3	-149	37	0	0.49	0.05	0.01	001	0.276	1.0	51.0	180	22	000	0.0	180
00:30:00	-3	-146	37	0	0.46	0.06	0.01	001	0.328	-0.3	51.0	180	19	000	0.0	180
00:30:10	-3	-144	37	0	0.41	0.06	0.01	001	0.319	-1.5	51.0	180	23	000	0.0	180
00:30:20	-3	-142	37	0	0.40	0.07	0.02	001	0.299	-2.0	34.0	180	27	000	0.0	180
00:30:30	-2	-140	37	0	0.39	0.07	0.03	001	0.251	-3.0	34.0	180	26	000	0.0	180
00:30:40	-2	-138	37	0	0.38	0.07	0.04	001	0.157	-3.3	34.0	180	22	000	0.0	180
00:30:50	-2	-136	37	0	0.40	0.06	0.07	001	-0.106	-18.0	34.0	180	27	000	0.0	180
00:31:00	-1	-134	37	0	0.32	0.03	0.14	001	-0.691	-17.3	34.0	180	22	000	0.0	180
00:31:10	-1	-133	37	0	0.27	0.01	0.19	001	-1.129	-12.4	25.0	180	21	000	0.0	180
00:31:20	0	-131	40	0	0.23	-0.01	0.21	001	-1.392	-7.0	25.0	180	26	000	0.0	180
00:31:30	0	-130	41	0	0.24	-0.01	0.22	000	-1.469	-2.4	25.0	180	19	000	0.0	180
00:31:40	1	-129	40	0	0.26	0.00	0.21	000	-1.368	1.3	25.0	180	26	000	0.0	180
00:31:50	1	-127	41	0	0.34	0.01	0.19	000	-1.167	3.3	25.0	180	22	000	0.0	180
00:32:00	2	-125	41	0	0.41	0.03	0.17	360	-0.905	4.8	25.0	180	28	000	0.0	180
00:32:10	2	-123	41	0	0.38	0.05	0.14	360	-0.589	6.3	75.0	180	27	000	0.0	180
00:32:20	3	-121	41	0	0.43	0.06	0.11	360	-0.366	-1.7	75.0	180	20	000	0.0	180
00:32:30	3	-119	38	0	0.47	0.03	0.15	360	-0.738	-8.9	75.0	180	23	000	0.0	180
00:32:40	4	-116	36	0	0.44	0.01	0.17	359	-1.002	-5.2	75.0	180	24	000	0.0	180
00:32:50	4	-114	36	0	0.34	-0.01	0.17	359	-1.121	-0.8	100.0	180	22	000	0.0	180
00:33:00	4	-113	36	0	0.24	0.00	0.16	359	-0.997	3.5	100.0	180	22	000	0.0	180
00:33:10	5	-112	36	0	0.26	0.00	0.14	359	-0.876	5.0	75.0	180	21	000	0.0	180
00:33:20	5	-110	36	0	0.28	0.00	0.11	359	-0.756	7.0	52.0	180	18	000	0.0	180
00:33:30	5	-109	36	0	0.24	0.01	0.09	359	-0.495	8.0	52.0	180	21	000	0.0	180
00:33:40	6	-108	36	0	0.19	0.02	0.06	359	-0.245	8.3	52.0	180	22	000	0.0	180
00:33:50	6	-107	36	0	0.16	0.02	0.03	359	-0.052	7.7	52.0	180	29	000	0.0	180
00:34:00	6	-106	36	0	0.07	0.01	0.00	359	0.035	6.8	63.0	180	22	000	0.0	180
00:34:10	6	-106	36	0	0.03	0.01	0.00	359	0.064	-4.3	63.0	180	23	000	0.0	180
00:34:20	6	-106	36	0	-0.01	-0.01	0.01	359	-0.143	4.3	26.0	180	22	000	0.0	180
00:34:30	6	-106	36	0	-0.02	-0.02	0.01	359	-0.166	0.5	26.0	180	24	000	0.0	180
00:34:40	6	-106	36	0	-0.03	-0.02	0.01	359	-0.214	-1.3	26.0	180	26	000	0.0	180
00:34:50	6	-106	36	0	0.03	-0.01	0.00	359	-0.045	3.8	26.0	180	25	000	0.0	180
00:35:00	6	-106	36	0	0.07	-0.02	0.01	358	-0.202	-5.7	26.0	180	32	000	0.0	180
00:35:10	6	-105	35	0	0.10	-0.05	0.03	358	-0.500	-1.9	26.0	180	24	000	0.0	180
00:35:20	6	-105	36	0	0.13	-0.08	0.03	358	-0.682	-0.3	26.0	180	26	000	0.0	180
00:35:30	5	-104	36	0	0.10	-0.08	0.03	358	-0.672	3.6	26.0	180	24	000	0.0	180
00:35:40	5	-104	36	0	0.08	-0.09	0.01	358	-0.620	6.4	26.0	180	21	000	0.0	180
00:35:50	5	-103	36	0	0.12	-0.11	-0.01	358	-0.624	5.7	51.0	180	17	000	0.0	180
00:36:00	5	-103	36	0	0.13	-0.11	-0.03	358	-0.565	6.2	63.0	180	19	000	0.0	180
00:36:10	4	-102	36	0	0.17	-0.13	-0.04	358	-0.553	6.9	75.0	180	23	000	0.0	180
00:36:20	4	-101	36	0	0.07	-0.13	-0.07	358	-0.391	8.4	100.0	180	25	000	0.0	180
00:36:30	3	-101	36	0	0.03	-0.12	-0.09	358	-0.191	7.7	52.0	180	21	000	0.0	180
00:36:40	3	-101	36	0	0.06	-0.15	-0.11	358	-0.284	8.5	52.0	180	22	000	0.0	180
00:36:50	2	-101	36	0	0.00	-0.13	-0.14	358	0.014	6.7	52.0	180	21	000	0.0	180
00:37:00	1	-101	35	0	-0.12	-0.07	-0.17	358	0.648	1.9	52.0	180	18	000	0.0	180
00:37:10	1	-102	36	0	-0.17	0.06	-0.20	358	1.632	-7.5	52.0	180	26	000	0.0	180
00:37:20	1	-103	36	0	-0.12	0.16	-0.18	358	2.175	-23.7	52.0	180	25	000	0.0	180
00:37:30	1	-103	36	0	-0.05	0.24	-0.11	359	2.223	-35.0	52.0	180	28	000	0.0	180
00:37:40	1	-103	36	0	0.05	0.28	-0.02	359	1.903	-32.7	52.0	180	21	000	0.0	180
00:37:50	2	-103	36	0	0.15	0.29	0.07	359	1.386	-28.6	52.0	180	26	000	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

00:16:40
00:17:10
00:17:40
00:18:10
00:18:40
00:19:10
00:19:40
00:20:10
00:20:40

Start Time [hrs:min:sec]: 00:16:40
End Time [hrs:min:sec]: 00:38:00
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

Date: 04-Feb-99 Time: 08:50:07

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 21
Start Time: 08:39
Length of run [secs]: 3664

Date: 4 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 45
Sea State, Significant wave height [m]:	5	Direction: 225
Current Speed [knots]:.....	1	Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.5

Evaluation:

The approach and deceleration were no problem.

The captain used long time on final mating, part of it was learning time. It was not possible to get a steady longitudinal thrust balance.

Shiphandling Simulator

Exercise date & time: 04-Feb-99

09:40:51

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 21**

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North			Long	Bow	Stern					Knots	Deg	Knots	Deg
00:33:20	-58	-100	25	0	0.23	0.01	-0.24	041	1.573	18.2	100.0	180	18	045	1.0
00:33:30	-58	-99	25	0	0.14	-0.01	-0.24	041	1.460	11.4	75.0	180	21	045	1.0
00:33:40	-58	-98	32	0	0.03	-0.01	-0.22	041	1.327	3.4	50.0	180	22	045	1.0
00:33:50	-58	-98	33	0	-0.01	-0.01	-0.19	041	1.117	-0.2	50.0	180	29	045	1.0
00:34:00	-59	-97	38	0	-0.05	-0.01	-0.15	041	0.882	-1.4	27.0	180	22	045	1.0
00:34:10	-59	-97	39	0	-0.05	0.00	-0.10	042	0.629	-2.9	27.0	180	23	045	1.0
00:34:20	-60	-97	39	0	-0.02	0.01	-0.05	042	0.411	-8.3	27.0	180	22	045	1.0
00:34:30	-60	-97	39	0	0.05	0.01	0.02	042	-0.042	-4.5	17.0	180	24	045	1.0
00:34:40	-59	-97	39	0	0.08	0.01	0.03	042	-0.084	6.8	17.0	180	26	045	1.0
00:34:50	-59	-97	39	0	0.13	-0.01	0.02	042	-0.162	7.7	17.0	180	25	045	1.0
00:35:00	-58	-96	39	0	0.14	0.01	0.01	042	0.007	6.2	17.0	180	32	045	1.0
00:35:10	-58	-96	39	0	0.09	0.02	0.01	042	0.087	5.0	27.0	180	24	045	1.0
00:35:20	-58	-96	39	0	0.13	0.00	0.01	042	-0.035	6.5	17.0	180	26	045	1.0
00:35:30	-57	-95	39	0	0.15	0.01	0.01	042	0.018	6.1	17.0	180	24	045	1.0
00:35:40	-56	-94	38	0	0.22	0.01	0.00	042	0.024	2.1	27.0	180	21	045	1.0
00:35:50	-56	-93	39	0	0.21	-0.02	0.05	042	-0.472	-16.9	50.0	180	17	045	1.0
00:36:00	-55	-93	39	0	0.14	-0.04	0.15	041	-1.241	-17.6	36.0	180	19	045	1.0
00:36:10	-54	-93	39	0	0.19	-0.11	0.22	041	-2.084	-9.4	36.0	180	23	045	1.0
00:36:20	-53	-92	39	0	0.18	-0.16	0.24	041	-2.526	0.6	36.0	180	25	045	1.0
00:36:30	-53	-91	39	0	0.10	-0.17	0.21	040	-2.420	17.0	45.0	180	21	045	1.0
00:36:40	-52	-91	39	0	0.00	-0.08	0.11	040	-1.165	35.0	45.0	180	22	045	1.0
00:36:50	-52	-91	39	0	0.00	0.01	-0.01	040	0.124	25.5	45.0	180	21	045	1.0
00:37:00	-52	-91	39	0	-0.01	0.05	-0.05	040	0.583	6.5	45.0	180	18	045	1.0
00:37:10	-52	-91	39	0	0.02	0.05	-0.01	040	0.336	-12.5	52.0	180	26	045	1.0
00:37:20	-52	-91	38	0	0.04	0.04	0.05	040	-0.011	-3.2	52.0	180	25	045	1.0
00:37:30	-52	-91	39	0	0.06	0.04	0.07	040	-0.185	-1.0	62.0	180	28	045	1.0
00:37:40	-51	-91	39	0	0.04	0.01	0.08	040	-0.446	6.9	62.0	180	21	045	1.0
00:37:50	-51	-91	39	0	0.05	0.02	0.07	040	-0.345	5.2	62.0	180	26	045	1.0
00:38:00	-51	-91	39	0	0.03	0.01	0.07	040	-0.348	3.9	62.0	180	28	045	1.0
00:38:10	-50	-91	39	0	0.05	-0.07	0.08	040	-0.944	4.7	62.0	180	24	045	1.0
00:38:20	-50	-91	39	0	0.06	-0.08	0.08	040	-0.988	5.9	65.0	180	26	045	1.0
00:38:30	-50	-91	39	0	0.04	-0.02	0.06	040	-0.555	5.8	65.0	180	23	045	1.0
00:38:40	-50	-91	39	0	0.08	-0.05	0.07	039	-0.746	2.3	70.0	180	22	045	1.0
00:38:50	-50	-90	39	0	0.06	-0.09	0.06	039	-0.943	11.4	77.0	180	21	045	1.0
00:39:00	-50	-90	38	0	0.06	-0.13	0.03	039	-0.987	11.9	77.0	180	23	045	1.0
00:39:10	-50	-90	38	0	0.01	-0.16	0.00	039	-1.011	14.2	77.0	180	24	045	1.0
00:39:20	-50	-90	39	0	-0.13	-0.14	-0.02	039	-0.759	8.1	66.0	180	24	045	1.0
00:39:30	-51	-90	39	0	-0.19	-0.17	-0.03	039	-0.901	9.5	66.0	180	20	045	1.0
00:39:40	-52	-90	39	0	-0.19	-0.17	-0.04	039	-0.807	11.8	66.0	180	29	045	1.0
00:39:50	-53	-91	39	0	-0.18	-0.17	-0.06	038	-0.671	13.3	66.0	180	23	045	1.0
00:40:00	-54	-91	39	0	-0.24	-0.10	-0.08	038	-0.094	11.8	0.0	180	21	045	1.0
00:40:10	-55	-92	39	0	-0.20	-0.03	-0.09	038	0.363	8.2	0.0	180	20	045	1.0
00:40:20	-56	-93	39	0	-0.15	-0.03	-0.09	038	0.386	6.3	0.0	180	20	045	1.0
00:40:30	-57	-93	39	0	-0.12	-0.07	-0.08	039	0.081	7.6	0.0	180	24	045	1.0
00:40:40	-57	-93	38	0	-0.12	-0.11	-0.08	039	-0.177	9.8	0.0	180	24	045	1.0
00:40:50	-58	-93	38	0	-0.11	-0.07	-0.09	039	0.114	8.0	0.0	180	29	045	1.0
00:41:00	-59	-93	39	0	-0.10	-0.11	-0.09	039	-0.136	9.5	0.0	180	22	045	1.0
00:41:10	-60	-93	39	0	-0.05	-0.12	-0.10	038	-0.093	10.0	0.0	180	20	045	1.0
00:41:20	-60	-93	39	0	-0.01	-0.07	-0.10	039	0.212	6.2	0.0	180	18	045	1.0
00:41:30	-60	-93	42	0	0.08	-0.10	-0.10	039	-0.008	8.4	0.0	180	24	045	1.0
00:41:40	-60	-92	41	0	0.14	-0.17	-0.12	038	-0.313	10.9	0.0	180	25	045	1.0
00:41:50	-61	-91	41	0	0.09	-0.16	-0.15	038	-0.046	19.6	0.0	180	24	045	1.0
00:42:00	-61	-90	41	0	0.09	-0.14	-0.23	039	0.571	23.8	0.0	180	27	045	1.0
00:42:10	-62	-89	44	0	0.07	-0.14	-0.29	039	0.965	19.7	0.0	180	28	045	1.0
00:42:20	-62	-88	44	0	0.05	-0.18	-0.33	039	0.984	17.5	0.0	180	23	045	1.0
00:42:30	-63	-87	44	0	0.07	-0.16	-0.36	039	1.241	13.1	0.0	180	27	045	1.0
00:42:40	-64	-86	44	0	0.04	-0.07	-0.37	039	1.916	19.7	0.0	180	26	045	1.0
00:42:50	-65	-85	47	0	0.05	0.00	-0.40	040	2.495	11.0	0.0	180	20	045	1.0
00:43:00	-65	-84	47	0	0.10	0.01	-0.37	040	2.406	3.7	0.0	180	25	045	1.0
00:43:10	-65	-83	46	0	0.22	-0.01	-0.33	040	2.020	2.0	0.0	180	20	045	1.0
00:43:20	-65	-82	44	0	0.17	-0.02	-0.28	041	1.633	-2.8	75.0	180	28	045	1.0
00:43:30	-65	-81	44	0	0.14	-0.04	-0.20	041	1.048	-5.7	54.0	180	20	045	1.0
00:43:40	-65	-80	44	0	0.14	-0.05	-0.14	041	0.540	-5.0	54.0	180	17	045	1.0
00:43:50	-65	-79	44	0	0.21	-0.06	-0.08	041	0.147	-1.1	54.0	180	24	045	1.0
00:44:00	-64	-78	39	0	0.24	-0.07	-0.10	041	0.176	15.0	100.0	180	19	045	1.0
00:44:10	-64	-76	34	0	0.20	0.00	-0.12	041	0.769	10.4	100.0	180	22	045	1.0
00:44:20	-64	-76	34	0	0.17	0.02	-0.12	041	0.901	5.8	100.0	180	24	045	1.0
00:44:30	-63	-75	29	0	0.17	0.01	-0.11	041	0.755	4.0	100.0	180	21	045	1.0
00:44:40	-63	-74	29	0	0.06	0.00	-0.09	042	0.560	-1.0	100.0	180	20	045	1.0
00:44:50	-63	-74	29	0	0.01	-0.03	-0.06	042	0.211	0.7	51.0	180	25	045	1.0
00:45:00	-63	-74	29	0	-0.03	-0.07	-0.05	042	-0.099	7.4	74.0	180	27	045	1.0
00:45:10	-64	-74	29	0	-0.17	-0.08	-0.04	042	-0.202	7.5	51.0	180	32	045	1.0
00:45:20	-65	-74	29	0	-0.24	-0.07	-0.03	042	-0.203	7.7	51.0	180	25	045	1.0

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg
00:45:30	-66	-75	29	0	-0.28	-0.03	-0.03	042	-0.038	7.5	0.0	180	25	045	1.0
00:45:40	-67	-76	29	0	-0.28	-0.03	-0.01	042	-0.126	7.8	0.0	180	24	045	1.0
00:45:50	-68	-77	29	0	-0.29	-0.04	-0.01	042	-0.237	8.8	0.0	180	22	045	1.0
00:46:00	-69	-79	43	0	-0.31	-0.01	0.00	042	-0.051	8.7	0.0	180	22	045	1.0
00:46:10	-70	-80	53	0	-0.29	0.03	-0.01	042	0.269	10.4	0.0	180	26	045	1.0
00:46:20	-71	-81	48	0	-0.27	0.07	-0.09	042	1.051	19.7	0.0	180	25	045	1.0
00:46:30	-72	-82	39	0	-0.17	0.09	-0.12	042	1.326	6.3	0.0	180	19	045	1.0
00:46:40	-72	-82	31	0	-0.19	0.08	-0.08	042	1.046	-7.7	28.0	180	28	045	1.0
00:46:50	-73	-83	39	0	-0.19	0.08	-0.02	042	0.640	-7.4	28.0	180	20	045	1.0
00:47:00	-73	-84	55	0	-0.14	0.05	0.05	042	-0.017	-4.5	28.0	180	21	045	1.0
00:47:10	-73	-84	57	0	0.03	0.05	0.11	042	-0.339	0.8	28.0	180	19	045	1.0
00:47:20	-73	-84	48	0	0.20	0.01	0.13	042	-0.733	1.8	28.0	180	19	045	1.0
00:47:30	-72	-83	44	0	0.22	0.01	0.13	042	-0.745	3.8	52.0	180	28	045	1.0
00:47:40	-71	-83	42	0	0.17	0.01	0.12	042	-0.697	6.9	52.0	180	25	045	1.0
00:47:50	-70	-82	41	0	0.19	0.01	0.10	042	-0.597	7.6	52.0	180	24	045	1.0
00:48:00	-69	-82	42	0	0.17	0.00	0.08	042	-0.481	8.9	25.0	180	28	045	1.0
00:48:10	-68	-81	44	0	0.14	0.02	0.05	042	-0.245	8.8	25.0	180	19	045	1.0
00:48:20	-68	-81	44	0	0.19	0.04	0.04	042	0.005	7.3	17.0	180	20	045	1.0
00:48:30	-67	-80	44	0	0.21	0.06	0.02	042	0.230	5.5	28.0	180	29	045	1.0
00:48:40	-66	-80	44	0	0.21	0.07	0.02	042	0.288	4.6	49.0	180	20	045	1.0
00:48:50	-65	-79	44	0	0.18	0.08	0.04	042	0.280	-6.4	49.0	180	26	045	1.0
00:49:00	-64	-79	43	0	0.19	0.04	0.12	042	-0.475	-10.3	61.0	180	20	045	1.0
00:49:10	-63	-78	43	0	0.19	-0.01	0.17	042	-1.157	-3.8	61.0	180	24	045	1.0
00:49:20	-62	-78	43	0	0.15	-0.03	0.18	041	-1.346	3.1	61.0	180	26	045	1.0
00:49:30	-62	-78	43	0	0.14	0.03	0.17	041	-0.905	3.5	78.0	180	24	045	1.0
00:49:40	-61	-77	43	0	0.12	0.07	0.17	041	-0.645	-0.3	78.0	180	26	045	1.0
00:49:50	-60	-77	43	0	0.22	0.01	0.23	041	-1.359	-9.5	90.0	180	25	045	1.0
00:50:00	-58	-77	33	0	0.22	-0.01	0.27	041	-1.763	-3.2	100.0	180	22	045	1.0
00:50:10	-57	-76	31	0	0.20	0.00	0.27	040	-1.747	2.7	100.0	180	22	045	1.0
00:50:20	-56	-76	31	0	0.12	-0.03	0.26	040	-1.818	12.1	100.0	180	29	045	1.0
00:50:30	-55	-76	36	0	0.03	-0.01	0.20	040	-1.352	20.3	100.0	180	21	045	1.0
00:50:40	-55	-76	36	0	0.03	-0.06	0.12	040	-1.137	35.0	75.0	180	23	045	1.0
00:50:50	-55	-76	32	0	-0.02	-0.04	0.03	039	-0.428	35.0	75.0	180	25	045	1.0
00:51:00	-55	-76	32	0	-0.14	-0.04	-0.02	039	-0.077	16.6	75.0	180	24	045	1.0
00:51:10	-56	-77	32	0	-0.19	-0.03	-0.03	039	0.026	11.1	75.0	180	22	045	1.0
00:51:20	-57	-78	33	0	-0.19	-0.02	-0.04	039	0.116	10.5	75.0	180	20	045	1.0
00:51:30	-58	-78	33	0	-0.23	-0.04	-0.04	039	0.003	10.7	26.0	180	15	045	1.0
00:51:40	-59	-79	43	0	-0.24	-0.06	-0.05	039	-0.087	11.7	26.0	180	21	045	1.0
00:51:50	-60	-80	43	0	-0.26	-0.05	-0.06	039	0.062	11.0	0.0	180	20	045	1.0
00:52:00	-61	-81	43	0	-0.25	-0.06	-0.07	039	0.060	10.4	0.0	180	24	045	1.0
00:52:10	-62	-82	42	0	-0.30	-0.06	-0.08	039	0.126	10.2	0.0	180	34	045	1.0
00:52:20	-63	-83	47	0	-0.29	-0.03	-0.09	039	0.392	8.6	0.0	180	19	045	1.0
00:52:30	-64	-84	50	0	-0.19	0.00	-0.08	040	0.541	5.2	0.0	180	25	045	1.0
00:52:40	-65	-84	49	0	-0.08	-0.03	-0.07	040	0.250	4.3	0.0	180	25	045	1.0
00:52:50	-65	-84	50	0	-0.01	0.00	-0.04	040	0.240	-3.9	25.0	180	23	045	1.0
00:53:00	-65	-84	49	0	0.03	0.00	0.04	040	-0.244	-3.8	25.0	180	28	045	1.0
00:53:10	-65	-84	50	0	0.17	-0.08	0.09	040	-1.064	-2.3	25.0	180	26	045	1.0
00:53:20	-64	-83	49	0	0.22	-0.16	0.11	039	-1.736	3.6	73.0	180	26	045	1.0
00:53:30	-63	-82	50	0	0.23	-0.19	0.08	039	-1.701	8.5	73.0	180	27	045	1.0
00:53:40	-63	-81	49	0	0.24	-0.17	0.03	039	-1.325	10.9	85.0	180	21	045	1.0
00:53:50	-62	-79	50	0	0.20	-0.12	-0.02	039	-0.637	10.9	85.0	180	23	045	1.0
00:54:00	-62	-78	49	0	0.27	-0.16	-0.07	038	-0.594	11.4	79.0	180	23	045	1.0
00:54:10	-62	-77	48	0	0.32	-0.14	-0.11	038	-0.132	11.2	95.0	180	14	045	1.0
00:54:20	-61	-75	45	0	0.29	-0.12	-0.15	038	0.198	9.4	95.0	180	22	045	1.0
00:54:30	-61	-74	29	0	0.17	-0.13	-0.16	038	0.145	8.8	95.0	180	22	045	1.0
00:54:40	-61	-73	29	0	0.07	-0.13	-0.17	038	0.258	23.8	75.0	180	22	045	1.0
00:54:50	-62	-72	29	0	-0.02	-0.13	-0.20	039	0.451	22.9	95.0	180	21	045	1.0
00:55:00	-63	-72	29	0	-0.12	-0.13	-0.24	039	0.700	35.0	95.0	180	24	045	1.0
00:55:10	-64	-72	29	0	-0.25	-0.09	-0.28	039	1.211	35.0	44.0	180	22	045	1.0
00:55:20	-66	-72	29	0	-0.26	-0.01	-0.32	039	1.949	27.5	44.0	180	26	045	1.0
00:55:30	-67	-73	29	0	-0.27	0.05	-0.34	039	2.451	35.0	21.0	180	27	045	1.0
00:55:40	-68	-74	29	0	-0.26	0.09	-0.36	040	2.877	26.9	0.0	180	23	045	1.0
00:55:50	-70	-74	36	0	-0.25	0.14	-0.36	040	3.194	15.3	0.0	180	26	045	1.0
00:56:00	-71	-75	36	0	-0.17	0.13	-0.37	041	3.122	29.5	0.0	180	16	045	1.0
00:56:10	-72	-75	37	0	-0.17	0.14	-0.41	041	3.479	27.1	0.0	180	26	045	1.0
00:56:20	-73	-75	37	0	-0.26	0.18	-0.41	042	3.749	14.6	0.0	180	29	045	1.0
00:56:30	-74	-76	40	0	-0.21	0.16	-0.35	043	3.252	-4.4	0.0	180	23	045	1.0
00:56:40	-75	-76	40	0	-0.15	0.10	-0.23	043	2.062	-16.8	0.0	180	26	045	1.0
00:56:50	-76	-76	40	0	-0.12	0.04	-0.10	043	0.907	-14.8	0.0	180	24	045	1.0
00:57:00	-76	-77	41	0	-0.09	0.00	-0.01	043	0.086	-9.2	0.0	180	17	045	1.0
00:57:10	-77	-77	42	0	-0.10	0.01	0.05	043	-0.300	-3.9	0.0	180	24	045	1.0
00:57:20	-77	-78	42	0	-0.07	-0.04	0.13	043	-1.056	-9.0	0.0	180	21	045	1.0
00:57:30	-77	-78	44	0	-0.05	-0.06	0.16	043	-1.383	2.4	0.0	180	24	045	1.0
00:57:40	-77	-78	48	0	-0.05	-0.05	0.16	043	-1.311	4.8	0.0	180	28	045	1.0
00:57:50	-77	-79	48	0	-0.09	-0.03	0.15	043	-1.153	10.1	0.0	180	20	045	1.0
00:58:00	-77	-79	46	0	-0.09	0.03	0.09	043	-0.416	13.0	0.0	180	31	045	1.0
00:58:10	-77	-80	46	0	-0.06	0.07	0.06	042	0.075	8.2	0.0	180	23	045	1.0
00:58:20	-77	-80	46	0	0.04	0.11	0.06	043	0.309	4.5	0.0	180	18	045	1.0
00:58:30	-76	-80	46	0	0.09	0.12	0.06	043	0.352	4.0	0.0	180	21	045	1.0
00:58:40	-75	-80	46	0	0.14	0.14	0.07	043	0.473	3.0	0.0	180	21	045	1.0
00:58:50	-74	-80	45	0	0.19	0.15	0.09	043	0.388	-4.5	0.0	180	21	045	1.0
00:59:00	-73	-79	45	0	0.26	0.09	0.17	043	-0.516	-11.1	49.0	180	26	045	1.0
00:59:10	-72	-79	46	0	0.24	0.05	0.24	043	-1.188	-5.8	49.0	180	25	045	1.0

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North			Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:59:20	-70	-79	46	0	0.29	0.03	0.27	042	-1.575	-0.6	49.0	180	20	045	1.0	180
00:59:30	-68	-78	46	0	0.37	0.02	0.28	042	-1.653	3.2	100.0	180	22	045	1.0	180
00:59:40	-67	-77	46	0	0.31	0.05	0.26	042	-1.328	7.4	100.0	180	21	045	1.0	180
00:59:50	-65	-76	45	0	0.31	0.04	0.27	042	-1.458	-6.3	100.0	180	28	045	1.0	180
01:00:00	-63	-76	45	0	0.34	0.02	0.30	041	-1.770	-0.6	100.0	180	26	045	1.0	180
01:00:10	-62	-75	46	0	0.34	-0.03	0.29	041	-2.043	6.1	100.0	180	23	045	1.0	180
01:00:20	-60	-74	46	0	0.28	-0.06	0.25	041	-1.948	13.4	100.0	180	25	045	1.0	180
01:00:30	-59	-73	46	0	0.14	0.01	0.17	040	-1.001	17.9	100.0	180	29	045	1.0	180
01:00:40	-58	-73	46	0	0.10	0.05	0.09	040	-0.267	15.0	0.0	180	22	045	1.0	180
01:00:50	-58	-73	31	0	0.11	0.03	0.05	040	-0.073	13.2	0.0	180	30	045	1.0	180
01:01:00	-57	-73	0	0	0.07	0.04	0.03	040	0.083	11.3	0.0	180	26	045	1.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99 Time: 09:40:51

Start Time [hrs:min:sec]: 00:33:20
End Time [hrs:min:sec]: 01:01:04
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 22
Start Time: 10:50
Length of run [secs]: 1665

Date: 4 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 45
Sea State, Significant wave height [m]:..	5	Direction: 225
Current Speed [knots]:.....	1	Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.5

Evaluation:

Started as the previous run # 21. The plan was to shorten the approach time first by incepting the course line closer to the buoy and second by waiting until closer to the buoy to get on the equilibrium heading. In doing this, the buoy was slightly overshoot when the captain had achieved the intercept heading at close to zero speed. Then to get back, he went slightly to the right of the up wind / up wave direction to get back quicker. The equilibrium heading at zero speed was about 044 to 045 degrees.

Shiphandling Simulator

Exercise date & time: 04-Feb-99
10:50:54

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run #22

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Stbd	Long	Bow	Stern					%	Deg	Knots	Deg	Knots	Deg
00:08:20	-169	-1096	42	0	4.09	-1.03	0.47		027	-9.549	-32.6	0.0	180	26	045	1.0	180
00:08:30	-161	-1076	42	0	4.02	-0.95	0.46		025	-8.968	-13.6	0.0	180	19	045	1.0	180
00:08:40	-154	-1057	42	0	3.95	-0.92	0.33		024	-7.974	5.4	0.0	180	25	045	1.0	180
00:08:50	-147	-1038	42	0	3.96	-0.63	0.10		023	-4.602	24.4	0.0	180	24	045	1.0	180
00:09:00	-141	-1018	42	0	3.93	-0.50	-0.22		022	-1.830	35.0	0.0	180	25	045	1.0	180
00:09:10	-135	-999	42	0	3.87	-0.43	-0.53		022	0.633	35.0	0.0	180	29	045	1.0	180
00:09:20	-131	-980	42	0	3.78	-0.38	-0.82		022	2.803	35.0	0.0	180	27	045	1.0	180
00:09:30	-126	-961	42	0	3.69	-0.27	-1.07		023	5.075	32.2	0.0	180	25	045	1.0	180
00:09:40	-122	-942	42	0	3.57	-0.29	-1.23		024	5.949	15.1	0.0	180	30	045	1.0	180
00:09:50	-118	-924	42	0	3.47	-0.26	-1.25		025	6.329	-3.4	0.0	180	18	045	1.0	180
00:10:00	-114	-906	42	0	3.43	-0.17	-1.15		026	6.223	-22.4	0.0	180	22	045	1.0	180
00:10:10	-109	-889	42	0	3.43	-0.32	-0.95		027	3.967	-35.0	0.0	180	26	045	1.0	180
00:10:20	-104	-872	42	0	3.42	-0.44	-0.75		028	1.967	-35.0	0.0	180	20	045	1.0	180
00:10:30	-98	-855	42	0	3.38	-0.31	-0.57		028	1.644	-35.0	0.0	180	21	045	1.0	180
00:10:40	-91	-839	42	0	3.37	-0.36	-0.39		028	0.216	-35.0	0.0	180	18	045	1.0	180
00:10:50	-85	-822	42	0	3.43	-0.69	-0.22		028	-2.959	-35.0	0.0	180	22	045	1.0	180
00:11:00	-79	-806	42	0	3.35	-0.90	-0.09		027	-5.119	-35.0	50.0	180	21	045	1.0	180
00:11:10	-74	-789	42	0	3.33	-1.00	0.01		026	-6.466	-35.0	50.0	180	26	045	1.0	180
00:11:20	-69	-773	42	0	3.25	-0.99	0.11		025	-6.959	-35.0	50.0	180	23	045	1.0	180
00:11:30	-64	-757	42	0	3.21	-1.02	0.20		024	-7.752	-35.0	50.0	180	24	045	1.0	180
00:11:40	-59	-741	42	0	3.25	-1.26	0.28		022	-9.774	-35.0	50.0	180	19	045	1.0	180
00:11:50	-55	-724	42	0	3.25	-1.14	0.34		021	-9.398	-35.0	50.0	180	21	045	1.0	180
00:12:00	-52	-708	42	0	3.18	-1.30	0.40		019	-10.815	-33.9	50.0	180	30	045	1.0	180
00:12:10	-49	-692	42	0	3.12	-1.26	0.38		017	-10.395	-14.9	50.0	180	24	045	1.0	180
00:12:20	-47	-676	42	0	3.09	-1.34	0.32		015	-10.584	-12.6	50.0	180	26	045	1.0	180
00:12:30	-45	-660	42	0	3.06	-1.32	0.17		014	-9.501	6.4	50.0	180	28	045	1.0	180
00:12:40	-45	-644	42	0	3.01	-1.32	-0.09		012	-7.819	25.4	50.0	180	22	045	1.0	180
00:12:50	-46	-628	42	0	2.98	-0.95	-0.40		011	-3.460	35.0	23.0	180	22	045	1.0	180
00:13:00	-46	-612	42	0	2.98	-0.56	-0.68		011	0.720	35.0	23.0	180	24	045	1.0	180
00:13:10	-46	-597	42	0	2.97	-0.41	-0.93		012	3.289	35.0	23.0	180	18	045	1.0	180
00:13:20	-46	-581	42	0	2.95	-0.18	-1.14		012	6.085	35.0	23.0	180	27	045	1.0	180
00:13:30	-46	-565	42	0	2.94	-0.20	-1.32		013	7.090	27.0	23.0	180	20	045	1.0	180
00:13:40	-47	-550	42	0	2.95	-0.59	-1.42		014	5.293	8.0	23.0	180	27	045	1.0	180
00:13:50	-49	-534	42	0	2.86	-0.71	-1.46		015	4.800	14.2	23.0	180	30	045	1.0	180
00:14:00	-50	-518	42	0	2.76	-0.63	-1.58		016	6.048	33.2	23.0	180	17	045	1.0	180
00:14:10	-52	-503	42	0	2.77	-0.72	-1.75		017	6.573	35.0	23.0	180	23	045	1.0	180
00:14:20	-54	-487	42	0	2.70	-0.85	-1.89		018	6.625	28.1	23.0	180	22	045	1.0	180
00:14:30	-56	-472	42	0	2.67	-0.95	-1.93		019	6.232	9.1	23.0	180	22	045	1.0	180
00:14:40	-58	-457	42	0	2.59	-0.83	-1.84		020	6.411	-9.9	23.0	180	25	045	1.0	180
00:14:50	-60	-442	42	0	2.51	-0.83	-1.65		021	5.162	-28.6	23.0	180	26	045	1.0	180
00:15:00	-61	-428	42	0	2.46	-1.35	-1.41		022	0.399	-35.0	23.0	180	20	045	1.0	180
00:15:10	-63	-414	42	0	2.42	-1.46	-1.21		022	-1.577	-32.0	23.0	180	22	045	1.0	180
00:15:20	-65	-400	42	0	2.35	-1.55	-1.08		021	-2.999	-17.7	23.0	180	20	045	1.0	180
00:15:30	-67	-386	42	0	2.27	-1.40	-1.07		021	-2.091	1.3	23.0	180	24	045	1.0	180
00:15:40	-69	-373	42	0	2.25	-1.27	-1.15		021	-0.750	20.3	23.0	180	24	045	1.0	180
00:15:50	-70	-360	42	0	2.25	-0.89	-1.31		021	2.721	35.0	23.0	180	19	045	1.0	180
00:16:00	-71	-347	42	0	2.25	-0.72	-1.48		022	4.807	35.0	23.0	180	22	045	1.0	180
00:16:10	-72	-335	42	0	2.20	-0.58	-1.61		022	6.533	35.0	23.0	180	25	045	1.0	180
00:16:20	-73	-322	42	0	2.14	-0.38	-1.71		024	8.443	35.0	23.0	180	23	045	1.0	180
00:16:30	-73	-310	42	0	2.10	-0.41	-1.78		025	8.697	35.0	23.0	180	25	045	1.0	180
00:16:40	-74	-298	42	0	2.02	-0.43	-1.84		027	8.948	35.0	23.0	180	32	045	1.0	180
00:16:50	-74	-286	42	0	1.91	-0.43	-1.88		028	9.171	30.8	23.0	180	21	045	1.0	180
00:17:00	-75	-275	42	0	1.92	-0.47	-1.88		030	8.955	11.8	23.0	180	29	045	1.0	180
00:17:10	-75	-263	42	0	1.88	-0.46	-1.79		031	8.446	-7.2	23.0	180	25	045	1.0	180
00:17:20	-75	-252	42	0	1.79	-0.45	-1.60		032	7.265	-26.2	23.0	180	22	045	1.0	180
00:17:30	-74	-242	42	0	1.80	-0.54	-1.33		033	4.995	-35.0	23.0	180	24	045	1.0	180
00:17:40	-73	-232	42	0	1.79	-0.70	-1.05		034	2.233	-35.0	23.0	180	16	045	1.0	180
00:17:50	-71	-221	42	0	1.78	-0.94	-0.81		034	-0.818	-35.0	23.0	180	25	045	1.0	180
00:18:00	-70	-212	42	0	1.64	-1.05	-0.61		034	-2.806	-35.0	100.0	180	26	045	1.0	180
00:18:10	-69	-203	42	0	1.50	-0.99	-0.43		033	-3.565	-35.0	100.0	180	20	045	1.0	180
00:18:20	-68	-194	42	0	1.43	-1.13	-0.25		033	-5.618	-35.0	100.0	180	23	045	1.0	180
00:18:30	-67	-186	42	0	1.38	-1.20	-0.09		032	-7.020	-35.0	100.0	180	20	045	1.0	180
00:18:40	-66	-179	42	0	1.34	-1.17	0.04		030	-7.655	-26.5	100.0	180	13	045	1.0	180
00:18:50	-65	-172	41	0	1.29	-0.93	0.07		029	-6.344	-7.4	100.0	180	25	045	1.0	180
00:19:00	-63	-165	30	0	1.27	-0.88	0.02		028	-5.705	11.6	100.0	180	23	045	1.0	180
00:19:10	-62	-158	29	0	1.19	-0.77	-0.08		027	-4.416	30.6	100.0	180	28	045	1.0	180
00:19:20	-62	-152	29	0	1.15	-0.75	-0.20		027	-3.506	35.0	100.0	180	27	045	1.0	180
00:19:30	-62	-146	36	0	1.06	-0.82	-0.32		026	-3.196	35.0	100.0	180	23	045	1.0	180
00:19:40	-62	-140	49	0	0.97	-0.72	-0.50		026	-1.382	35.0	100.0	180	28	045	1.0	180
00:19:50	-63	-134	54	0	0.97	-0.63	-0.76		026	0.802	35.0	100.0	180	24	045	1.0	180
00:20:00	-64	-127	54	0	1.01	-0.44	-1.01		026	3.615	35.0	100.0	180	23	045	1.0	180
00:20:10	-65	-121	60	0	1.00	-0.31	-1.25		027	5.928	35.0	100.0	180	24	045	1.0	180
00:20:20	-67	-115	61	0	1.04	-0.30	-1.47		028	7.434	35.0	100.0	180	26	045	1.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg
00:20:30	-68	-107	62	0	1.08	-0.19	-1.65	029	9.308	35.0	100.0	125	20	045	180
00:20:40	-70	-100	63	0	1.03	-0.09	-1.79	031	10.831	35.0	100.0	125	27	045	180
00:20:50	-71	-93	63	0	0.99	-0.03	-1.89	033	11.796	35.0	100.0	125	25	045	180
00:21:00	-72	-87	63	0	0.93	0.09	-1.96	035	12.991	35.0	100.0	125	19	045	180
00:21:10	-73	-80	63	0	0.94	0.17	-1.98	037	13.673	35.0	100.0	125	22	045	180
00:21:20	-74	-73	62	0	0.90	0.24	-1.91	039	13.656	18.2	100.0	125	21	045	180
00:21:30	-74	-67	62	0	0.85	0.30	-1.65	042	12.397	-0.8	100.0	125	24	045	180
00:21:40	-73	-62	62	0	0.91	0.23	-1.25	043	9.421	-19.8	100.0	125	25	045	180
00:21:50	-71	-57	59	0	0.97	0.08	-0.80	045	5.605	-35.0	100.0	125	19	045	180
00:22:00	-69	-52	59	0	1.02	-0.07	-0.36	045	1.839	-35.0	100.0	125	23	045	180
00:22:10	-66	-48	59	0	0.99	-0.18	-0.01	045	-1.058	-21.7	100.0	125	25	045	180
00:22:20	-62	-44	33	0	1.02	-0.15	0.12	045	-1.684	-2.7	100.0	125	19	045	180
00:22:30	-59	-41	-24	0	0.91	-0.04	0.11	045	-0.985	16.3	100.0	125	33	045	180
00:22:40	-55	-38	-52	0	0.81	0.04	0.11	045	-0.450	35.0	100.0	180	23	045	180
00:22:50	-52	-35	-61	0	0.65	0.06	0.12	045	-0.379	35.0	100.0	180	19	045	180
00:23:00	-50	-34	-61	0	0.45	0.08	0.15	045	-0.414	35.0	100.0	180	22	045	180
00:23:10	-48	-33	-30	0	0.28	0.09	0.16	045	-0.439	35.0	100.0	180	19	045	180
00:23:20	-47	-33	0	0	0.22	0.13	0.15	045	-0.123	35.0	100.0	180	25	045	180
00:23:30	-46	-32	0	0	0.10	0.16	0.13	045	0.158	35.0	74.0	180	24	045	180
00:23:40	-45	-33	0	0	-0.01	0.18	0.12	045	0.354	35.0	74.0	180	25	045	180
00:23:50	-45	-34	0	0	-0.13	0.20	0.12	045	0.518	23.1	74.0	180	27	045	180
00:24:00	-45	-35	0	0	-0.27	0.22	0.12	045	0.652	4.1	74.0	180	25	045	180
00:24:10	-45	-37	0	0	-0.38	0.24	0.12	045	0.739	-14.9	74.0	180	21	045	180
00:24:20	-46	-39	0	0	-0.50	0.25	0.13	045	0.789	-33.9	52.0	180	28	045	180
00:24:30	-47	-42	0	0	-0.54	0.27	0.14	045	0.814	-35.0	52.0	180	21	045	180
00:24:40	-49	-44	0	0	-0.57	0.28	0.15	045	0.843	-35.0	32.0	180	23	045	180
00:24:50	-50	-48	0	0	-0.69	0.29	0.16	045	0.843	-35.0	0.0	180	27	045	180
00:25:00	-52	-51	0	0	-0.80	0.30	0.17	046	0.809	-35.0	0.0	180	28	045	180
00:25:10	-54	-55	32	0	-0.83	0.29	0.22	046	0.455	-35.0	0.0	180	24	045	180
00:25:20	-56	-59	58	0	-0.75	0.21	0.38	046	-1.098	-35.0	0.0	180	21	045	180
00:25:30	-58	-63	66	0	-0.70	-0.01	0.77	045	-4.939	-35.0	0.0	180	19	045	180
00:25:40	-58	-67	66	0	-0.54	-0.23	1.16	044	-8.849	-35.0	0.0	180	17	045	180
00:25:50	-58	-70	66	0	-0.39	-0.41	1.49	042	-12.071	-27.9	0.0	180	23	045	180
00:26:00	-57	-73	45	0	-0.24	-0.47	1.57	040	-12.946	-8.9	0.0	180	19	045	180
00:26:10	-56	-76	37	0	-0.20	-0.51	1.48	038	-12.588	10.1	0.0	180	27	045	180
00:26:20	-54	-78	31	0	-0.20	-0.42	1.32	036	-11.075	29.1	0.0	180	20	045	180
00:26:30	-53	-80	34	0	-0.28	-0.51	1.18	034	-10.705	35.0	0.0	180	19	045	180
00:26:40	-53	-82	29	0	-0.32	-0.58	1.05	032	-10.340	35.0	0.0	180	29	045	180
00:26:50	-53	-84	29	0	-0.38	-0.61	0.93	031	-9.775	35.0	0.0	180	25	045	180
00:27:00	-54	-86	29	0	-0.40	-0.65	0.83	029	-9.363	35.0	0.0	180	25	045	180
00:27:10	-54	-88	29	0	-0.43	-0.75	0.73	028	-9.394	35.0	0.0	180	27	045	180
00:27:20	-56	-90	29	0	-0.48	-0.70	0.62	026	-8.398	35.0	0.0	180	23	045	180
00:27:30	-57	-92	0	0	-0.50	-0.67	0.54	025	-7.700	35.0	0.0	180	25	045	180
00:27:40	-58	-95	0	0	-0.58	-0.75	0.53	023	-8.127	19.8	0.0	180	26	045	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99

Time: 10:50:54

Start Time [hrs:min:sec]: 00:08:20

End Time [hrs:min:sec]: 00:27:45

Delta Plot Time [sec]: 30

East-West Scale [m]: 926.

East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 23

Date: 4 February 1999

Start Time: 11:32

Length of run [secs]: 2160

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 25 Direction: 90

Sea State, Significant wave height [m]:.. 5 Direction: 270

Current Speed [knots]:..... 1 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.0

Evaluation:

The approach went well. The ship came into the approximate equilibrium heading 080 at zero speed near the buoy. The captain decided not to mate on the first pass through the center of the moon pool. Going to the left and changing the heading to about 085 degrees and then let the current force push the ship sideways.

Shiphandling Simulator

Exercise date & time: 04-Feb-99
11:32:04

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #23**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:16:40	-85	-154	36	0	0.35	-0.52	-0.72	068	1.273	-1.0	83.0	180	32	090	1.0	180
00:16:50	-85	-150	36	0	0.29	-0.65	-0.60	068	-0.289	-0.1	76.0	180	21	090	1.0	180
00:17:00	-85	-147	36	0	0.33	-0.83	-0.51	068	-1.990	11.6	76.0	180	29	090	1.0	180
00:17:10	-85	-143	36	0	0.32	-0.82	-0.50	067	-2.062	30.6	76.0	180	25	090	1.0	180
00:17:20	-85	-139	36	0	0.25	-0.72	-0.53	067	-1.243	35.0	76.0	180	22	090	1.0	180
00:17:30	-85	-136	36	0	0.28	-0.68	-0.56	067	-0.810	35.0	52.0	180	24	090	1.0	180
00:17:40	-85	-132	36	0	0.29	-0.77	-0.58	067	-1.173	35.0	52.0	180	16	090	1.0	180
00:17:50	-85	-128	36	0	0.29	-1.06	-0.60	067	-2.962	35.0	52.0	180	25	090	1.0	180
00:18:00	-85	-124	36	0	0.19	-1.14	-0.61	066	-3.405	35.0	75.0	180	26	090	1.0	180
00:18:10	-86	-119	36	0	0.08	-0.91	-0.62	066	-1.880	35.0	75.0	180	20	090	1.0	180
00:18:20	-88	-116	36	0	0.06	-1.07	-0.62	065	-2.900	35.0	0.0	180	23	090	1.0	180
00:18:30	-89	-111	36	0	0.06	-1.09	-0.61	065	-3.031	35.0	26.0	180	20	090	1.0	180
00:18:40	-91	-107	36	0	0.06	-0.96	-0.61	064	-2.202	35.0	26.0	180	13	090	1.0	180
00:18:50	-92	-104	36	0	0.04	-0.58	-0.62	064	0.254	35.0	26.0	180	25	090	1.0	180
00:19:00	-93	-101	44	0	0.06	-0.55	-0.65	064	0.623	35.0	26.0	180	23	090	1.0	180
00:19:10	-94	-98	45	0	0.07	-0.45	-0.71	064	1.645	35.0	52.0	180	28	090	1.0	180
00:19:20	-95	-95	45	0	0.11	-0.46	-0.76	065	1.905	35.0	52.0	180	27	090	1.0	180
00:19:30	-96	-92	44	0	0.12	-0.58	-0.81	065	1.429	35.0	52.0	180	23	090	1.0	180
00:19:40	-97	-89	44	0	0.08	-0.52	-0.85	065	2.099	35.0	52.0	180	28	090	1.0	180
00:19:50	-98	-85	47	0	0.11	-0.54	-0.88	066	2.202	35.0	52.0	180	24	090	1.0	180
00:20:00	-99	-82	47	0	0.19	-0.41	-0.93	066	3.307	35.0	52.0	180	23	090	1.0	180
00:20:10	-100	-78	48	0	0.20	-0.38	-0.97	067	3.734	35.0	27.0	180	24	090	1.0	180
00:20:20	-100	-74	47	0	0.27	-0.48	-1.00	067	3.310	35.0	49.0	180	26	090	1.0	180
00:20:30	-100	-70	48	0	0.32	-0.50	-1.04	068	3.393	35.0	49.0	180	20	090	1.0	180
00:20:40	-100	-66	48	0	0.29	-0.54	-1.06	068	3.308	35.0	49.0	180	27	090	1.0	180
00:20:50	-100	-61	47	0	0.26	-0.65	-1.08	069	2.716	35.0	49.0	180	25	090	1.0	180
00:21:00	-101	-57	47	0	0.23	-0.66	-1.07	069	2.586	28.1	49.0	180	19	090	1.0	180
00:21:10	-101	-52	47	0	0.26	-0.77	-1.05	070	1.805	35.0	49.0	180	22	090	1.0	180
00:21:20	-102	-47	47	0	0.23	-0.78	-1.06	070	1.812	35.0	49.0	180	21	090	1.0	180
00:21:30	-102	-43	47	0	0.18	-0.44	-1.05	070	3.889	23.9	49.0	180	24	090	1.0	180
00:21:40	-102	-39	47	0	0.23	-0.29	-0.95	071	4.197	12.3	25.0	180	25	090	1.0	180
00:21:50	-102	-36	48	0	0.31	-0.31	-0.87	072	3.549	16.8	25.0	180	19	090	1.0	180
00:22:00	-101	-32	47	0	0.37	-0.45	-0.78	072	2.126	11.1	25.0	180	23	090	1.0	180
00:22:10	-100	-29	48	0	0.34	-0.29	-0.75	073	2.934	20.0	50.0	180	25	090	1.0	180
00:22:20	-99	-26	48	0	0.37	-0.28	-0.69	073	2.576	12.2	74.0	180	19	090	1.0	180
00:22:30	-98	-23	47	0	0.34	-0.29	-0.68	073	2.475	31.2	74.0	180	33	090	1.0	180
00:22:40	-97	-20	48	0	0.37	-0.23	-0.75	074	3.274	35.0	97.0	180	23	090	1.0	180
00:22:50	-96	-17	48	0	0.40	-0.18	-0.80	075	3.965	35.0	97.0	180	19	090	1.0	180
00:23:00	-95	-14	47	0	0.40	0.00	-0.85	075	5.420	35.0	97.0	180	22	090	1.0	180
00:23:10	-93	-11	41	0	0.37	-0.03	-0.87	076	5.334	35.0	97.0	180	19	090	1.0	180
00:23:20	-92	-9	33	0	0.37	-0.01	-0.84	077	5.291	35.0	97.0	180	25	090	1.0	180
00:23:30	-91	-6	33	0	0.29	-0.06	-0.78	078	4.566	23.2	97.0	180	24	090	1.0	180
00:23:40	-90	-4	33	0	0.20	-0.23	-0.69	079	2.883	18.4	97.0	180	25	090	1.0	180
00:23:50	-90	-1	33	0	0.10	-0.35	-0.59	079	1.524	15.4	97.0	180	27	090	1.0	180
00:24:00	-90	1	33	0	-0.01	-0.34	-0.53	079	1.206	29.4	97.0	180	25	090	1.0	180
00:24:10	-91	3	33	0	-0.09	-0.33	-0.48	079	0.927	27.2	75.0	180	21	090	1.0	180
00:24:20	-92	5	33	0	-0.17	-0.28	-0.43	080	0.916	24.2	75.0	180	28	090	1.0	180
00:24:30	-93	6	33	0	-0.17	-0.26	-0.37	080	0.694	21.9	75.0	180	21	090	1.0	180
00:24:40	-94	8	33	0	-0.17	-0.28	-0.32	080	0.214	31.0	52.0	180	23	090	1.0	180
00:24:50	-95	9	33	0	-0.25	-0.19	-0.36	080	1.069	35.0	52.0	180	27	090	1.0	180
00:25:00	-97	10	33	0	-0.34	-0.07	-0.42	080	2.259	35.0	52.0	180	28	090	1.0	180
00:25:10	-99	11	33	0	-0.36	-0.01	-0.47	081	2.937	35.0	52.0	180	24	090	1.0	180
00:25:20	-101	12	33	0	-0.33	-0.05	-0.51	081	2.943	35.0	52.0	180	21	090	1.0	180
00:25:30	-103	13	33	0	-0.40	0.05	-0.55	082	3.778	35.0	0.0	180	19	090	1.0	180
00:25:40	-105	14	43	0	-0.37	0.20	-0.62	082	5.197	34.5	0.0	180	17	090	1.0	180
00:25:50	-107	15	43	0	-0.30	0.33	-0.67	083	6.297	15.5	0.0	180	23	090	1.0	180
00:26:00	-108	15	47	0	-0.19	0.34	-0.62	084	6.085	-3.5	0.0	180	19	090	1.0	180
00:26:10	-109	16	38	0	-0.11	0.25	-0.50	085	4.785	-22.5	0.0	180	27	090	1.0	180
00:26:20	-110	16	43	0	-0.09	0.20	-0.32	086	3.306	-35.0	0.0	180	20	090	1.0	180
00:26:30	-110	17	43	0	-0.12	0.08	-0.13	086	1.288	-35.0	0.0	180	19	090	1.0	180
00:26:40	-111	17	48	0	-0.10	-0.02	0.04	086	-0.322	-21.5	0.0	180	29	090	1.0	180
00:26:50	-111	16	49	0	-0.08	-0.05	0.13	086	-1.133	-8.2	0.0	180	25	090	1.0	180
00:27:00	-112	16	49	0	-0.02	-0.07	0.19	086	-1.636	7.3	0.0	180	25	090	1.0	180
00:27:10	-112	16	48	0	0.02	-0.06	0.19	086	-1.557	13.6	0.0	180	27	090	1.0	180
00:27:20	-111	15	49	0	0.05	-0.02	0.20	086	-1.372	7.1	0.0	180	23	090	1.0	180
00:27:30	-111	15	49	0	0.11	0.00	0.23	085	-1.451	5.6	26.0	180	25	090	1.0	180
00:27:40	-110	14	48	0	0.13	0.01	0.25	085	-1.502	9.1	26.0	180	26	090	1.0	180
00:27:50	-109	14	48	0	0.14	0.02	0.24	085	-1.449	12.8	26.0	180	23	090	1.0	180
00:28:00	-109	13	48	0	0.19	0.02	0.22	085	-1.265	14.4	50.0	180	29	090	1.0	180
00:28:10	-107	13	49	0	0.21	0.06	0.19	084	-0.832	15.3	50.0	180	19	090	1.0	180
00:28:20	-106	12	48	0	0.20	0.14	0.16	084	-0.134	13.6	75.0	180	24	090	1.0	180
00:28:30	-105	11	48	0	0.22	0.20	0.15	084	0.377	10.8	75.0	180	24	090	1.0	180
00:28:40	-103	11	49	0	0.40	0.21	0.14	084	0.410	10.1	75.0	180	19	090	1.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Knots	Deg	Knots
00:28:50	-101	10	48	0	0.43	0.21	0.15	084	0.434	9.0	100.0	180	18	090	1.0
00:29:00	-99	9	45	0	0.43	0.21	0.16	085	0.351	7.6	100.0	180	19	090	1.0
00:29:10	-97	8	40	0	0.38	0.22	0.17	085	0.288	7.1	100.0	180	24	090	1.0
00:29:20	-95	8	34	0	0.35	0.18	0.19	085	-0.059	7.4	100.0	180	24	090	1.0
00:29:30	-93	7	30	0	0.29	0.06	0.22	085	-1.038	12.7	100.0	180	28	090	1.0
00:29:40	-92	6	30	0	0.19	0.07	0.22	084	-0.989	17.2	100.0	180	24	090	1.0
00:29:50	-91	6	30	0	0.08	0.07	0.22	084	-0.978	22.1	100.0	180	22	090	1.0
00:30:00	-91	5	30	0	0.02	0.08	0.22	084	-0.888	25.2	100.0	180	19	090	1.0
00:30:10	-91	4	30	0	-0.06	0.08	0.21	084	-0.822	26.6	100.0	180	23	090	1.0
00:30:20	-91	3	30	0	-0.11	0.10	0.20	084	-0.591	26.3	54.0	180	27	090	1.0
00:30:30	-92	3	30	0	-0.12	0.09	0.17	084	-0.480	27.4	52.0	180	26	090	1.0
00:30:40	-92	2	30	0	-0.23	0.09	0.12	084	-0.166	26.1	52.0	180	22	090	1.0
00:30:50	-94	1	30	0	-0.30	0.12	0.07	084	0.295	24.3	25.0	180	27	090	1.0
00:31:00	-95	1	30	0	-0.35	0.18	0.04	084	0.867	20.8	0.0	180	22	090	1.0
00:31:10	-97	0	40	0	-0.35	0.22	-0.01	084	1.451	15.6	0.0	180	21	090	1.0
00:31:20	-99	-1	41	0	-0.31	0.26	-0.04	084	1.930	8.2	0.0	180	26	090	1.0
00:31:30	-100	-2	40	0	-0.21	0.29	-0.04	085	2.125	-1.2	0.0	180	19	090	1.0
00:31:40	-101	-2	41	0	-0.15	0.33	-0.01	085	2.156	-9.3	0.0	180	26	090	1.0
00:31:50	-102	-3	40	0	-0.16	0.32	0.05	085	1.737	-12.0	0.0	180	22	090	1.0
00:32:00	-102	-4	45	0	-0.04	0.23	0.14	085	0.585	-11.2	0.0	180	28	090	1.0
00:32:10	-102	-5	45	0	0.01	0.14	0.25	085	-0.734	-3.0	0.0	180	27	090	1.0
00:32:20	-102	-6	45	0	0.05	0.06	0.31	085	-1.578	6.1	0.0	180	20	090	1.0
00:32:30	-101	-7	45	0	0.02	0.06	0.32	085	-1.651	12.2	0.0	180	23	090	1.0
00:32:40	-101	-8	44	0	0.05	0.11	0.30	085	-1.244	12.5	0.0	180	24	090	1.0
00:32:50	-100	-9	44	0	0.17	0.06	0.29	084	-1.469	16.8	0.0	180	22	090	1.0
00:33:00	-99	-10	44	0	0.20	0.08	0.24	084	-1.065	18.4	0.0	180	22	090	1.0
00:33:10	-98	-11	29	0	0.19	0.11	0.21	084	-0.668	19.5	0.0	180	21	090	1.0
00:33:20	-97	-11	25	0	0.14	0.12	0.22	084	-0.594	21.2	0.0	180	18	090	1.0
00:33:30	-97	-12	25	0	0.08	0.07	0.22	084	-0.943	26.8	0.0	180	21	090	1.0
00:33:40	-97	-13	25	0	-0.02	0.06	0.22	084	-0.992	32.1	0.0	180	22	090	1.0
00:33:50	-97	-14	25	0	-0.06	0.07	0.21	084	-0.878	32.8	0.0	180	29	090	1.0
00:34:00	-97	-14	25	0	-0.12	0.09	0.20	083	-0.662	33.0	0.0	180	22	090	1.0
00:34:10	-98	-15	25	0	-0.15	0.15	0.15	083	-0.030	30.1	0.0	180	23	090	1.0
00:34:20	-98	-16	25	0	-0.16	0.23	0.12	083	0.700	25.3	0.0	180	22	090	1.0
00:34:30	-99	-17	25	0	-0.12	0.30	0.09	084	1.313	19.2	0.0	180	24	090	1.0
00:34:40	-100	-18	25	0	-0.13	0.29	0.08	084	1.352	14.3	0.0	180	26	090	1.0
00:34:50	-100	-19	25	0	-0.12	0.23	0.08	084	0.967	12.1	0.0	180	25	090	1.0
00:35:00	-101	-20	25	0	-0.13	0.23	0.08	084	1.009	9.4	0.0	180	32	090	1.0
00:35:10	-101	-21	25	0	-0.22	0.24	0.08	084	1.005	7.3	0.0	180	24	090	1.0
00:35:20	-102	-22	25	0	-0.21	0.18	0.09	084	0.604	6.7	0.0	180	26	090	1.0
00:35:30	-103	-23	25	0	-0.22	0.17	0.10	085	0.437	5.8	0.0	180	24	090	1.0
00:35:40	-104	-23	25	0	-0.18	0.14	0.11	085	0.230	5.5	0.0	180	21	090	1.0
00:35:50	-105	-24	25	0	-0.22	0.13	0.12	085	0.093	6.3	0.0	180	17	090	1.0

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99 Time: 11:32:04

Start Time [hrs:min:sec]: 00:16:40
End Time [hrs:min:sec]: 00:36:00
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORING TECHNOLOGY

Simulation Number: 24
Start Time: 13:55
Length of run [secs]: 2235

Date: 4 February 1999

Ship Condition: draft = 13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 90
Sea State, Significant wave height [m]:..	5	Direction: 270
Current Speed [knots]:.....	1	Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 2.4

Evaluation:

The approach went well.

Fairly close replay of run # 23.

The captain tried to use the thruster at 120 degrees to get the ship to move faster, and it worked. The captain feels the rudder rate is too slow.

Shiphhandling Simulator

Exercise date & time: 04-Feb-99

13:55:29

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run #24

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Deg	%	Deg	Knots	Deg	Knots
00:16:40	-124	-152	76	0	1.77	0.07	-2.91	049	18.932	35.0	99.0	129	32	090	1.0	180
00:16:50	-122	-141	76	0	1.73	0.06	-2.90	052	18.738	35.0	99.0	129	21	090	1.0	180
00:17:00	-119	-130	76	0	1.78	-0.04	-2.88	055	18.005	35.0	99.0	129	29	090	1.0	180
00:17:10	-115	-118	76	0	1.79	0.08	-2.84	058	18.539	35.0	99.0	129	25	090	1.0	180
00:17:20	-111	-108	76	0	1.74	0.27	-2.77	061	19.299	35.0	99.0	129	22	090	1.0	180
00:17:30	-105	-98	61	0	1.77	0.35	-2.65	065	19.040	35.0	99.0	129	24	090	1.0	180
00:17:40	-99	-90	54	0	1.70	0.25	-2.44	068	17.046	35.0	99.0	129	16	090	1.0	180
00:17:50	-94	-81	29	0	1.58	-0.04	-2.22	070	13.775	35.0	99.0	129	25	090	1.0	180
00:18:00	-88	-73	31	0	1.36	-0.10	-2.02	072	12.171	35.0	99.0	129	26	090	1.0	180
00:18:10	-84	-67	8	0	1.14	0.09	-1.83	074	12.188	35.0	99.0	129	20	090	1.0	180
00:18:20	-79	-61	-47	0	0.96	0.01	-1.65	076	10.526	35.0	99.0	129	23	090	1.0	180
00:18:30	-76	-56	-61	0	0.74	0.02	-1.46	078	9.350	29.9	99.0	129	20	090	1.0	180
00:18:40	-73	-52	-61	0	0.52	0.10	-1.28	079	8.784	10.9	99.0	129	13	090	1.0	180
00:18:50	-72	-49	-30	0	0.31	0.28	-1.13	081	8.968	-8.1	99.0	129	25	090	1.0	180
00:19:00	-71	-47	26	0	0.22	0.29	-0.94	082	7.812	-27.1	99.0	129	23	090	1.0	180
00:19:10	-70	-46	37	0	0.15	0.20	-0.64	083	5.336	-35.0	99.0	176	28	090	1.0	180
00:19:20	-69	-45	37	0	0.14	0.07	-0.36	084	2.762	-35.0	75.0	176	27	090	1.0	180
00:19:30	-69	-44	37	0	0.11	-0.07	-0.12	084	0.338	-35.0	52.0	180	23	090	1.0	180
00:19:40	-68	-44	37	0	0.05	-0.16	0.09	084	-1.579	-35.0	52.0	180	28	090	1.0	180
00:19:50	-68	-44	37	0	0.05	-0.25	0.27	084	-3.351	-23.6	52.0	180	24	090	1.0	180
00:20:00	-68	-44	37	0	0.11	-0.31	0.44	083	-4.767	-35.0	52.0	180	23	090	1.0	180
00:20:10	-67	-44	37	0	0.09	-0.37	0.58	082	-6.037	-16.0	74.0	180	24	090	1.0	180
00:20:20	-67	-45	37	0	0.13	-0.45	0.64	081	-6.900	3.0	74.0	180	26	090	1.0	180
00:20:30	-66	-45	37	0	0.14	-0.46	0.63	080	-6.898	22.0	74.0	180	20	090	1.0	180
00:20:40	-65	-45	37	0	0.06	-0.46	0.56	079	-6.422	35.0	74.0	180	27	090	1.0	180
00:20:50	-65	-45	37	0	-0.01	-0.50	0.48	078	-6.236	35.0	74.0	180	25	090	1.0	180
00:21:00	-65	-45	37	0	-0.11	-0.51	0.40	077	-5.799	35.0	100.0	180	19	090	1.0	180
00:21:10	-66	-45	37	0	-0.11	-0.60	0.34	076	-5.948	35.0	25.0	180	22	090	1.0	180
00:21:20	-67	-44	37	0	-0.15	-0.64	0.28	075	-5.852	35.0	26.0	180	21	090	1.0	180
00:21:30	-68	-44	37	0	-0.22	-0.40	0.21	074	-3.875	35.0	26.0	180	24	090	1.0	180
00:21:40	-69	-44	39	0	-0.21	-0.25	0.14	074	-2.498	35.0	26.0	180	25	090	1.0	180
00:21:50	-70	-44	45	0	-0.14	-0.24	0.04	073	-1.772	35.0	26.0	180	19	090	1.0	180
00:22:00	-71	-43	49	0	-0.09	-0.32	-0.07	073	-1.577	35.0	26.0	180	23	090	1.0	180
00:22:10	-72	-42	49	0	-0.11	-0.13	-0.20	073	0.411	35.0	26.0	180	25	090	1.0	180
00:22:20	-73	-42	48	0	-0.07	-0.08	-0.31	073	1.436	35.0	26.0	180	19	090	1.0	180
00:22:30	-73	-41	48	0	-0.07	-0.07	-0.41	073	2.109	35.0	78.0	180	33	090	1.0	180
00:22:40	-74	-40	45	0	-0.04	-0.06	-0.47	074	2.555	35.0	78.0	180	23	090	1.0	180
00:22:50	-74	-38	45	0	0.01	-0.06	-0.52	074	2.915	35.0	78.0	180	19	090	1.0	180
00:23:00	-75	-37	45	0	0.02	0.08	-0.57	075	4.126	35.0	78.0	180	22	090	1.0	180
00:23:10	-75	-36	44	0	0.02	0.02	-0.60	075	3.930	35.0	78.0	180	19	090	1.0	180
00:23:20	-75	-34	44	0	0.07	0.05	-0.63	076	4.274	35.0	78.0	180	25	090	1.0	180
00:23:30	-75	-33	44	0	0.05	0.01	-0.65	077	4.178	35.0	78.0	180	24	090	1.0	180
00:23:40	-75	-31	45	0	0.01	-0.14	-0.67	077	3.361	35.0	99.0	180	25	090	1.0	180
00:23:50	-76	-28	41	0	-0.07	-0.23	-0.67	078	2.763	35.0	99.0	180	27	090	1.0	180
00:24:00	-77	-26	38	0	-0.17	-0.20	-0.64	078	2.817	35.0	99.0	180	25	090	1.0	180
00:24:10	-78	-25	38	0	-0.25	-0.16	-0.67	079	3.260	35.0	99.0	180	21	090	1.0	180
00:24:20	-80	-23	38	0	-0.35	-0.03	-0.74	079	4.471	35.0	99.0	180	28	090	1.0	180
00:24:30	-82	-21	38	0	-0.34	0.05	-0.76	080	5.139	18.9	49.0	180	21	090	1.0	180
00:24:40	-84	-20	38	0	-0.31	0.05	-0.72	081	4.858	3.2	49.0	180	23	090	1.0	180
00:24:50	-86	-18	38	0	-0.38	0.07	-0.63	082	4.467	-9.6	49.0	180	27	090	1.0	180
00:25:00	-89	-18	42	0	-0.43	0.09	-0.51	083	3.804	-20.1	49.0	180	28	090	1.0	180
00:25:10	-91	-17	45	0	-0.41	0.02	-0.34	083	2.310	-26.6	24.0	180	24	090	1.0	180
00:25:20	-93	-16	52	0	-0.30	-0.13	-0.14	083	0.040	-24.5	24.0	180	21	090	1.0	180
00:25:30	-94	-16	52	0	-0.28	-0.18	0.02	083	-1.272	-16.9	24.0	180	19	090	1.0	180
00:25:40	-96	-16	52	0	-0.17	-0.15	0.12	083	-1.686	-5.9	24.0	180	17	090	1.0	180
00:25:50	-96	-16	56	0	-0.05	-0.11	0.15	083	-1.656	11.7	24.0	180	23	090	1.0	180
00:26:00	-96	-16	50	0	0.10	-0.07	0.09	082	-1.044	15.5	24.0	180	19	090	1.0	180
00:26:10	-95	-16	48	0	0.19	-0.16	0.13	082	-1.830	7.2	74.0	180	27	090	1.0	180
00:26:20	-94	-16	47	0	0.22	-0.13	0.14	082	-1.731	10.9	74.0	180	20	090	1.0	180
00:26:30	-93	-16	36	0	0.14	-0.22	0.14	082	-2.266	24.7	100.0	180	19	090	1.0	180
00:26:40	-93	-15	36	0	0.07	-0.25	0.10	081	-2.205	35.0	100.0	180	29	090	1.0	180
00:26:50	-93	-15	36	0	-0.03	-0.23	0.05	081	-1.764	35.0	100.0	180	25	090	1.0	180
00:27:00	-93	-14	36	0	-0.09	-0.22	0.01	081	-1.414	35.0	100.0	180	25	090	1.0	180
00:27:10	-94	-14	36	0	-0.15	-0.24	-0.03	080	-1.332	34.5	100.0	180	27	090	1.0	180
00:27:20	-95	-13	36	0	-0.24	-0.15	-0.08	080	-0.463	15.5	100.0	180	23	090	1.0	180
00:27:30	-96	-13	37	0	-0.27	-0.11	-0.08	080	-0.164	-3.5	100.0	180	25	090	1.0	180
00:27:40	-98	-13	40	0	-0.36	-0.14	-0.01	080	-0.797	-22.5	100.0	180	26	090	1.0	180
00:27:50	-100	-13	54	0	-0.36	-0.29	0.18	080	-2.995	-23.4	25.0	180	23	090	1.0	180
00:28:00	-101	-13	58	0	-0.27	-0.41	0.31	079	-4.583	-4.7	25.0	180	29	090	1.0	180
00:28:10	-103	-13	58	0	-0.18	-0.40	0.30	078	-4.424	14.3	25.0	180	19	090	1.0	180
00:28:20	-103	-13	57	0	-0.14	-0.22	0.16	078	-2.448	33.3	25.0	180	24	090	1.0	180
00:28:30	-104	-13	58	0	-0.06	0.01	-0.06	078	0.406	35.0	51.0	180	24	090	1.0	180
00:28:40	-104	-13	57	0	0.13	0.11	-0.25	078	2.285	35.0	75.0	180	19	090	1.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Knots	Deg	Knots	Deg
00:28:50	-103	-12	58	0	0.22	0.20	-0.43	078	4.008	35.0	52.0	180	18	090	1.0	180
00:29:00	-102	-11	57	0	0.30	0.29	-0.58	079	5.506	35.0	52.0	180	19	090	1.0	180
00:29:10	-100	-10	57	0	0.33	0.40	-0.70	080	6.997	35.0	98.0	180	24	090	1.0	180
00:29:20	-99	-9	38	0	0.31	0.39	-0.70	081	6.917	35.0	98.0	180	24	090	1.0	180
00:29:30	-97	-8	39	0	0.27	0.22	-0.66	082	5.587	26.9	98.0	180	28	090	1.0	180
00:29:40	-96	-7	39	0	0.19	0.21	-0.58	083	5.003	7.9	98.0	180	24	090	1.0	180
00:29:50	-96	-6	40	0	0.14	0.15	-0.42	084	3.609	-11.1	74.0	180	22	090	1.0	180
00:30:00	-95	-5	40	0	0.12	0.05	-0.20	085	1.619	-30.1	99.0	180	19	090	1.0	180
00:30:10	-95	-5	40	0	0.06	-0.07	0.03	085	-0.603	-24.9	99.0	180	23	090	1.0	180
00:30:20	-95	-5	40	0	0.03	-0.11	0.17	084	-1.775	-5.9	99.0	180	27	090	1.0	180
00:30:30	-94	-5	40	0	-0.01	-0.15	0.22	084	-2.377	13.1	99.0	180	26	090	1.0	180
00:30:40	-95	-5	40	0	-0.12	-0.17	0.23	084	-2.547	30.8	99.0	180	22	090	1.0	180
00:30:50	-96	-5	40	0	-0.21	-0.09	0.14	083	-1.461	21.0	99.0	180	27	090	1.0	180
00:31:00	-97	-6	39	0	-0.24	-0.01	0.06	083	-0.460	18.1	28.0	180	22	090	1.0	180
00:31:10	-98	-6	39	0	-0.23	0.05	0.01	083	0.296	14.3	15.0	180	21	090	1.0	180
00:31:20	-99	-6	40	0	-0.19	0.11	-0.05	083	1.013	23.7	15.0	180	26	090	1.0	180
00:31:30	-100	-6	40	0	-0.10	0.18	-0.10	083	1.806	9.6	15.0	180	19	090	1.0	180
00:31:40	-100	-7	40	0	-0.06	0.21	-0.03	084	1.527	5.2	74.0	180	26	090	1.0	180
00:31:50	-100	-7	40	0	-0.09	0.20	0.02	084	1.161	8.9	49.0	180	22	090	1.0	180
00:32:00	-101	-8	40	0	0.00	0.16	0.04	084	0.746	24.6	49.0	180	28	090	1.0	180
00:32:10	-100	-8	40	0	0.00	0.13	0.02	084	0.676	21.0	75.0	180	27	090	1.0	180
00:32:20	-100	-9	39	0	-0.01	0.08	0.02	084	0.400	20.7	52.0	180	20	090	1.0	180
00:32:30	-101	-9	39	0	-0.07	0.09	0.01	084	0.514	21.6	37.0	180	23	090	1.0	180
00:32:40	-101	-9	40	0	-0.06	0.15	0.01	085	0.885	16.5	25.0	180	24	090	1.0	180
00:32:50	-101	-10	40	0	0.03	0.08	0.03	085	0.339	17.7	19.0	180	22	090	1.0	180
00:33:00	-101	-10	40	0	0.05	0.08	0.05	085	0.204	6.3	0.0	180	22	090	1.0	180
00:33:10	-101	-10	40	0	0.03	0.05	0.13	085	-0.563	-5.4	0.0	180	21	090	1.0	180
00:33:20	-100	-11	40	0	0.03	0.03	0.21	085	-1.135	1.5	0.0	180	18	090	1.0	180
00:33:30	-100	-11	40	0	0.02	-0.03	0.24	084	-1.734	13.4	0.0	180	21	090	1.0	180
00:33:40	-100	-12	40	0	-0.03	-0.03	0.23	084	-1.657	18.7	0.0	180	22	090	1.0	180
00:33:50	-100	-13	39	0	-0.02	0.00	0.21	084	-1.383	19.8	0.0	180	29	090	1.0	180
00:34:00	-100	-13	40	0	-0.04	0.03	0.19	084	-1.052	19.2	0.0	180	22	090	1.0	180
00:34:10	-100	-14	40	0	-0.03	0.08	0.18	083	-0.659	17.4	0.0	180	23	090	1.0	180
00:34:20	-100	-14	40	0	0.01	0.14	0.17	083	-0.213	14.1	0.0	180	22	090	1.0	180
00:34:30	-100	-15	40	0	0.10	0.20	0.18	083	0.128	11.7	0.0	180	24	090	1.0	180
00:34:40	-99	-16	40	0	0.14	0.18	0.19	083	-0.045	12.0	0.0	180	26	090	1.0	180
00:34:50	-98	-17	40	0	0.19	0.11	0.19	083	-0.501	15.4	0.0	180	25	090	1.0	180
00:35:00	-97	-18	40	0	0.21	0.12	0.17	083	-0.345	16.2	0.0	180	32	090	1.0	180
00:35:10	-96	-18	39	0	0.17	0.13	0.16	083	-0.205	16.2	0.0	180	24	090	1.0	180
00:35:20	-95	-19	40	0	0.22	0.08	0.15	083	-0.462	18.5	0.0	180	26	090	1.0	180
00:35:30	-94	-19	40	0	0.25	0.07	0.13	083	-0.350	19.0	0.0	180	24	090	1.0	180
00:35:40	-92	-20	40	0	0.33	0.06	0.11	083	-0.269	18.9	0.0	180	21	090	1.0	180
00:35:50	-90	-20	40	0	0.33	0.07	0.08	083	-0.088	19.5	0.0	180	17	090	1.0	180
00:36:00	-89	-20	40	0	0.28	0.14	0.06	083	0.498	16.6	0.0	180	19	090	1.0	180
00:36:10	-87	-20	40	0	0.34	0.08	0.06	083	0.150	16.3	0.0	180	23	090	1.0	180
00:36:20	-85	-20	40	0	0.35	0.03	0.05	083	-0.138	17.9	0.0	180	25	090	1.0	180
00:36:30	-84	-20	39	0	0.28	-0.01	0.04	083	-0.298	19.3	0.0	180	21	090	1.0	180
00:36:40	-83	-20	40	0	0.20	0.06	0.03	083	0.211	16.9	0.0	180	22	090	1.0	180
00:36:50	-82	-20	40	0	0.22	0.10	0.03	083	0.434	14.7	0.0	180	21	090	1.0	180
00:37:00	-80	-21	40	0	0.24	0.12	0.03	083	0.536	13.2	0.0	180	18	090	1.0	180
00:37:10	-79	-21	40	0	0.28	0.16	0.05	083	0.708	10.8	0.0	180	26	090	1.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99 Time: 13:55:29

Start Time [hrs:min:sec]: 00:16:40
End Time [hrs:min:sec]: 00:37:15
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 25

Date: 4 February 1999

Start Time: 14:49

Length of run [secs]: 3465

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 25 Direction: 90

Sea State, Significant wave height [m]:.. 5 Direction: 270

Current Speed [knots]:..... 2 Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 1.8

Evaluation:

The approach was similar to the previous run # 24.

When the captain was 400 m from the buoy, he backed down, reversed RPM and killed most of the speed. Then he used the thruster at 120 degrees to bring the bow around more quickly. First equilibrium – he tried 070 degrees and it was not an equilibrium heading. With a heading of 055 degrees he was able to close sidewise to the buoy. After that it was maneuvering between 060 and 0.70 degrees heading to play back and forth over the buoy. Higher rudder rate and lift would help.

Shiphhandling Simulator

Exercise date & time: 04-Feb-99
14:49:56

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 25**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind Knots	Current	
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Deg	Knots
00:33:20	-75	-102	39	0	0.08	-0.20	-0.59	053	2.462	25.6	51.0	180	18	090
00:33:30	-76	-100	39	0	0.04	-0.41	-0.58	054	1.110	24.2	51.0	180	21	090
00:33:40	-77	-98	39	0	-0.02	-0.43	-0.56	054	0.804	22.9	51.0	180	22	090
00:33:50	-79	-96	39	0	-0.03	-0.36	-0.52	054	1.027	19.2	27.0	180	29	090
00:34:00	-80	-94	39	0	-0.05	-0.27	-0.47	054	1.278	14.5	0.0	180	22	090
00:34:10	-82	-93	39	0	-0.04	-0.11	-0.38	054	1.715	6.0	0.0	180	23	090
00:34:20	-82	-93	39	0	-0.01	0.11	-0.24	055	2.175	-12.0	0.0	180	22	090
00:34:30	-82	-93	42	0	0.06	0.24	-0.04	055	1.771	-21.6	0.0	180	24	090
00:34:40	-81	-93	42	0	0.10	0.08	0.09	055	-0.045	-2.6	0.0	180	26	090
00:34:50	-81	-92	42	0	0.16	-0.26	0.08	055	-2.135	16.3	0.0	180	25	090
00:35:00	-80	-91	41	0	0.18	-0.22	0.03	055	-1.598	17.7	24.0	180	32	090
00:35:10	-80	-91	42	0	0.15	-0.19	-0.01	054	-1.104	19.1	51.0	180	24	090
00:35:20	-80	-89	42	0	0.18	-0.41	-0.09	054	-2.047	24.7	51.0	180	26	090
00:35:30	-80	-88	42	0	0.20	-0.42	-0.17	054	-1.589	27.8	51.0	180	24	090
00:35:40	-80	-86	41	0	0.24	-0.45	-0.26	054	-1.226	29.8	100.0	180	21	090
00:35:50	-80	-83	42	0	0.18	-0.43	-0.34	053	-0.544	31.4	100.0	180	17	090
00:36:00	-81	-82	42	0	0.09	-0.13	-0.37	053	1.520	21.5	100.0	180	19	090
00:36:10	-81	-80	42	0	0.11	-0.38	-0.39	054	0.063	24.4	51.0	180	23	090
00:36:20	-82	-78	42	0	0.11	-0.59	-0.45	054	-0.912	28.5	51.0	180	25	090
00:36:30	-83	-75	42	0	0.04	-0.71	-0.52	053	-1.197	35.0	51.0	180	21	090
00:36:40	-85	-73	42	0	-0.03	-0.38	-0.55	053	1.071	35.0	23.0	180	22	090
00:36:50	-87	-71	41	0	-0.01	-0.18	-0.58	054	2.528	35.0	0.0	180	21	090
00:37:00	-88	-70	48	0	-0.01	-0.03	-0.61	054	3.652	35.0	0.0	180	18	090
00:37:10	-88	-69	49	0	0.05	0.21	-0.65	055	5.503	35.0	0.0	180	26	090
00:37:20	-89	-68	50	0	0.11	0.45	-0.68	056	7.160	29.3	0.0	180	25	090
00:37:30	-88	-67	50	0	0.17	0.54	-0.59	057	7.177	10.3	24.0	180	28	090
00:37:40	-87	-66	50	0	0.20	0.29	-0.41	058	4.394	-8.7	24.0	180	21	090
00:37:50	-86	-66	49	0	0.27	0.16	-0.14	059	1.886	-20.3	24.0	180	26	090
00:38:00	-85	-65	50	0	0.30	0.02	0.08	059	-0.399	-13.4	76.0	180	28	090
00:38:10	-84	-64	49	0	0.34	-0.43	0.26	058	-4.377	-26.9	76.0	180	24	090
00:38:20	-82	-63	49	0	0.38	-0.57	0.47	057	-6.601	-16.4	76.0	180	26	090
00:38:30	-81	-62	43	0	0.35	-0.32	0.52	056	-5.346	2.6	100.0	180	23	090
00:38:40	-79	-61	38	0	0.36	-0.37	0.46	056	-5.237	21.6	100.0	180	22	090
00:38:50	-78	-60	30	0	0.30	-0.49	0.33	055	-5.221	35.0	100.0	180	21	090
00:39:00	-77	-59	30	0	0.25	-0.70	0.21	054	-5.756	35.0	100.0	180	23	090
00:39:10	-77	-57	30	0	0.16	-0.84	0.10	053	-5.966	35.0	100.0	180	24	090
00:39:20	-78	-55	30	0	-0.01	-0.70	0.02	052	-4.570	35.0	100.0	180	24	090
00:39:30	-79	-54	36	0	-0.10	-0.73	-0.06	051	-4.276	35.0	100.0	180	20	090
00:39:40	-81	-53	36	0	-0.14	-0.66	-0.14	051	-3.288	35.0	100.0	180	29	090
00:39:50	-83	-51	36	0	-0.18	-0.62	-0.22	050	-2.508	35.0	100.0	180	23	090
00:40:00	-85	-51	36	0	-0.29	-0.26	-0.25	050	-0.054	35.0	100.0	180	21	090
00:40:10	-87	-51	36	0	-0.32	0.08	-0.26	050	2.150	35.0	100.0	180	20	090
00:40:20	-88	-52	36	0	-0.31	0.15	-0.29	050	2.813	35.0	0.0	180	20	090
00:40:30	-90	-53	36	0	-0.29	0.01	-0.34	051	2.215	35.0	0.0	180	24	090
00:40:40	-92	-53	36	0	-0.31	-0.18	-0.39	051	1.343	35.0	0.0	180	24	090
00:40:50	-94	-53	38	0	-0.31	0.02	-0.40	052	2.675	35.0	0.0	180	29	090
00:41:00	-96	-53	44	0	-0.29	-0.11	-0.46	052	2.201	35.0	0.0	180	22	090
00:41:10	-98	-52	44	0	-0.24	-0.10	-0.50	052	2.542	35.0	0.0	180	20	090
00:41:20	-99	-52	45	0	-0.20	0.15	-0.52	053	4.278	35.0	0.0	180	18	090
00:41:30	-101	-52	46	0	-0.12	0.05	-0.57	054	3.958	35.0	0.0	180	24	090
00:41:40	-102	-50	48	0	-0.06	-0.21	-0.64	054	2.778	35.0	0.0	180	25	090
00:41:50	-104	-49	50	0	-0.08	-0.15	-0.70	055	3.478	35.0	0.0	180	24	090
00:42:00	-105	-47	53	0	-0.04	-0.18	-0.75	055	3.627	35.0	0.0	180	27	090
00:42:10	-107	-45	53	0	-0.04	-0.27	-0.82	056	3.495	35.0	0.0	180	28	090
00:42:20	-109	-43	59	0	-0.02	-0.45	-0.89	056	2.753	35.0	0.0	180	23	090
00:42:30	-111	-40	58	0	0.04	-0.33	-0.95	057	3.932	35.0	0.0	180	27	090
00:42:40	-112	-37	62	0	0.07	0.15	-1.00	058	7.253	35.0	49.0	180	26	090
00:42:50	-112	-35	61	0	0.11	0.45	-1.01	059	9.296	35.0	49.0	180	20	090
00:43:00	-112	-34	61	0	0.18	0.60	-1.01	061	10.225	32.9	49.0	180	25	090
00:43:10	-112	-33	62	0	0.32	0.57	-0.88	063	9.227	14.9	49.0	160	20	090
00:43:20	-110	-31	62	0	0.36	0.52	-0.63	064	7.303	-2.5	49.0	136	28	090
00:43:30	-109	-30	60	0	0.43	0.45	-0.35	065	5.111	-2.8	49.0	136	20	090
00:43:40	-106	-30	60	0	0.50	0.37	-0.04	066	2.654	-15.6	49.0	180	17	090
00:43:50	-103	-30	59	0	0.64	0.27	0.24	066	0.138	-15.0	77.0	180	24	090
00:44:00	-99	-29	30	0	0.66	0.01	0.39	066	-2.380	-6.2	99.0	180	19	090
00:44:10	-96	-29	30	0	0.60	0.25	0.41	065	-1.031	-2.7	99.0	180	22	090
00:44:20	-92	-30	30	0	0.57	0.30	0.45	065	-0.936	-0.8	99.0	130	24	090
00:44:30	-89	-30	25	0	0.57	0.18	0.47	065	-1.811	4.9	99.0	130	21	090
00:44:40	-86	-30	25	0	0.46	0.09	0.47	065	-2.413	13.1	99.0	160	20	090
00:44:50	-84	-31	25	0	0.37	-0.04	0.45	064	-3.150	24.8	99.0	160	25	090
00:45:00	-82	-30	25	0	0.29	-0.29	0.41	063	-4.472	35.0	99.0	160	27	090
00:45:10	-81	-30	25	0	0.12	-0.36	0.38	063	-4.687	35.0	99.0	160	32	090
00:45:20	-80	-30	25	0	0.01	-0.28	0.36	062	-4.079	35.0	99.0	160	25	090

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:45:30	-80	-31	25	0	-0.09	-0.02	0.35	061	-2.355	35.0	99.0	160	25	090	2.0	180
00:45:40	-80	-32	34	0	-0.15	-0.04	0.32	061	-2.334	35.0	99.0	140	24	090	2.0	180
00:45:50	-81	-33	35	0	-0.18	-0.08	0.29	061	-2.342	35.0	99.0	131	22	090	2.0	180
00:46:00	-81	-34	35	0	-0.24	0.13	0.26	060	-0.792	35.0	99.0	131	22	090	2.0	180
00:46:10	-82	-36	35	0	-0.31	0.36	0.24	060	0.818	35.0	99.0	131	26	090	2.0	180
00:46:20	-83	-38	35	0	-0.40	0.28	0.21	060	0.438	35.0	99.0	131	25	090	2.0	180
00:46:30	-84	-40	35	0	-0.39	0.14	0.20	060	-0.394	35.0	74.0	131	19	090	2.0	180
00:46:40	-85	-41	35	0	-0.42	0.24	0.19	060	0.347	35.0	74.0	131	28	090	2.0	180
00:46:50	-87	-44	35	0	-0.43	0.38	0.18	061	1.306	35.0	74.0	131	20	090	2.0	180
00:47:00	-88	-46	35	0	-0.45	0.48	0.17	061	1.972	35.0	74.0	131	21	090	2.0	180
00:47:10	-89	-49	39	0	-0.40	0.67	0.18	061	3.137	35.0	74.0	131	19	090	2.0	180
00:47:20	-90	-51	55	0	-0.30	0.37	0.09	062	1.776	35.0	74.0	161	19	090	2.0	180
00:47:30	-90	-53	56	0	-0.25	0.32	-0.05	062	2.352	35.0	74.0	236	28	090	2.0	180
00:47:40	-91	-54	57	0	-0.26	0.23	-0.17	062	2.531	34.0	74.0	236	25	090	2.0	180
00:47:50	-92	-54	57	0	-0.17	0.10	-0.24	063	2.147	25.1	49.0	236	24	090	2.0	180
00:48:00	-93	-54	58	0	-0.12	-0.04	-0.24	063	1.298	24.8	49.0	236	28	090	2.0	180
00:48:10	-94	-54	55	0	-0.09	-0.06	-0.25	063	1.206	22.0	49.0	226	19	090	2.0	180
00:48:20	-95	-53	55	0	0.00	-0.02	-0.20	064	1.130	14.6	49.0	180	20	090	2.0	180
00:48:30	-95	-53	55	0	0.06	0.04	-0.09	064	0.836	8.4	49.0	180	29	090	2.0	180
00:48:40	-94	-52	55	0	0.12	0.04	-0.05	064	0.559	15.8	49.0	180	20	090	2.0	180
00:48:50	-94	-52	56	0	0.15	0.20	0.00	064	1.245	10.2	49.0	208	26	090	2.0	180
00:49:00	-93	-52	53	0	0.22	0.20	0.06	064	0.901	10.9	49.0	208	20	090	2.0	180
00:49:10	-91	-52	42	0	0.23	0.01	0.10	064	-0.542	16.5	49.0	208	24	090	2.0	180
00:49:20	-90	-52	41	0	0.20	-0.05	0.09	064	-0.857	22.2	75.0	208	26	090	2.0	180
00:49:30	-89	-52	42	0	0.15	0.29	0.10	064	1.155	11.5	100.0	208	24	090	2.0	180
00:49:40	-88	-53	42	0	0.12	0.44	0.16	064	1.756	5.3	100.0	239	26	090	2.0	180
00:49:50	-87	-54	41	0	0.21	0.26	0.22	065	0.279	7.3	100.0	239	25	090	2.0	180
00:50:00	-85	-54	38	0	0.23	0.24	0.25	065	-0.054	8.7	100.0	239	22	090	2.0	180
00:50:10	-83	-55	38	0	0.24	0.27	0.28	065	-0.055	4.7	100.0	207	22	090	2.0	180
00:50:20	-82	-56	38	0	0.19	0.08	0.36	064	-1.780	-14.3	100.0	207	29	090	2.0	180
00:50:30	-81	-57	38	0	0.11	-0.07	0.52	064	-3.708	-33.3	100.0	207	21	090	2.0	180
00:50:40	-80	-57	35	0	0.10	-0.54	0.65	063	-7.538	-16.3	100.0	207	23	090	2.0	180
00:50:50	-79	-57	35	0	0.06	-0.68	0.71	062	-8.818	2.7	100.0	207	25	090	2.0	180
00:51:00	-79	-57	35	0	-0.05	-0.74	0.69	060	-9.074	21.7	100.0	207	24	090	2.0	180
00:51:10	-80	-57	35	0	-0.11	-0.63	0.63	059	-7.954	35.0	100.0	207	22	090	2.0	180
00:51:20	-80	-57	35	0	-0.10	-0.49	0.54	057	-6.561	35.0	53.0	179	20	090	2.0	180
00:51:30	-81	-58	36	0	-0.13	-0.50	0.46	056	-6.085	35.0	53.0	179	15	090	2.0	180
00:51:40	-81	-58	42	0	-0.14	-0.53	0.33	055	-5.515	35.0	53.0	179	21	090	2.0	180
00:51:50	-82	-58	36	0	-0.16	-0.44	0.22	055	-4.205	35.0	25.0	179	20	090	2.0	180
00:52:00	-84	-58	36	0	-0.18	-0.48	0.14	054	-3.906	27.0	25.0	179	24	090	2.0	180
00:52:10	-85	-58	44	0	-0.23	-0.47	0.12	053	-3.749	8.0	25.0	179	34	090	2.0	180
00:52:20	-86	-58	45	0	-0.20	-0.32	0.21	053	-3.377	-11.0	25.0	125	19	090	2.0	180
00:52:30	-87	-58	45	0	-0.13	-0.23	0.33	052	-3.587	-4.3	25.0	125	25	090	2.0	180
00:52:40	-87	-59	45	0	-0.04	-0.37	0.32	051	-4.354	14.7	25.0	125	25	090	2.0	180
00:52:50	-87	-59	45	0	0.00	-0.07	0.22	051	-1.847	33.7	25.0	125	23	090	2.0	180
00:53:00	-87	-59	44	0	0.02	0.31	0.08	051	1.473	35.0	16.0	146	28	090	2.0	180
00:53:10	-86	-60	44	0	0.11	0.08	-0.10	051	1.136	35.0	16.0	146	26	090	2.0	180
00:53:20	-86	-59	45	0	0.13	-0.28	-0.28	051	0.029	35.0	16.0	146	26	090	2.0	180
00:53:30	-87	-57	45	0	0.14	-0.39	-0.43	051	0.262	35.0	50.0	146	27	090	2.0	180
00:53:40	-87	-55	45	0	0.14	-0.35	-0.54	051	1.155	35.0	50.0	121	21	090	2.0	180
00:53:50	-88	-53	43	0	0.10	-0.15	-0.60	052	2.867	35.0	50.0	121	23	090	2.0	180
00:54:00	-89	-51	43	0	0.13	-0.36	-0.68	052	2.044	35.0	50.0	121	23	090	2.0	180
00:54:10	-90	-48	43	0	0.18	-0.27	-0.73	053	2.921	35.0	50.0	121	14	090	2.0	180
00:54:20	-91	-45	38	0	0.15	-0.18	-0.74	053	3.554	35.0	50.0	121	22	090	2.0	180
00:54:30	-92	-43	38	0	0.08	-0.20	-0.75	054	3.462	35.0	50.0	136	22	090	2.0	180
00:54:40	-93	-41	38	0	0.05	-0.16	-0.74	054	3.685	35.0	50.0	137	22	090	2.0	180
00:54:50	-94	-39	38	0	0.00	-0.18	-0.73	055	3.454	35.0	50.0	137	21	090	2.0	180
00:55:00	-96	-37	38	0	-0.04	-0.23	-0.71	055	3.028	35.0	50.0	137	24	090	2.0	180
00:55:10	-97	-35	38	0	-0.11	-0.11	-0.67	056	3.564	35.0	75.0	116	22	090	2.0	180
00:55:20	-99	-35	38	0	-0.11	0.26	-0.61	057	5.511	35.0	99.0	088	26	090	2.0	180
00:55:30	-99	-34	38	0	-0.10	0.49	-0.55	058	6.554	35.0	99.0	088	27	090	2.0	180
00:55:40	-100	-35	38	0	-0.08	0.64	-0.49	059	7.162	35.0	99.0	088	23	090	2.0	180
00:55:50	-100	-36	41	0	-0.05	0.84	-0.42	060	7.997	35.0	99.0	088	26	090	2.0	180
00:56:00	-99	-36	40	0	0.02	0.64	-0.38	061	6.501	35.0	77.0	088	16	090	2.0	180
00:56:10	-99	-37	41	0	0.03	0.47	-0.36	062	5.274	35.0	77.0	089	26	090	2.0	180
00:56:20	-99	-37	40	0	-0.04	0.57	-0.33	063	5.747	35.0	77.0	089	29	090	2.0	180
00:56:30	-99	-38	42	0	0.00	0.54	-0.30	064	5.374	35.0	77.0	089	23	090	2.0	180
00:56:40	-98	-38	44	0	0.06	0.44	-0.29	065	4.650	35.0	77.0	089	26	090	2.0	180
00:56:50	-98	-38	44	0	0.08	0.32	-0.29	066	3.861	35.0	26.0	089	24	090	2.0	180
00:57:00	-97	-38	36	0	0.09	0.37	-0.26	066	4.010	35.0	26.0	109	17	090	2.0	180
00:57:10	-97	-39	36	0	0.05	0.60	-0.22	067	5.205	35.0	26.0	089	24	090	2.0	180
00:57:20	-96	-39	36	0	0.05	0.39	-0.16	068	3.506	23.3	26.0	059	21	090	2.0	180
00:57:30	-96	-39	36	0	0.04	0.15	-0.07	068	1.382	20.1	26.0	059	24	090	2.0	180
00:57:40	-96	-40	36	0	0.01	0.14	-0.01	068	0.949	27.1	26.0	059	28	090	2.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99 Time: 14:49:56

Start Time [hrs:min:sec]: 00:33:20
End Time [hrs:min:sec]: 00:57:45
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 26
Start Time: 16:29
Length of run [secs]: 3912

Date: 4 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	25	Direction: 90
Sea State, Significant wave height [m]:..	5	Direction: 270
Current Speed [knots]:.....	2	Direction: 180

Ship Operator: J.A.

Observer: B.K.J & J.K.

Final Mating, distance between center of buoy and center of moon pool [m]: 1.5

Evaluation:

The approach was okay.

The final positioning and mating took a long time maneuvering over the buoy. A reason for this may be found primarily in slow rudder response. There was also problems in keeping an equilibrium speed of zero knots due to the randomness of the wind and waves.

Shiphandling Simulator

Exercise date & time: 04-Feb-99
16:29:29

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run # 26

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind Knots	Wind Deg	Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg			Knots	Deg
00:41:40	-80	-44	40	0	0.51	-0.14	0.30	063	-2.768	11.4	96.0	180	25	090	2.0	180
00:41:50	-78	-43	33	0	0.39	-0.12	0.28	062	-2.529	20.5	96.0	180	24	090	2.0	180
00:42:00	-76	-42	30	0	0.31	-0.18	0.24	062	-2.671	30.8	96.0	180	27	090	2.0	180
00:42:10	-75	-42	25	0	0.19	-0.31	0.19	061	-3.190	35.0	96.0	180	28	090	2.0	180
00:42:20	-75	-41	25	0	0.07	-0.54	0.17	061	-4.525	35.0	96.0	180	23	090	2.0	180
00:42:30	-75	-40	25	0	-0.01	-0.53	0.16	060	-4.352	35.0	96.0	180	27	090	2.0	180
00:42:40	-76	-40	25	0	-0.14	-0.18	0.16	059	-2.144	31.7	96.0	180	26	090	2.0	180
00:42:50	-76	-40	25	0	-0.24	0.00	0.18	059	-1.173	20.3	96.0	180	20	090	2.0	180
00:43:00	-77	-42	25	0	-0.30	0.04	0.20	059	-1.027	35.0	96.0	180	25	090	2.0	180
00:43:10	-78	-43	25	0	-0.30	-0.03	0.20	059	-1.408	35.0	51.0	180	20	090	2.0	180
00:43:20	-80	-44	25	0	-0.39	-0.02	0.20	059	-1.378	35.0	51.0	180	28	090	2.0	180
00:43:30	-81	-46	25	0	-0.46	-0.01	0.21	058	-1.345	35.0	29.0	180	20	090	2.0	180
00:43:40	-83	-47	25	0	-0.50	0.03	0.22	058	-1.214	35.0	29.0	180	17	090	2.0	180
00:43:50	-85	-49	25	0	-0.47	0.04	0.23	058	-1.203	35.0	29.0	180	24	090	2.0	180
00:44:00	-87	-51	25	0	-0.48	-0.23	0.23	058	-2.902	35.0	29.0	180	19	090	2.0	180
00:44:10	-89	-53	27	0	-0.48	0.02	0.24	057	-1.405	35.0	0.0	180	22	090	2.0	180
00:44:20	-90	-55	44	0	-0.45	0.06	0.20	057	-0.853	35.0	0.0	180	24	090	2.0	180
00:44:30	-92	-56	58	0	-0.34	-0.06	0.05	057	-0.694	35.0	0.0	180	21	090	2.0	180
00:44:40	-93	-57	59	0	-0.27	-0.10	-0.15	057	0.315	35.0	0.0	180	20	090	2.0	180
00:44:50	-95	-56	55	0	-0.21	-0.19	-0.29	057	0.638	35.0	0.0	180	25	090	2.0	180
00:45:00	-96	-55	56	0	-0.14	-0.43	-0.43	057	0.006	35.0	0.0	180	27	090	2.0	180
00:45:10	-98	-54	62	0	-0.13	-0.43	-0.58	057	0.938	35.0	0.0	180	32	090	2.0	180
00:45:20	-100	-52	64	0	-0.07	-0.23	-0.71	057	3.068	35.0	0.0	180	25	090	2.0	180
00:45:30	-101	-50	64	0	0.01	0.17	-0.82	058	6.271	35.0	0.0	180	25	090	2.0	180
00:45:40	-102	-49	56	0	0.12	0.23	-0.86	059	6.966	24.8	0.0	180	24	090	2.0	180
00:45:50	-102	-47	48	0	0.16	0.13	-0.73	060	5.466	11.7	0.0	180	22	090	2.0	180
00:46:00	-102	-46	48	0	0.18	0.25	-0.52	061	4.884	-5.9	0.0	180	22	090	2.0	180
00:46:10	-101	-45	48	0	0.19	0.32	-0.23	062	3.491	-19.4	0.0	180	26	090	2.0	180
00:46:20	-100	-45	49	0	0.19	0.11	0.00	062	0.684	-8.4	0.0	180	25	090	2.0	180
00:46:30	-99	-44	49	0	0.29	-0.09	0.13	062	-1.371	3.9	0.0	180	19	090	2.0	180
00:46:40	-97	-44	43	0	0.33	0.04	0.13	062	-0.584	21.4	0.0	180	28	090	2.0	180
00:46:50	-96	-44	42	0	0.35	0.21	0.11	062	0.623	16.7	51.0	180	20	090	2.0	180
00:47:00	-94	-44	39	0	0.35	0.32	0.12	062	1.287	12.2	51.0	180	21	090	2.0	180
00:47:10	-91	-44	39	0	0.42	0.50	0.16	062	2.119	5.3	51.0	180	19	090	2.0	180
00:47:20	-88	-44	39	0	0.49	0.14	0.20	063	-0.355	7.4	99.0	180	19	090	2.0	180
00:47:30	-86	-44	33	0	0.42	0.05	0.20	062	-0.954	12.1	99.0	180	28	090	2.0	180
00:47:40	-84	-43	33	0	0.30	-0.08	0.20	062	-1.756	19.6	99.0	180	25	090	2.0	180
00:47:50	-83	-43	33	0	0.24	-0.21	0.17	062	-2.416	31.3	99.0	180	24	090	2.0	180
00:48:00	-82	-42	33	0	0.15	-0.33	0.12	061	-2.829	35.0	97.0	180	28	090	2.0	180
00:48:10	-82	-41	33	0	0.05	-0.34	0.08	061	-2.677	35.0	97.0	180	19	090	2.0	180
00:48:20	-82	-40	33	0	0.00	-0.28	0.06	061	-2.096	35.0	97.0	180	20	090	2.0	180
00:48:30	-83	-40	33	0	-0.07	-0.15	0.03	060	-1.154	35.0	97.0	180	29	090	2.0	180
00:48:40	-83	-40	33	0	-0.15	-0.13	0.01	060	-0.950	35.0	97.0	180	20	090	2.0	180
00:48:50	-84	-41	33	0	-0.24	0.05	0.01	060	0.257	35.0	76.0	180	26	090	2.0	180
00:49:00	-85	-41	38	0	-0.26	0.08	0.00	060	0.466	35.0	51.0	180	20	090	2.0	180
00:49:10	-86	-42	38	0	-0.28	-0.11	-0.03	060	-0.521	35.0	51.0	180	24	090	2.0	180
00:49:20	-88	-42	39	0	-0.33	-0.18	-0.05	060	-0.815	35.0	51.0	180	26	090	2.0	180
00:49:30	-90	-43	39	0	-0.35	0.21	-0.05	060	1.697	35.0	26.0	180	24	090	2.0	180
00:49:40	-91	-45	39	0	-0.35	0.45	-0.06	061	3.235	35.0	0.0	180	26	090	2.0	180
00:49:50	-92	-46	39	0	-0.25	0.33	-0.05	061	2.410	26.1	0.0	180	25	090	2.0	180
00:50:00	-92	-47	40	0	-0.20	0.34	-0.02	061	2.245	19.1	0.0	180	22	090	2.0	180
00:50:10	-93	-49	50	0	-0.11	0.38	0.04	062	2.189	11.5	0.0	180	22	090	2.0	180
00:50:20	-93	-50	49	0	-0.06	0.18	0.15	062	0.204	-1.1	60.0	180	29	090	2.0	180
00:50:30	-92	-51	50	0	-0.05	0.07	0.23	062	-1.028	8.4	22.0	180	21	090	2.0	180
00:50:40	-92	-51	50	0	0.05	-0.31	0.21	062	-3.304	27.4	22.0	180	23	090	2.0	180
00:50:50	-92	-50	50	0	0.09	-0.33	0.08	061	-2.608	35.0	22.0	180	25	090	2.0	180
00:51:00	-92	-50	49	0	0.06	-0.29	-0.04	061	-1.547	34.1	22.0	180	24	090	2.0	180
00:51:10	-92	-49	50	0	0.09	-0.12	-0.15	061	0.210	35.0	22.0	180	22	090	2.0	180
00:51:20	-92	-48	49	0	0.16	0.06	-0.25	061	1.975	35.0	22.0	180	20	090	2.0	180
00:51:30	-92	-47	50	0	0.18	0.10	-0.33	061	2.731	35.0	22.0	180	15	090	2.0	180
00:51:40	-91	-46	50	0	0.20	0.10	-0.40	062	3.180	35.0	0.0	180	21	090	2.0	180
00:51:50	-90	-45	50	0	0.19	0.21	-0.46	062	4.210	35.0	50.0	180	20	090	2.0	180
00:52:00	-90	-44	50	0	0.18	0.23	-0.50	063	4.632	35.0	50.0	180	24	090	2.0	180
00:52:10	-89	-43	49	0	0.13	0.32	-0.52	064	5.351	35.0	50.0	180	34	090	2.0	180
00:52:20	-89	-42	49	0	0.13	0.55	-0.53	065	6.833	33.5	50.0	180	19	090	2.0	180
00:52:30	-88	-42	50	0	0.20	0.73	-0.50	066	7.774	30.7	50.0	180	25	090	2.0	180
00:52:40	-87	-42	49	0	0.27	0.67	-0.43	067	6.961	21.2	50.0	180	25	090	2.0	180
00:52:50	-85	-43	39	0	0.27	0.81	-0.30	068	7.043	5.7	99.0	180	23	090	2.0	180
00:53:00	-83	-44	39	0	0.22	0.94	-0.10	070	6.607	-12.3	99.0	180	28	090	2.0	180
00:53:10	-81	-46	39	0	0.26	0.65	0.16	070	3.136	-31.3	99.0	180	26	090	2.0	180
00:53:20	-79	-47	39	0	0.21	0.26	0.42	071	-1.003	-35.0	99.0	180	26	090	2.0	180
00:53:30	-78	-48	39	0	0.14	0.03	0.66	070	-3.986	-35.0	99.0	180	27	090	2.0	180
00:53:40	-77	-50	39	0	0.07	-0.12	0.88	069	-6.292	-35.0	99.0	180	21	090	2.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern						Knots	Deg	Knots	Deg
00:53:50	-76	-52	39	0	-0.02	-0.16	1.07	068	-7.790	-35.0	99.0	229	23	090	2.0	180
00:54:00	-75	-54	39	0	-0.02	-0.49	1.25	067	-11.034	-35.0	99.0	229	23	090	2.0	180
00:54:10	-75	-56	39	0	-0.01	-0.60	1.41	065	-12.784	-35.0	99.0	229	14	090	2.0	180
00:54:20	-74	-58	39	0	-0.06	-0.69	1.54	062	-14.161	-22.5	99.0	229	22	090	2.0	180
00:54:30	-73	-60	38	0	-0.15	-0.81	1.58	060	-15.190	-3.5	99.0	229	22	090	2.0	180
00:54:40	-73	-62	39	0	-0.19	-0.84	1.53	057	-15.032	15.5	99.0	229	22	090	2.0	180
00:54:50	-73	-64	39	0	-0.26	-0.87	1.40	055	-14.374	34.5	99.0	177	21	090	2.0	180
00:55:00	-74	-65	39	0	-0.32	-0.90	1.23	053	-13.519	35.0	99.0	177	24	090	2.0	180
00:55:10	-75	-67	39	0	-0.41	-0.79	1.07	050	-11.783	35.0	99.0	177	22	090	2.0	180
00:55:20	-76	-69	39	0	-0.44	-0.43	0.93	049	-8.637	35.0	99.0	177	26	090	2.0	180
00:55:30	-76	-72	42	0	-0.43	-0.22	0.77	048	-6.291	35.0	0.0	177	27	090	2.0	180
00:55:40	-77	-74	43	0	-0.39	-0.08	0.59	047	-4.215	35.0	0.0	177	23	090	2.0	180
00:55:50	-77	-77	56	0	-0.32	0.16	0.37	046	-1.328	35.0	0.0	177	26	090	2.0	180
00:56:00	-78	-78	62	0	-0.17	-0.03	0.02	046	-0.295	35.0	0.0	177	16	090	2.0	180
00:56:10	-79	-78	50	0	-0.10	-0.21	-0.26	046	0.315	35.0	0.0	177	26	090	2.0	180
00:56:20	-80	-77	57	0	-0.10	-0.05	-0.47	046	2.669	35.0	0.0	177	29	090	2.0	180
00:56:30	-81	-76	57	0	0.00	-0.05	-0.68	047	3.949	35.0	0.0	177	23	090	2.0	180
00:56:40	-83	-75	56	0	0.09	-0.18	-0.87	048	4.365	35.0	0.0	177	26	090	2.0	180
00:56:50	-84	-72	57	0	0.15	-0.31	-1.03	048	4.613	35.0	0.0	177	24	090	2.0	180
00:57:00	-86	-69	57	0	0.21	-0.15	-1.13	049	6.200	35.0	0.0	177	17	090	2.0	180
00:57:10	-87	-66	57	0	0.23	0.24	-1.16	050	8.917	35.0	0.0	177	24	090	2.0	180
00:57:20	-87	-63	57	0	0.27	0.01	-1.22	052	7.821	35.0	25.0	177	21	090	2.0	180
00:57:30	-88	-59	57	0	0.30	-0.22	-1.29	053	6.796	35.0	25.0	147	24	090	2.0	180
00:57:40	-89	-55	57	0	0.30	-0.13	-1.31	054	7.467	35.0	25.0	146	28	090	2.0	180
00:57:50	-90	-51	57	0	0.25	0.00	-1.30	056	8.265	35.0	76.0	146	20	090	2.0	180
00:58:00	-91	-48	57	0	0.22	0.21	-1.26	057	9.352	35.0	76.0	146	31	090	2.0	180
00:58:10	-91	-46	57	0	0.22	0.47	-1.20	059	10.611	35.0	76.0	146	23	090	2.0	180
00:58:20	-91	-44	56	0	0.29	0.77	-1.12	061	11.956	35.0	76.0	146	18	090	2.0	180
00:58:30	-90	-43	57	0	0.32	0.83	-1.04	063	11.809	35.0	76.0	146	21	090	2.0	180
00:58:40	-88	-42	44	0	0.33	1.02	-0.92	065	12.260	35.0	76.0	146	21	090	2.0	180
00:58:50	-87	-41	44	0	0.32	1.04	-0.76	067	11.437	26.9	76.0	180	21	090	2.0	180
00:59:00	-85	-41	44	0	0.32	0.87	-0.56	068	9.063	7.9	100.0	180	26	090	2.0	180
00:59:10	-83	-42	40	0	0.26	0.74	-0.30	070	6.556	-11.1	100.0	180	25	090	2.0	180
00:59:20	-82	-43	30	0	0.21	0.53	-0.07	070	3.804	-30.1	100.0	180	20	090	2.0	180
00:59:30	-80	-43	30	0	0.20	0.36	0.15	071	1.280	-35.0	100.0	228	22	090	2.0	180
00:59:40	-79	-45	30	0	0.10	0.31	0.34	071	-0.174	-35.0	100.0	228	21	090	2.0	180
00:59:50	-78	-46	30	0	0.06	0.21	0.51	071	-1.896	-35.0	100.0	228	28	090	2.0	180
01:00:00	-77	-48	30	0	0.05	0.09	0.66	070	-3.587	-35.0	100.0	228	26	090	2.0	180
01:00:10	-76	-49	30	0	0.00	-0.25	0.81	070	-6.714	-35.0	100.0	228	23	090	2.0	180
01:00:20	-76	-51	30	0	-0.09	-0.58	0.96	068	-9.746	-35.0	100.0	228	25	090	2.0	180
01:00:30	-77	-52	30	0	-0.26	-0.54	1.10	066	-10.404	-35.0	100.0	228	29	090	2.0	180
01:00:40	-77	-54	30	0	-0.35	-0.62	1.22	065	-11.672	-35.0	100.0	228	22	090	2.0	180
01:00:50	-78	-56	30	0	-0.42	-0.89	1.34	062	-14.134	-24.1	100.0	228	30	090	2.0	180
01:01:00	-80	-58	30	0	-0.47	-0.88	1.40	060	-14.458	-5.1	100.0	238	26	090	2.0	180
01:01:10	-81	-61	38	0	-0.51	-0.63	1.40	058	-12.856	13.9	100.0	262	19	090	2.0	180
01:01:20	-82	-64	53	0	-0.47	-0.36	1.26	056	-10.311	32.9	100.0	262	25	090	2.0	180
01:01:30	-83	-67	59	0	-0.41	-0.31	0.96	054	-8.034	35.0	100.0	262	17	090	2.0	180
01:01:40	-83	-70	60	0	-0.30	-0.11	0.64	053	-4.743	35.0	29.0	262	23	090	2.0	180
01:01:50	-84	-71	61	0	-0.19	-0.20	0.32	053	-3.294	35.0	0.0	180	19	090	2.0	180
01:02:00	-85	-71	62	0	-0.11	-0.09	0.03	052	-0.798	35.0	0.0	180	18	090	2.0	180
01:02:10	-85	-71	64	0	-0.03	0.04	-0.24	052	1.760	35.0	0.0	180	26	090	2.0	180
01:02:20	-85	-71	62	0	0.13	0.18	-0.48	053	4.204	35.0	0.0	180	24	090	2.0	180
01:02:30	-85	-70	45	0	0.18	0.34	-0.57	054	5.761	35.0	0.0	180	21	090	2.0	180
01:02:40	-85	-68	46	0	0.21	0.23	-0.63	055	5.472	35.0	0.0	180	26	090	2.0	180
01:02:50	-84	-67	46	0	0.29	0.11	-0.68	055	5.035	35.0	0.0	180	19	090	2.0	180
01:03:00	-84	-65	45	0	0.28	0.14	-0.72	056	5.435	35.0	27.0	180	20	090	2.0	180
01:03:10	-84	-62	46	0	0.24	-0.06	-0.76	057	4.434	35.0	52.0	180	28	090	2.0	180
01:03:20	-84	-60	46	0	0.19	-0.09	-0.76	058	4.301	27.4	52.0	180	28	090	2.0	180
01:03:30	-84	-58	46	0	0.18	-0.24	-0.69	059	2.811	9.5	52.0	180	31	090	2.0	180
01:03:40	-85	-55	45	0	0.20	-0.48	-0.51	059	0.153	-9.5	52.0	180	23	090	2.0	180
01:03:50	-85	-52	46	0	0.14	-0.39	-0.24	059	-1.009	-28.5	52.0	180	24	090	2.0	180
01:04:00	-85	-52	46	0	0.14	-0.10	0.09	058	-1.211	-35.0	52.0	180	22	090	2.0	180
01:04:10	-84	-51	46	0	0.18	-0.20	0.37	058	-3.605	-35.0	52.0	180	23	090	2.0	180
01:04:20	-83	-51	46	0	0.23	-0.49	0.60	057	-6.902	-35.0	52.0	180	20	090	2.0	180
01:04:30	-82	-51	45	0	0.21	-0.59	0.80	056	-8.834	-35.0	52.0	180	25	090	2.0	180
01:04:40	-81	-51	46	0	0.21	-0.47	1.00	054	-9.332	-35.0	52.0	180	23	090	2.0	180
01:04:50	-79	-51	46	0	0.21	-0.70	1.12	053	-11.524	-21.7	52.0	180	19	090	2.0	180
01:05:00	-77	-51	46	0	0.25	-0.68	1.12	051	-11.439	-2.7	52.0	180	28	090	2.0	180
01:05:10	-76	-51	45	0	0.33	-0.76	0.98	049	-11.013	16.3	52.0	180	22	090	2.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 04-Feb-99 Time: 16:29:29

Start Time [hrs:min:sec]: 00:41:40
End Time [hrs:min:sec]: 01:05:12
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 27

Date: 5 February 1999

Start Time: 08:06

Length of run [secs]: 5704

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 40 Direction: 0

Sea State, Significant wave height [m]:.. 8 Direction: 180

Current Speed [knots]:..... 0 Direction: 0

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 5.1

Evaluation:

Mating 5.1 m off on the centerline. The challenge is to time when to push the button for release of the buoy during the buoy motion cycle. The captain was two seconds too early in the cycle.

The approach was good until the buoy came into camera view. It was possible to stop the ship entirely through a buoy cycle (approx. 14 secs).

The captain spent considerable time using the thruster only at 180 degrees and varying the heading orders for steering constantly seeking to keep zero ground speed, but it was not possible. Then the captain changed tactics and began experimenting by shifting the thruster vector. This proved to give better control.

Shiphhandling Simulator

Exercise date & time: 05-Feb-99

08:06:56

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #28**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Knots	Deg	Knots	Deg	
00:58:20	20	-96	50	0	-0.42	0.28	0.29	357	-0.036	17.6	0.0	180	35	000	0.0	180
00:58:30	22	-98	49	0	-0.46	0.32	0.19	357	0.858	14.4	0.0	180	39	000	0.0	180
00:58:40	23	-100	49	0	-0.53	0.32	0.11	357	1.306	10.3	0.0	180	44	000	0.0	180
00:58:50	24	-103	50	0	-0.43	0.29	0.07	358	1.418	5.4	0.0	180	34	000	0.0	180
00:59:00	25	-105	52	0	-0.35	0.26	0.05	358	1.329	0.4	0.0	180	34	000	0.0	180
00:59:10	26	-107	51	0	-0.36	0.26	0.06	358	1.231	-3.1	0.0	180	41	000	0.0	180
00:59:20	27	-108	51	0	-0.29	0.22	0.10	358	0.791	-5.1	0.0	180	30	000	0.0	180
00:59:30	28	-110	52	0	-0.26	0.16	0.19	358	-0.205	-20.5	0.0	180	40	000	0.0	180
00:59:40	29	-111	56	0	-0.12	0.08	0.33	358	-1.602	-11.3	0.0	180	35	000	0.0	180
00:59:50	30	-111	55	0	0.12	0.01	0.36	358	-2.228	-1.2	0.0	180	33	000	0.0	180
01:00:00	31	-109	56	0	0.27	-0.05	0.33	357	-2.442	3.8	0.0	180	46	000	0.0	180
01:00:10	31	-108	56	0	0.27	-0.05	0.26	357	-1.949	9.1	0.0	180	45	000	0.0	180
01:00:20	32	-107	55	0	0.18	-0.05	0.15	357	-1.280	13.7	0.0	180	51	000	0.0	180
01:00:30	32	-106	55	0	0.23	-0.07	0.04	357	-0.696	12.7	24.0	180	35	000	0.0	180
01:00:40	31	-104	55	0	0.29	-0.08	-0.05	356	-0.222	11.0	24.0	180	40	000	0.0	180
01:00:50	31	-103	55	0	0.22	-0.13	-0.13	356	0.002	10.7	24.0	180	41	000	0.0	180
01:01:00	30	-102	56	0	0.19	-0.14	-0.19	356	0.304	8.7	24.0	180	43	000	0.0	180
01:01:10	29	-101	56	0	0.27	-0.16	-0.24	357	0.503	7.2	51.0	180	29	000	0.0	180
01:01:20	28	-100	55	0	0.30	-0.15	-0.29	357	0.884	15.5	51.0	180	40	000	0.0	180
01:01:30	26	-98	55	0	0.31	-0.11	-0.41	357	1.904	15.2	51.0	180	31	000	0.0	180
01:01:40	25	-97	55	0	0.29	-0.10	-0.46	357	2.292	7.5	51.0	180	39	000	0.0	180
01:01:50	23	-95	55	0	0.24	-0.11	-0.45	358	2.199	0.2	51.0	180	43	000	0.0	180
01:02:00	22	-94	56	0	0.26	-0.15	-0.40	358	1.562	-3.2	51.0	180	39	000	0.0	180
01:02:10	20	-93	56	0	0.26	-0.23	-0.34	358	0.698	-3.9	100.0	180	40	000	0.0	180
01:02:20	19	-92	55	0	0.21	-0.30	-0.28	358	-0.159	-2.4	100.0	180	37	000	0.0	180
01:02:30	17	-91	55	0	0.12	-0.34	-0.25	358	-0.544	0.3	100.0	180	42	000	0.0	180
01:02:40	16	-90	55	0	0.07	-0.32	-0.24	358	-0.456	1.9	100.0	180	28	000	0.0	180
01:02:50	14	-90	56	0	0.04	-0.30	-0.24	358	-0.343	2.6	100.0	180	44	000	0.0	180
01:03:00	13	-90	55	0	0.12	-0.31	-0.25	358	-0.392	3.8	100.0	180	37	000	0.0	180
01:03:10	12	-89	55	0	0.30	-0.34	-0.26	358	-0.470	5.2	100.0	180	36	000	0.0	180
01:03:20	10	-87	56	0	0.33	-0.33	-0.29	358	-0.246	5.7	100.0	180	30	000	0.0	180
01:03:30	8	-86	53	0	0.41	-0.31	-0.31	358	-0.033	5.1	100.0	180	38	000	0.0	180
01:03:40	7	-83	45	0	0.39	-0.34	-0.32	358	-0.127	5.8	100.0	180	36	000	0.0	180
01:03:50	5	-82	46	0	0.24	-0.36	-0.33	358	-0.149	6.0	100.0	180	38	000	0.0	180
01:04:00	3	-81	46	0	0.19	-0.36	-0.38	358	0.111	21.7	100.0	180	28	000	0.0	180
01:04:10	1	-80	46	0	0.21	-0.36	-0.52	358	1.019	35.0	100.0	180	29	000	0.0	180
01:04:20	-2	-79	46	0	0.16	-0.30	-0.66	358	2.284	30.3	100.0	180	33	000	0.0	180
01:04:30	-4	-79	45	0	-0.02	-0.25	-0.75	358	3.179	20.1	100.0	180	34	000	0.0	180
01:04:40	-7	-79	45	0	-0.18	-0.21	-0.82	359	3.889	8.5	76.0	180	46	000	0.0	180
01:04:50	-10	-80	45	0	-0.19	-0.19	-0.83	360	4.025	-4.2	76.0	180	29	000	0.0	180
01:05:00	-12	-81	46	0	-0.16	-0.21	-0.76	000	3.520	-14.9	76.0	180	39	000	0.0	180
01:05:10	-14	-82	46	0	-0.24	-0.25	-0.65	001	2.589	-22.4	76.0	180	45	000	0.0	180
01:05:20	-17	-84	46	0	-0.30	-0.30	-0.52	001	1.414	-25.3	76.0	180	35	000	0.0	180
01:05:30	-19	-85	46	0	-0.39	-0.35	-0.38	001	0.171	-25.2	52.0	180	36	000	0.0	180
01:05:40	-21	-88	46	0	-0.46	-0.41	-0.25	001	-1.041	-21.5	27.0	180	38	000	0.0	180
01:05:50	-22	-90	49	0	-0.50	-0.45	-0.14	001	-1.961	-15.2	0.0	180	28	000	0.0	180
01:06:00	-24	-93	53	0	-0.59	-0.48	-0.06	001	-2.681	-7.0	0.0	180	34	000	0.0	180
01:06:10	-25	-96	54	0	-0.62	-0.49	-0.04	000	-2.887	1.7	0.0	180	32	000	0.0	180
01:06:20	-26	-99	54	0	-0.56	-0.46	-0.08	360	-2.450	9.7	0.0	180	36	000	0.0	180
01:06:30	-28	-102	53	0	-0.44	-0.39	-0.20	359	-1.177	25.4	0.0	180	44	000	0.0	180
01:06:40	-30	-104	59	0	-0.32	-0.22	-0.48	359	1.640	35.0	0.0	180	39	000	0.0	180
01:06:50	-32	-105	63	0	-0.23	-0.02	-0.80	360	4.934	25.5	0.0	180	41	000	0.0	180
01:07:00	-34	-106	62	0	-0.16	0.09	-0.95	001	6.566	6.5	0.0	180	40	000	0.0	180
01:07:10	-36	-107	62	0	-0.06	0.08	-0.89	002	6.161	-12.5	0.0	180	39	000	0.0	180
01:07:20	-38	-106	62	0	0.18	-0.02	-0.59	003	3.604	-25.0	0.0	180	51	000	0.0	180
01:07:30	-39	-105	63	0	0.28	-0.04	-0.38	003	2.192	-6.0	0.0	180	33	000	0.0	180
01:07:40	-40	-103	62	0	0.31	0.02	-0.34	004	2.275	-2.1	0.0	180	33	000	0.0	180
01:07:50	-40	-101	62	0	0.42	0.05	-0.26	004	1.975	-6.5	51.0	180	41	000	0.0	180
01:08:00	-41	-99	52	0	0.37	0.04	-0.17	004	1.364	-10.5	75.0	180	41	000	0.0	180
01:08:10	-41	-98	53	0	0.29	0.01	-0.07	005	0.538	-11.3	48.0	180	40	000	0.0	180
01:08:20	-41	-96	52	0	0.36	0.07	0.01	005	0.371	-11.3	48.0	180	41	000	0.0	180
01:08:30	-40	-94	53	0	0.48	0.13	0.10	005	0.236	-11.9	48.0	180	37	000	0.0	180
01:08:40	-39	-91	53	0	0.54	0.10	0.18	005	-0.505	-10.2	48.0	180	36	000	0.0	180
01:08:50	-38	-89	53	0	0.47	0.15	0.23	005	-0.532	-7.8	100.0	180	42	000	0.0	180
01:09:00	-37	-87	53	0	0.32	0.19	0.27	004	-0.474	-6.5	100.0	180	36	000	0.0	180
01:09:10	-36	-85	53	0	0.25	0.22	0.29	004	-0.460	-4.6	100.0	180	40	000	0.0	180
01:09:20	-34	-84	53	0	0.17	0.29	0.31	004	-0.132	-5.2	100.0	180	35	000	0.0	180
01:09:30	-32	-84	52	0	0.09	0.31	0.36	004	-0.299	-18.2	100.0	180	46	000	0.0	180
01:09:40	-30	-84	53	0	-0.01	0.28	0.53	004	-1.576	-34.4	100.0	180	33	000	0.0	180
01:09:50	-28	-84	53	0	-0.16	0.18	0.75	004	-3.648	-22.3	100.0	180	44	000	0.0	180
01:10:00	-26	-85	53	0	-0.18	0.09	0.86	003	-4.924	-6.3	100.0	180	41	000	0.0	180
01:10:10	-23	-86	53	0	-0.16	0.10	0.86	002	-4.826	3.5	100.0	130	41	000	0.0	180
01:10:20	-21	-87	52	0	-0.13	0.10	0.91	001	-5.156	-12.6	100.0	130	30	000	0.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
01:10:30	-18	-88	53	0	-0.07	0.10	0.94	000	-5.337	3.9	100.0	130	27	000	0.0	180
01:10:40	-16	-88	53	0	-0.05	0.17	0.86	360	-4.437	16.9	100.0	130	37	000	0.0	180
01:10:50	-13	-88	52	0	0.05	0.29	0.69	359	-2.529	24.2	100.0	130	31	000	0.0	180
01:11:00	-11	-87	52	0	0.13	0.41	0.47	359	-0.367	23.0	100.0	130	36	000	0.0	180
01:11:10	-8	-87	53	0	0.08	0.52	0.31	359	1.384	17.1	100.0	130	33	000	0.0	180
01:11:20	-6	-87	53	0	-0.07	0.60	0.22	359	2.417	7.8	100.0	130	35	000	0.0	180
01:11:30	-4	-87	52	0	-0.03	0.63	0.21	360	2.649	-0.6	100.0	130	37	000	0.0	180
01:11:40	-2	-87	53	0	0.09	0.63	0.24	000	2.483	-7.2	100.0	130	52	000	0.0	180
01:11:50	0	-87	53	0	0.06	0.59	0.30	000	1.851	-12.2	100.0	180	28	000	0.0	180
01:12:00	3	-86	52	0	0.10	0.51	0.37	001	0.922	-14.3	100.0	232	38	000	0.0	180
01:12:10	5	-86	53	0	0.12	0.42	0.43	001	-0.063	-12.8	100.0	232	33	000	0.0	180
01:12:20	7	-85	48	0	0.04	0.34	0.47	001	-0.806	-9.5	100.0	232	32	000	0.0	180
01:12:30	9	-85	48	0	0.00	0.29	0.48	000	-1.208	-5.3	100.0	213	35	000	0.0	180
01:12:40	11	-85	49	0	-0.02	0.25	0.50	000	-1.566	0.4	100.0	213	31	000	0.0	180
01:12:50	13	-85	49	0	-0.07	0.21	0.48	360	-1.687	6.1	100.0	269	37	000	0.0	180
01:13:00	15	-86	49	0	-0.11	0.18	0.42	360	-1.517	10.7	100.0	269	36	000	0.0	180
01:13:10	16	-87	49	0	-0.24	0.16	0.34	359	-1.117	13.4	100.0	269	33	000	0.0	180
01:13:20	17	-88	49	0	-0.36	0.15	0.24	359	-0.575	13.5	100.0	290	39	000	0.0	180
01:13:30	18	-90	48	0	-0.37	0.15	0.15	359	-0.027	13.1	100.0	296	42	000	0.0	180
01:13:40	19	-92	48	0	-0.34	0.14	0.06	359	0.498	10.8	100.0	296	35	000	0.0	180
01:13:50	19	-93	49	0	-0.19	0.13	0.00	359	0.816	5.3	100.0	296	45	000	0.0	180
01:14:00	19	-94	49	0	-0.12	0.09	-0.03	360	0.720	1.2	100.0	270	29	000	0.0	180
01:14:10	19	-95	49	0	-0.10	0.04	-0.05	360	0.520	-0.2	100.0	270	37	000	0.0	180
01:14:20	19	-95	49	0	-0.08	-0.01	-0.06	360	0.301	0.5	100.0	244	49	000	0.0	180
01:14:30	19	-96	48	0	-0.09	-0.04	-0.08	360	0.217	1.6	100.0	218	41	000	0.0	180
01:14:40	19	-96	49	0	-0.05	-0.07	-0.09	360	0.154	1.4	100.0	218	37	000	0.0	180
01:14:50	18	-96	49	0	-0.11	-0.09	-0.11	360	0.126	1.8	100.0	218	38	000	0.0	180
01:15:00	18	-97	48	0	-0.18	-0.12	-0.14	360	0.098	1.7	100.0	272	39	000	0.0	180
01:15:10	17	-98	48	0	-0.05	-0.16	-0.17	360	0.026	2.1	100.0	288	41	000	0.0	180
01:15:20	16	-98	48	0	0.10	-0.21	-0.19	360	-0.125	2.9	100.0	288	36	000	0.0	180
01:15:30	15	-97	49	0	0.09	-0.25	-0.21	360	-0.229	3.9	100.0	278	36	000	0.0	180
01:15:40	14	-97	48	0	0.04	-0.28	-0.24	360	-0.290	5.2	100.0	253	34	000	0.0	180
01:15:50	12	-96	49	0	0.16	-0.28	-0.25	360	-0.179	5.2	50.0	253	40	000	0.0	180
01:16:00	11	-95	48	0	0.23	-0.28	-0.27	360	-0.068	5.3	50.0	253	43	000	0.0	180
01:16:10	9	-94	48	0	0.26	-0.29	-0.29	360	0.004	5.1	50.0	253	44	000	0.0	180
01:16:20	8	-93	49	0	0.25	-0.29	-0.30	360	0.071	4.9	50.0	205	41	000	0.0	180
01:16:30	6	-92	48	0	0.07	-0.29	-0.31	360	0.117	4.1	50.0	205	46	000	0.0	180
01:16:40	5	-92	49	0	-0.10	-0.28	-0.33	360	0.326	2.7	50.0	242	38	000	0.0	180
01:16:50	3	-93	49	0	-0.13	-0.27	-0.35	360	0.476	1.1	50.0	242	33	000	0.0	180
01:17:00	2	-93	49	0	-0.15	-0.28	-0.36	360	0.518	-0.6	50.0	242	37	000	0.0	180
01:17:10	0	-94	49	0	-0.14	-0.28	-0.36	000	0.482	-1.6	50.0	242	39	000	0.0	180
01:17:20	-2	-95	49	0	-0.12	-0.29	-0.35	000	0.398	-3.1	24.0	242	32	000	0.0	180
01:17:30	-3	-95	49	0	-0.16	-0.29	-0.33	000	0.253	-3.7	24.0	242	26	000	0.0	180
01:17:40	-5	-96	48	0	-0.11	-0.30	-0.32	000	0.108	-3.8	24.0	140	42	000	0.0	180
01:17:50	-6	-97	48	0	-0.12	-0.27	-0.29	000	0.113	-3.8	98.0	118	33	000	0.0	180
01:18:00	-8	-97	49	0	-0.10	-0.24	-0.25	000	0.105	-4.4	98.0	118	47	000	0.0	180
01:18:10	-9	-98	49	0	-0.03	-0.21	-0.22	000	0.060	-4.3	99.0	118	37	000	0.0	180
01:18:20	-10	-98	48	0	-0.01	-0.17	-0.18	000	0.068	-5.0	99.0	090	33	000	0.0	180
01:18:30	-11	-98	48	0	-0.03	-0.13	-0.14	000	0.020	-4.7	99.0	090	34	000	0.0	180
01:18:40	-11	-98	49	0	-0.10	-0.10	-0.09	000	-0.026	-4.3	99.0	090	42	000	0.0	180
01:18:50	-12	-99	48	0	-0.02	-0.06	-0.05	000	-0.051	-3.5	99.0	090	33	000	0.0	180
01:19:00	-12	-98	49	0	0.13	-0.03	-0.01	000	-0.078	-3.2	99.0	090	35	000	0.0	180
01:19:10	-12	-97	49	0	0.14	0.00	0.02	000	-0.107	-3.0	99.0	118	31	000	0.0	180
01:19:20	-12	-97	48	0	0.16	0.04	0.05	000	-0.084	-2.8	99.0	118	36	000	0.0	180
01:19:30	-12	-96	48	0	0.28	0.07	0.08	000	-0.058	-3.1	99.0	118	39	000	0.0	180
01:19:40	-11	-94	48	0	0.32	0.10	0.11	000	-0.058	-3.2	76.0	118	26	000	0.0	180
01:19:50	-10	-93	49	0	0.22	0.11	0.13	000	-0.105	-2.3	76.0	151	45	000	0.0	180
01:20:00	-10	-92	48	0	0.12	0.13	0.14	000	-0.089	-2.2	98.0	151	28	000	0.0	180
01:20:10	-9	-91	48	0	0.01	0.15	0.16	000	-0.024	-2.1	52.0	090	33	000	0.0	180
01:20:20	-8	-91	49	0	-0.03	0.16	0.18	000	-0.132	-1.4	52.0	090	34	000	0.0	180
01:20:30	-7	-92	49	0	0.02	0.16	0.19	000	-0.153	-0.6	39.0	090	36	000	0.0	180
01:20:40	-6	-91	49	0	-0.02	0.17	0.19	000	-0.112	-0.4	39.0	090	37	000	0.0	180
01:20:50	-5	-92	48	0	-0.16	0.17	0.20	000	-0.200	-0.2	39.0	124	49	000	0.0	180
01:21:00	-4	-93	48	0	-0.21	0.17	0.21	000	-0.239	1.0	39.0	065	33	000	0.0	180
01:21:10	-3	-94	48	0	-0.14	0.17	0.21	360	-0.225	1.7	39.0	065	38	000	0.0	180
01:21:20	-2	-94	49	0	-0.05	0.18	0.21	360	-0.177	2.2	39.0	065	44	000	0.0	180
01:21:30	-1	-94	48	0	0.04	0.19	0.20	360	-0.034	1.9	39.0	065	40	000	0.0	180
01:21:40	0	-94	48	0	-0.04	0.20	0.19	360	0.083	0.6	39.0	153	39	000	0.0	180
01:21:50	1	-95	48	0	-0.12	0.20	0.19	360	0.072	0.7	100.0	176	26	000	0.0	180
01:22:00	2	-95	48	0	-0.14	0.20	0.20	360	0.040	0.9	100.0	176	37	000	0.0	180
01:22:10	3	-96	49	0	-0.21	0.17	0.19	360	-0.118	1.6	100.0	242	36	000	0.0	180
01:22:20	3	-97	49	0	-0.15	0.12	0.16	360	-0.270	3.2	100.0	272	40	000	0.0	180
01:22:30	4	-98	48	0	-0.05	0.08	0.13	360	-0.301	5.3	100.0	272	42	000	0.0	180
01:22:40	4	-98	48	0	0.07	0.06	0.08	360	-0.139	5.1	100.0	242	42	000	0.0	180
01:22:50	5	-97	48	0	0.08	0.03	0.04	360	-0.040	3.9	100.0	242	40	000	0.0	180
01:23:00	5	-97	49	0	0.06	0.00	0.00	360	-0.020	3.8	100.0	242	47	000	0.0	180
01:23:10	5	-97	49	0	0.16	-0.03	-0.03	360	-0.016	3.5	100.0	211	42	000	0.0	180
01:23:20	4	-96	48	0	0.18	-0.05	-0.05	360	0.029	3.2	100.0	211	38	000	0.0	180
01:23:30	4	-95	49	0	0.10	-0.07	-0.08	360	0.030	3.1	100.0	211	40	000	0.0	180
01:23:40	4	-94	49	0	0.04	-0.09	-0.10	360	0.007	3.3	100.0	211	39	000	0.0	180
01:23:50	3	-94	49	0	-0.03	-0.12	-0.12	360	0.003	3.4	100.0	239	31	000	0.0	180
01:24:00	2	-95	49	0	-0.14	-0.14	-0.15	360	0.068	3.						

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
01:24:20	1	-97	49	0	-0.24	-0.15	-0.19	360	0.268	1.2	51.0	239	39	000	0.0	180
01:24:30	0	-98	48	0	-0.30	-0.15	-0.20	360	0.299	0.2	51.0	249	34	000	0.0	180
01:24:40	-1	-100	49	0	-0.25	-0.16	-0.20	360	0.265	-0.5	51.0	272	37	000	0.0	180
01:24:50	-2	-101	49	0	-0.13	-0.18	-0.21	000	0.194	-1.0	51.0	272	33	000	0.0	180
01:25:00	-3	-101	49	0	-0.12	-0.17	-0.20	000	0.180	-1.5	51.0	088	43	000	0.0	180
01:25:10	-4	-102	49	0	-0.23	-0.16	-0.18	000	0.157	-1.8	51.0	088	37	000	0.0	180
01:25:20	-5	-103	48	0	-0.31	-0.15	-0.17	000	0.103	-2.0	51.0	059	34	000	0.0	180
01:25:30	-6	-105	49	0	-0.32	-0.15	-0.15	000	0.045	-1.8	51.0	059	36	000	0.0	180
01:25:40	-6	-106	49	0	-0.16	-0.12	-0.13	000	0.092	-2.8	100.0	059	36	000	0.0	180
01:25:50	-7	-107	49	0	-0.10	-0.08	-0.10	000	0.114	-3.3	100.0	059	46	000	0.0	180
01:26:00	-7	-108	49	0	-0.16	-0.05	-0.07	000	0.086	-3.4	100.0	059	35	000	0.0	180
01:26:10	-7	-108	48	0	-0.06	-0.03	-0.03	000	0.038	-3.4	100.0	059	32	000	0.0	180
01:26:20	-7	-108	49	0	0.05	0.00	0.00	000	-0.008	-2.6	100.0	059	35	000	0.0	180
01:26:30	-7	-108	49	0	0.18	0.03	0.04	000	-0.013	-2.7	100.0	059	33	000	0.0	180
01:26:40	-7	-106	49	0	0.35	0.07	0.07	000	0.009	-2.8	100.0	059	22	000	0.0	180
01:26:50	-7	-104	48	0	0.49	0.10	0.10	000	0.038	-2.9	100.0	059	42	000	0.0	180
01:27:00	-6	-101	48	0	0.56	0.13	0.12	000	0.045	-2.9	100.0	059	27	000	0.0	180
01:27:10	-5	-99	49	0	0.46	0.15	0.15	000	0.016	-3.4	100.0	152	38	000	0.0	180
01:27:20	-4	-97	48	0	0.36	0.17	0.17	000	-0.015	-3.3	100.0	152	38	000	0.0	180
01:27:30	-4	-95	48	0	0.29	0.17	0.19	000	-0.105	-2.5	100.0	184	36	000	0.0	180
01:27:40	-3	-94	48	0	0.17	0.16	0.19	000	-0.183	-1.9	100.0	184	45	000	0.0	180
01:27:50	-2	-93	48	0	0.11	0.16	0.19	000	-0.192	-1.1	100.0	184	41	000	0.0	180
01:28:00	-1	-93	49	0	0.08	0.16	0.18	000	-0.159	-0.7	100.0	184	39	000	0.0	180
01:28:10	0	-93	48	0	-0.02	0.16	0.18	000	-0.143	-0.1	100.0	184	29	000	0.0	180
01:28:20	1	-93	48	0	-0.08	0.15	0.18	000	-0.224	0.9	100.0	184	32	000	0.0	180
01:28:30	2	-93	48	0	-0.10	0.14	0.18	360	-0.245	1.5	100.0	184	36	000	0.0	180
01:28:40	3	-94	49	0	-0.19	0.14	0.18	360	-0.225	2.2	100.0	184	44	000	0.0	180
01:28:50	3	-95	49	0	-0.27	0.17	0.18	360	-0.077	2.0	100.0	089	25	000	0.0	180
01:29:00	4	-97	48	0	-0.31	0.16	0.17	360	-0.082	1.9	100.0	268	43	000	0.0	180
01:29:10	5	-98	48	0	-0.26	0.12	0.15	360	-0.199	3.1	100.0	303	37	000	0.0	180
01:29:20	6	-99	48	0	-0.24	0.08	0.12	360	-0.240	3.9	100.0	303	43	000	0.0	180
01:29:30	6	-101	48	0	-0.28	0.05	0.09	360	-0.219	4.3	100.0	272	44	000	0.0	180
01:29:40	6	-102	49	0	-0.33	0.03	0.05	360	-0.152	4.5	100.0	306	40	000	0.0	180
01:29:50	7	-104	48	0	-0.18	0.01	0.02	360	-0.017	4.6	100.0	336	37	000	0.0	180
01:30:00	7	-104	48	0	0.15	0.00	-0.01	360	0.062	3.4	100.0	336	39	000	0.0	180
01:30:10	6	-103	48	0	0.25	-0.03	-0.04	360	0.056	3.7	100.0	298	43	000	0.0	180
01:30:20	6	-101	49	0	0.30	-0.06	-0.07	360	0.041	3.8	100.0	298	36	000	0.0	180
01:30:30	6	-100	49	0	0.37	-0.10	-0.10	360	0.018	3.9	100.0	298	44	000	0.0	180
01:30:40	5	-98	49	0	0.37	-0.13	-0.13	360	-0.001	3.9	100.0	298	42	000	0.0	180
01:30:50	4	-96	49	0	0.39	-0.16	-0.16	360	-0.008	4.0	100.0	209	39	000	0.0	180
01:31:00	4	-94	48	0	0.39	-0.17	-0.17	360	0.031	3.9	100.0	184	32	000	0.0	180
01:31:10	3	-92	49	0	0.32	-0.17	-0.18	360	0.095	3.1	100.0	184	42	000	0.0	180
01:31:20	2	-90	49	0	0.20	-0.17	-0.19	360	0.153	2.7	100.0	184	38	000	0.0	180
01:31:30	1	-90	48	0	0.11	-0.17	-0.19	360	0.133	2.1	100.0	184	37	000	0.0	180
01:31:40	0	-89	48	0	0.09	-0.17	-0.19	360	0.122	1.5	100.0	141	31	000	0.0	180
01:31:50	-1	-89	49	0	0.07	-0.13	-0.17	360	0.214	0.2	100.0	119	36	000	0.0	180
01:32:00	-2	-89	48	0	0.01	-0.10	-0.14	360	0.227	-1.1	100.0	142	43	000	0.0	180
01:32:10	-2	-89	49	0	0.02	-0.09	-0.12	360	0.141	-1.0	100.0	156	42	000	0.0	180
01:32:20	-3	-89	49	0	-0.04	-0.07	-0.09	360	0.137	-1.8	100.0	153	45	000	0.0	180
01:32:30	-3	-89	48	0	-0.20	-0.05	-0.08	000	0.159	-0.9	100.0	153	36	000	0.0	180
01:32:40	-3	-90	49	0	-0.31	-0.03	-0.06	000	0.216	-1.4	100.0	121	32	000	0.0	180
01:32:50	-4	-92	48	0	-0.40	0.01	-0.03	000	0.263	-2.5	100.0	121	45	000	0.0	180
01:33:00	-4	-95	49	0	-0.44	0.04	0.00	000	0.257	-2.9	100.0	121	30	000	0.0	180
01:33:10	-3	-97	49	0	-0.44	0.07	0.04	000	0.211	-3.4	100.0	062	29	000	0.0	180
01:33:20	-3	-99	49	0	-0.37	0.10	0.08	000	0.124	-3.8	100.0	062	34	000	0.0	180
01:33:30	-2	-101	49	0	-0.23	0.12	0.12	000	0.017	-4.0	100.0	062	30	000	0.0	180
01:33:40	-2	-101	49	0	-0.07	0.15	0.16	000	-0.101	-2.7	100.0	062	33	000	0.0	180
01:33:50	-1	-101	49	0	-0.03	0.17	0.20	000	-0.173	-2.3	100.0	119	39	000	0.0	180
01:34:00	0	-102	48	0	-0.10	0.20	0.23	000	-0.208	-1.8	100.0	119	37	000	0.0	180
01:34:10	1	-102	49	0	0.01	0.23	0.26	000	-0.180	-1.4	100.0	119	42	000	0.0	180
01:34:20	3	-102	49	0	0.10	0.28	0.27	000	0.053	-1.9	100.0	119	36	000	0.0	180
01:34:30	4	-101	49	0	0.08	0.32	0.28	000	0.215	-3.1	100.0	119	32	000	0.0	180
01:34:40	6	-101	49	0	0.05	0.35	0.30	000	0.326	-4.0	100.0	119	40	000	0.0	180
01:34:50	8	-101	49	0	-0.07	0.37	0.34	000	0.217	-4.7	100.0	119	30	000	0.0	180
01:35:00	9	-102	49	0	-0.16	0.38	0.39	000	-0.051	-4.4	100.0	119	45	000	0.0	180

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 08:06:56

Start Time [hrs:min:sec]: 00:58:20
End Time [hrs:min:sec]: 01:35:04
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 28
Start Time: 09:53
Length of run [secs]: 2145

Date: 5 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	40	Direction: 0
Sea State, Significant wave height [m]:..	8	Direction: 180
Current Speed [knots]:.....	0	Direction: 0

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 2.4

Evaluation:

The approach was okay.

The maneuvering over the buoy was done from the start by varying the thruster vector direction and the forces. Throughout the positioning operation the autopilot was kept at 000 degrees and the RPM 44. All maneuvers were controlled by adjusting the thruster vector.

Shiphhandling Simulator

Exercise date & time: 05-Feb-99
09:53:08

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run # 28

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Deg	%	Deg	Knots	Deg	Knots
00:16:40	10	-132	44	0	0.15	0.42	0.37	360	0.320	4.8	100.0	303	46	000	0.0	180
00:16:50	12	-131	44	0	0.21	0.39	0.31	360	0.481	3.1	100.0	303	40	000	0.0	180
00:17:00	14	-130	45	0	0.26	0.35	0.27	360	0.502	1.9	100.0	244	43	000	0.0	180
00:17:10	15	-128	45	0	0.35	0.31	0.24	360	0.408	0.6	100.0	244	43	000	0.0	180
00:17:20	16	-126	45	0	0.39	0.26	0.22	360	0.259	-0.1	100.0	244	36	000	0.0	180
00:17:30	18	-124	45	0	0.27	0.19	0.24	360	-0.373	-16.2	100.0	244	47	000	0.0	180
00:17:40	19	-124	45	0	0.10	0.09	0.30	360	-1.346	-22.3	100.0	244	31	000	0.0	180
00:17:50	20	-123	45	0	0.16	-0.01	0.38	359	-2.464	-15.0	100.0	264	38	000	0.0	180
00:18:00	20	-122	44	0	0.26	-0.10	0.39	359	-3.131	-6.3	100.0	272	27	000	0.0	180
00:18:10	21	-121	44	0	0.25	-0.16	0.36	358	-3.285	5.5	100.0	242	33	000	0.0	180
00:18:20	21	-119	44	0	0.27	-0.18	0.25	358	-2.704	23.7	100.0	242	39	000	0.0	180
00:18:30	21	-118	45	0	0.22	-0.13	0.05	358	-1.155	35.0	100.0	242	43	000	0.0	180
00:18:40	21	-117	45	0	0.10	-0.05	-0.14	358	0.623	35.0	100.0	265	27	000	0.0	180
00:18:50	20	-117	45	0	0.08	-0.04	-0.31	358	1.740	28.8	100.0	265	36	000	0.0	180
00:19:00	19	-116	45	0	0.08	-0.09	-0.44	358	2.165	24.5	100.0	293	39	000	0.0	180
00:19:10	18	-116	45	0	0.04	-0.12	-0.52	359	2.548	17.2	100.0	293	36	000	0.0	180
00:19:20	16	-116	45	0	-0.02	-0.16	-0.57	359	2.641	10.1	100.0	293	38	000	0.0	180
00:19:30	14	-116	44	0	-0.17	-0.16	-0.61	359	2.887	2.6	51.0	293	31	000	0.0	180
00:19:40	12	-118	44	0	-0.27	-0.17	-0.61	360	2.789	-5.3	75.0	316	37	000	0.0	180
00:19:50	10	-119	44	0	-0.29	-0.20	-0.57	000	2.303	-11.3	75.0	316	31	000	0.0	180
00:20:00	8	-120	44	0	-0.24	-0.26	-0.50	001	1.506	-15.8	99.0	342	44	000	0.0	180
00:20:10	6	-121	45	0	-0.09	-0.33	-0.42	001	0.576	-17.0	99.0	303	31	000	0.0	180
00:20:20	4	-122	45	0	-0.06	-0.40	-0.35	001	-0.293	-14.3	54.0	272	38	000	0.0	180
00:20:30	2	-122	45	0	-0.06	-0.43	-0.29	001	-0.909	-10.6	26.0	272	34	000	0.0	180
00:20:40	0	-122	45	0	-0.03	-0.45	-0.25	001	-1.286	-5.8	72.0	000	33	000	0.0	180
00:20:50	-2	-122	45	0	0.03	-0.44	-0.22	000	-1.408	-1.2	72.0	072	29	000	0.0	180
00:21:00	-3	-122	45	0	0.11	-0.41	-0.20	000	-1.326	2.6	87.0	072	35	000	0.0	180
00:21:10	-5	-121	44	0	0.05	-0.35	-0.20	360	-0.983	5.9	99.0	072	40	000	0.0	180
00:21:20	-6	-121	44	0	0.04	-0.29	-0.20	360	-0.572	6.7	99.0	072	38	000	0.0	180
00:21:30	-7	-121	44	0	0.17	-0.24	-0.21	360	-0.181	5.9	99.0	072	34	000	0.0	180
00:21:40	-8	-119	45	0	0.27	-0.18	-0.21	360	0.161	4.5	99.0	072	42	000	0.0	180
00:21:50	-9	-118	45	0	0.17	-0.14	-0.20	360	0.413	1.9	99.0	119	49	000	0.0	180
00:22:00	-10	-118	45	0	0.12	-0.11	-0.18	360	0.466	-0.2	53.0	119	38	000	0.0	180
00:22:10	-11	-117	45	0	0.21	-0.10	-0.16	360	0.391	-0.2	77.0	119	45	000	0.0	180
00:22:20	-11	-116	45	0	0.25	-0.10	-0.15	360	0.310	-0.8	62.0	119	31	000	0.0	180
00:22:30	-12	-114	45	0	0.28	-0.09	-0.12	000	0.235	-1.5	62.0	087	31	000	0.0	180
00:22:40	-12	-113	45	0	0.23	-0.06	-0.10	000	0.248	-2.3	100.0	087	44	000	0.0	180
00:22:50	-13	-112	44	0	0.03	-0.02	-0.05	000	0.202	-6.1	100.0	087	35	000	0.0	180
00:23:00	-13	-112	44	0	-0.10	0.00	-0.01	000	0.083	-3.3	97.0	061	34	000	0.0	180
00:23:10	-13	-113	44	0	-0.09	0.03	0.02	000	0.078	-3.2	97.0	061	41	000	0.0	180
00:23:20	-13	-113	45	0	-0.11	0.06	0.05	000	0.059	-3.4	97.0	061	39	000	0.0	180
00:23:30	-12	-114	45	0	-0.06	0.08	0.08	000	-0.024	-2.6	97.0	031	46	000	0.0	180
00:23:40	-12	-114	45	0	-0.04	0.09	0.11	000	-0.090	-1.3	97.0	031	41	000	0.0	180
00:23:50	-11	-114	45	0	-0.04	0.11	0.13	000	-0.127	-1.0	97.0	031	43	000	0.0	180
00:24:00	-11	-114	46	0	0.04	0.13	0.14	000	-0.077	-1.0	97.0	031	43	000	0.0	180
00:24:10	-10	-114	46	0	0.06	0.16	0.15	000	0.040	-1.9	97.0	088	35	000	0.0	180
00:24:20	-9	-114	45	0	0.12	0.17	0.16	000	0.041	-1.9	49.0	088	35	000	0.0	180
00:24:30	-8	-113	45	0	0.19	0.17	0.17	000	0.036	-2.4	49.0	088	44	000	0.0	180
00:24:40	-7	-112	46	0	0.18	0.18	0.18	000	0.022	-2.4	49.0	088	33	000	0.0	180
00:24:50	-6	-111	46	0	0.13	0.18	0.18	000	-0.014	-2.2	49.0	345	45	000	0.0	180
00:25:00	-5	-111	46	0	0.07	0.17	0.18	000	-0.089	-1.1	49.0	332	34	000	0.0	180
00:25:10	-4	-110	45	0	0.21	0.16	0.18	000	-0.127	-1.1	99.0	332	30	000	0.0	180
00:25:20	-4	-108	45	0	0.34	0.14	0.17	000	-0.215	-0.4	51.0	269	41	000	0.0	180
00:25:30	-3	-107	46	0	0.31	0.12	0.16	000	-0.246	0.3	99.0	215	40	000	0.0	180
00:25:40	-2	-105	46	0	0.32	0.10	0.14	360	-0.257	1.4	77.0	215	34	000	0.0	180
00:25:50	-2	-103	46	0	0.44	0.09	0.12	360	-0.219	1.7	77.0	215	28	000	0.0	180
00:26:00	-1	-101	46	0	0.40	0.09	0.11	360	-0.127	2.1	99.0	187	38	000	0.0	180
00:26:10	-1	-99	45	0	0.25	0.09	0.09	360	-0.035	1.8	99.0	207	36	000	0.0	180
00:26:20	0	-98	46	0	0.16	0.05	0.06	360	-0.115	3.0	99.0	260	44	000	0.0	180
00:26:30	0	-98	46	0	0.05	0.01	0.03	360	-0.121	4.8	99.0	260	35	000	0.0	180
00:26:40	0	-98	46	0	0.00	-0.02	-0.02	360	-0.010	3.4	99.0	260	41	000	0.0	180
00:26:50	0	-98	46	0	0.02	-0.06	-0.05	360	-0.054	3.9	99.0	260	30	000	0.0	180
00:27:00	-1	-98	45	0	-0.07	-0.10	-0.08	360	-0.075	3.6	99.0	260	39	000	0.0	180
00:27:10	-1	-98	45	0	-0.23	-0.13	-0.12	360	-0.076	3.2	99.0	260	30	000	0.0	180
00:27:20	-2	-100	46	0	-0.25	-0.16	-0.15	360	-0.048	3.6	99.0	260	31	000	0.0	180
00:27:30	-3	-101	46	0	-0.21	-0.14	-0.17	360	0.199	2.5	99.0	099	31	000	0.0	180
00:27:40	-3	-102	46	0	-0.10	-0.10	-0.16	360	0.431	-0.8	99.0	052	33	000	0.0	180
00:27:50	-4	-102	46	0	-0.01	-0.07	-0.14	360	0.450	-4.4	99.0	052	35	000	0.0	180
00:28:00	-5	-102	45	0	-0.12	-0.04	-0.10	000	0.385	-3.9	99.0	125	30	000	0.0	180
00:28:10	-5	-103	45	0	-0.18	-0.01	-0.07	000	0.357	-3.9	99.0	125	50	000	0.0	180
00:28:20	-5	-104	46	0	-0.21	0.02	-0.03	000	0.324	-4.6	99.0	086	40	000	0.0	180
00:28:30	-5	-105	46	0	-0.23	0.04	0.00	000	0.221	-4.5	99.0	036	37	000	0.0	180
00:28:40	-5	-106	46	0	-0.11	0.05	0.04	000	0.063	-4.6	99.0	036	35	000	0.0	180

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:28:50	-4	-106	45	0	0.03	0.07	0.08	000	-0.041	-3.3	99.0	036	40	000	0.0	180
00:29:00	-4	-106	45	0	0.17	0.09	0.10	000	-0.089	-3.4	99.0	036	33	000	0.0	180
00:29:10	-3	-105	46	0	0.20	0.11	0.12	000	-0.069	-3.0	99.0	089	44	000	0.0	180
00:29:20	-3	-104	46	0	0.23	0.15	0.15	000	0.018	-3.4	99.0	089	28	000	0.0	180
00:29:30	-2	-102	46	0	0.36	0.19	0.18	000	0.082	-3.6	99.0	089	34	000	0.0	180
00:29:40	-1	-100	46	0	0.39	0.23	0.21	000	0.133	-4.3	99.0	089	42	000	0.0	180
00:29:50	0	-98	45	0	0.33	0.27	0.24	000	0.178	-5.0	99.0	089	40	000	0.0	180
00:30:00	2	-97	46	0	0.32	0.28	0.26	000	0.101	-5.4	99.0	272	44	000	0.0	180
00:30:10	3	-95	46	0	0.23	0.24	0.27	000	-0.189	-3.9	99.0	216	33	000	0.0	180
00:30:20	4	-95	46	0	0.08	0.20	0.26	000	-0.364	-2.2	99.0	216	41	000	0.0	180
00:30:30	6	-94	46	0	-0.01	0.18	0.25	000	-0.448	-0.4	99.0	216	43	000	0.0	180
00:30:40	7	-95	45	0	-0.12	0.15	0.24	000	-0.611	2.0	99.0	216	35	000	0.0	180
00:30:50	8	-96	45	0	-0.22	0.12	0.22	360	-0.659	3.9	99.0	216	42	000	0.0	180
00:31:00	8	-97	46	0	-0.21	0.10	0.20	360	-0.595	5.6	99.0	176	47	000	0.0	180
00:31:10	9	-98	46	0	-0.12	0.16	0.19	360	-0.192	5.1	99.0	065	35	000	0.0	180
00:31:20	10	-98	46	0	-0.13	0.20	0.18	360	0.136	3.3	99.0	065	44	000	0.0	180
00:31:30	11	-99	45	0	-0.24	0.18	0.16	360	0.133	3.4	99.0	270	39	000	0.0	180
00:31:40	12	-101	45	0	-0.33	0.14	0.14	360	0.034	3.3	99.0	270	37	000	0.0	180
00:31:50	13	-102	46	0	-0.34	0.10	0.11	360	-0.046	3.5	99.0	270	43	000	0.0	180
00:32:00	13	-104	46	0	-0.21	0.06	0.08	360	-0.120	4.6	99.0	270	34	000	0.0	180
00:32:10	13	-105	46	0	-0.20	0.02	0.04	360	-0.114	4.6	99.0	300	28	000	0.0	180
00:32:20	13	-106	46	0	-0.25	0.00	0.00	360	-0.055	4.8	99.0	300	34	000	0.0	180
00:32:30	13	-107	45	0	-0.14	-0.03	-0.03	360	0.012	4.4	99.0	300	39	000	0.0	180
00:32:40	13	-107	45	0	-0.06	-0.06	-0.07	360	0.056	3.7	99.0	300	45	000	0.0	180
00:32:50	13	-107	46	0	0.07	-0.09	-0.09	360	0.016	3.8	99.0	300	34	000	0.0	180
00:33:00	12	-107	46	0	0.21	-0.13	-0.12	360	-0.051	4.2	99.0	300	40	000	0.0	180
00:33:10	11	-105	46	0	0.31	-0.16	-0.15	360	-0.090	4.8	99.0	240	41	000	0.0	180
00:33:20	10	-104	46	0	0.28	-0.19	-0.18	360	-0.091	4.8	99.0	240	41	000	0.0	180
00:33:30	9	-103	45	0	0.17	-0.23	-0.21	360	-0.125	5.6	99.0	240	36	000	0.0	180
00:33:40	8	-102	46	0	0.09	-0.26	-0.24	360	-0.167	6.4	99.0	240	35	000	0.0	180
00:33:50	7	-102	46	0	0.04	-0.28	-0.26	360	-0.112	6.1	50.0	240	28	000	0.0	180
00:34:00	5	-102	46	0	-0.02	-0.28	-0.29	360	0.095	5.8	50.0	240	30	000	0.0	180
00:34:10	4	-102	46	0	-0.02	-0.27	-0.33	360	0.379	3.6	50.0	240	35	000	0.0	180
00:34:20	2	-102	45	0	-0.01	-0.26	-0.35	360	0.551	1.8	50.0	240	31	000	0.0	180
00:34:30	1	-102	45	0	-0.09	-0.26	-0.36	360	0.636	-0.1	50.0	240	36	000	0.0	180
00:34:40	-1	-103	46	0	-0.11	-0.27	-0.36	360	0.616	-2.2	50.0	240	38	000	0.0	180
00:34:50	-3	-103	46	0	-0.09	-0.22	-0.37	000	0.941	-5.6	50.0	240	40	000	0.0	180
00:35:00	-4	-104	46	0	-0.13	-0.09	-0.36	000	1.698	-13.2	50.0	240	26	000	0.0	180
00:35:10	-5	-104	45	0	-0.14	0.07	-0.31	001	2.404	-27.2	50.0	240	46	000	0.0	180
00:35:20	-5	-105	45	0	-0.10	0.22	-0.19	001	2.608	-35.0	50.0	240	35	000	0.0	180
00:35:30	-5	-105	46	0	0.01	0.37	-0.05	002	2.667	-35.0	0.0	240	38	000	0.0	180
00:35:40	-3	-105	46	0	0.08	0.44	0.10	002	2.179	-35.0	0.0	240	32	000	0.0	180

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 29
Start Time: 10:41
Length of run [secs]: 2595

Date: 5 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	40	Direction: 0
Sea State, Significant wave height [m]:..	8	Direction: 180
Current Speed [knots]:.....	1	Direction: 135

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 1.8

Evaluation:

The mating was successful on the third try.

The approach was good up to the buoy, 30 to 40 m from the buoy.

When the ship was brought to approximately a stop short of the buoy on approximately equilibrium heading, the bow fell off to the port having low RPM, and the rudder power was not sufficient to stop the yaw. After about 25 degrees of yaw the captain put on full power briefly and thruster to 090 degrees at full power. This stopped the yaw and started recovering. From that point there was no particular problem as the bow was brought to starboard to close with the buoy. During the final part of this process the autopilot was kept on about 356 degrees, and later adjusted to 357 degrees, and the propeller RPM was kept at 47 throughout. All adjustments were made with the thruster vector.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
10:41:18

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **RUN #29**

Time HH:MM:SS	Position (m)		Port	RPM		Long	Speed (Knots)			Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North		Stbd			Bow	Stern	Heading				Deg	Knots	Deg	Knots
00:20:00	-84	-89	48	0		-0.06	0.27	0.21	358	0.373	-2.4	100.0	118	44	000	1.0
00:20:10	-82	-89	48	0		0.03	0.30	0.26	358	0.256	-2.8	100.0	118	31	000	1.0
00:20:20	-81	-89	48	0		0.02	0.31	0.31	358	0.010	-1.7	100.0	118	38	000	1.0
00:20:30	-79	-89	47	0		0.02	0.32	0.34	358	-0.123	-1.3	76.0	118	34	000	1.0
00:20:40	-78	-89	47	0		0.03	0.34	0.37	358	-0.174	-0.6	76.0	118	33	000	1.0
00:20:50	-76	-89	48	0		0.06	0.34	0.40	358	-0.331	0.5	76.0	118	29	000	1.0
00:21:00	-74	-88	48	0		0.11	0.34	0.41	358	-0.454	1.9	76.0	118	35	000	1.0
00:21:10	-72	-88	47	0		0.03	0.34	0.41	358	-0.425	3.6	76.0	118	40	000	1.0
00:21:20	-70	-88	48	0		0.00	0.35	0.41	358	-0.400	4.6	76.0	118	38	000	1.0
00:21:30	-68	-87	47	0		0.11	0.34	0.40	358	-0.373	5.7	76.0	118	34	000	1.0
00:21:40	-66	-86	48	0		0.18	0.35	0.38	358	-0.206	6.2	76.0	118	42	000	1.0
00:21:50	-64	-86	47	0		0.09	0.38	0.37	358	0.097	5.3	76.0	118	49	000	1.0
00:22:00	-62	-85	48	0		0.06	0.40	0.36	358	0.238	4.3	76.0	118	38	000	1.0
00:22:10	-60	-85	48	0		0.16	0.41	0.36	358	0.319	3.1	76.0	118	45	000	1.0
00:22:20	-58	-84	48	0		0.19	0.41	0.37	358	0.246	2.7	76.0	118	31	000	1.0
00:22:30	-56	-82	47	0		0.22	0.37	0.38	358	-0.069	3.0	76.0	158	31	000	1.0
00:22:40	-55	-81	48	0		0.13	0.32	0.38	358	-0.327	4.4	99.0	161	44	000	1.0
00:22:50	-53	-81	48	0		-0.11	0.33	0.36	358	-0.222	5.2	99.0	161	35	000	1.0
00:23:00	-51	-82	47	0		-0.29	0.37	0.36	358	0.085	4.3	99.0	091	34	000	1.0
00:23:10	-49	-84	47	0		-0.29	0.38	0.36	358	0.075	4.3	99.0	060	41	000	1.0
00:23:20	-47	-85	48	0		-0.29	0.37	0.37	358	0.018	4.5	48.0	060	39	000	1.0
00:23:30	-45	-86	48	0		-0.27	0.37	0.36	358	0.059	3.8	48.0	060	46	000	1.0
00:23:40	-43	-88	47	0		-0.27	0.39	0.36	358	0.175	3.5	100.0	060	41	000	1.0
00:23:50	-41	-89	48	0		-0.28	0.46	0.37	358	0.557	1.5	100.0	034	43	000	1.0
00:24:00	-39	-90	47	0		-0.18	0.47	0.39	358	0.484	-0.1	100.0	034	43	000	1.0
00:24:10	-37	-91	48	0		-0.19	0.46	0.42	358	0.267	-0.7	37.0	094	35	000	1.0
00:24:20	-34	-92	47	0		-0.12	0.45	0.44	358	0.079	-0.8	27.0	058	35	000	1.0
00:24:30	-32	-92	48	0		-0.04	0.42	0.46	358	-0.255	0.1	27.0	058	44	000	1.0
00:24:40	-30	-92	48	0		-0.04	0.36	0.49	358	-0.830	-11.8	27.0	058	33	000	1.0
00:24:50	-27	-92	48	0		-0.10	0.27	0.63	358	-2.269	-24.8	27.0	058	45	000	1.0
00:25:00	-25	-93	47	0		-0.14	0.20	0.74	357	-3.465	-13.7	99.0	058	34	000	1.0
00:25:10	-23	-93	48	0		0.00	0.19	0.79	357	-3.821	-1.5	99.0	058	30	000	1.0
00:25:20	-20	-93	48	0		0.13	0.24	0.76	356	-3.288	7.6	99.0	058	41	000	1.0
00:25:30	-18	-92	47	0		0.12	0.29	0.69	355	-2.501	14.8	99.0	117	40	000	1.0
00:25:40	-15	-91	48	0		0.16	0.30	0.58	355	-1.807	19.8	49.0	117	34	000	1.0
00:25:50	-13	-90	48	0		0.29	0.29	0.46	355	-1.052	22.4	49.0	117	28	000	1.0
00:26:00	-12	-88	48	0		0.30	0.32	0.33	355	-0.061	21.6	49.0	117	38	000	1.0
00:26:10	-10	-87	47	0		0.20	0.30	0.22	355	0.459	19.2	0.0	183	36	000	1.0
00:26:20	-9	-86	48	0		0.09	0.22	0.14	355	0.494	16.3	100.0	183	44	000	1.0
00:26:30	-8	-85	48	0		-0.03	0.19	0.08	355	0.666	11.8	52.0	183	35	000	1.0
00:26:40	-8	-86	48	0		-0.10	0.12	0.05	355	0.481	11.4	75.0	183	41	000	1.0
00:26:50	-7	-86	47	0		-0.09	0.04	0.01	355	0.187	12.3	52.0	183	30	000	1.0
00:27:00	-7	-87	48	0		-0.18	0.00	-0.03	355	0.180	12.9	52.0	183	39	000	1.0
00:27:10	-7	-88	47	0		-0.34	0.08	-0.06	355	0.879	10.0	53.0	091	30	000	1.0
00:27:20	-7	-90	48	0		-0.34	0.19	-0.05	355	1.504	4.0	100.0	062	31	000	1.0
00:27:30	-6	-92	47	0		-0.24	0.20	0.00	356	1.274	-0.6	100.0	062	31	000	1.0
00:27:40	-6	-93	48	0		-0.13	0.18	0.07	356	0.681	-2.9	100.0	091	33	000	1.0
00:27:50	-5	-93	48	0		-0.07	0.10	0.12	356	-0.067	1.6	52.0	091	35	000	1.0
00:28:00	-4	-94	48	0		-0.18	0.12	0.13	356	-0.097	1.7	52.0	090	30	000	1.0
00:28:10	-4	-95	47	0		-0.21	0.14	0.15	356	-0.053	1.9	52.0	062	50	000	1.0
00:28:20	-3	-96	48	0		-0.21	0.09	0.17	356	-0.450	4.4	52.0	062	40	000	1.0
00:28:30	-2	-97	48	0		-0.24	0.08	0.16	356	-0.525	6.2	52.0	062	37	000	1.0
00:28:40	-1	-98	47	0		-0.15	0.09	0.16	356	-0.431	7.6	98.0	047	35	000	1.0
00:28:50	-1	-98	48	0		-0.03	0.08	0.13	356	-0.358	10.1	51.0	090	40	000	1.0
00:29:00	0	-98	48	0		0.06	0.14	0.11	356	0.155	5.5	100.0	090	33	000	1.0
00:29:10	1	-98	48	0		0.06	0.19	0.12	356	0.421	2.7	100.0	119	44	000	1.0
00:29:20	1	-97	47	0		0.07	0.16	0.14	356	0.090	4.4	100.0	119	28	000	1.0
00:29:30	2	-97	48	0		0.17	0.17	0.15	356	0.097	4.0	100.0	119	34	000	1.0
00:29:40	3	-95	48	0		0.17	0.17	0.17	356	0.026	4.3	100.0	147	42	000	1.0
00:29:50	4	-95	48	0		0.07	0.11	0.17	356	-0.378	7.9	100.0	147	40	000	1.0
00:30:00	4	-95	47	0		0.00	0.03	0.13	356	-0.642	16.1	100.0	147	44	000	1.0
00:30:10	4	-95	48	0		-0.11	-0.01	0.06	356	-0.446	13.3	100.0	179	33	000	1.0
00:30:20	5	-96	47	0		-0.24	0.01	0.04	355	-0.143	9.7	100.0	063	41	000	1.0
00:30:30	5	-97	48	0		-0.25	0.03	0.03	355	0.002	9.6	100.0	063	43	000	1.0
00:30:40	5	-98	47	0		-0.29	0.07	0.03	356	0.264	8.0	100.0	043	35	000	1.0
00:30:50	6	-100	48	0		-0.30	0.10	0.03	356	0.442	6.2	100.0	035	42	000	1.0
00:31:00	6	-101	48	0		-0.19	0.11	0.05	356	0.439	4.2	100.0	035	47	000	1.0
00:31:10	6	-102	48	0		-0.06	0.10	0.07	356	0.210	3.1	100.0	105	35	000	1.0
00:31:20	7	-102	47	0		-0.15	0.07	0.07	356	-0.046	6.0	100.0	181	44	000	1.0
00:31:30	7	-103	48	0		-0.24	0.08	0.06	356	0.082	5.3	100.0	357	39	000	1.0
00:31:40	8	-104	48	0		-0.26	0.09	0.07	356	0.113	4.6	100.0	357	37	000	1.0
00:31:50	8	-106	47	0		-0.21	0.07	0.07	356	-0.044	5.3	100.0	357	43	000	1.0
00:32:00	9	-106	48	0		-0.02	0.00	0.06	356	-0.386	14.1	100.0	357	34	000	1.0

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:32:10	9	-106	48	0	0.02	-0.02	-0.01	356	-0.052	10.3	100.0	357	28	000	1.0	135
00:32:20	9	-106	48	0	0.00	0.02	0.00	356	0.070	-2.6	100.0	357	34	000	1.0	135
00:32:30	9	-106	47	0	0.14	0.05	0.01	356	0.212	3.8	100.0	357	39	000	1.0	135
00:32:40	9	-105	48	0	0.25	0.07	0.01	356	0.362	3.4	100.0	027	45	000	1.0	135
00:32:50	9	-103	48	0	0.33	0.11	0.04	356	0.466	1.7	100.0	124	34	000	1.0	135
00:33:00	9	-101	48	0	0.43	-0.01	0.05	356	-0.387	4.4	100.0	263	40	000	1.0	135
00:33:10	9	-99	47	0	0.48	-0.11	0.03	356	-0.876	7.2	100.0	214	41	000	1.0	135
00:33:20	8	-97	48	0	0.43	-0.10	-0.01	356	-0.559	8.9	100.0	214	41	000	1.0	135
00:33:30	8	-95	48	0	0.29	-0.18	-0.06	355	-0.756	12.2	100.0	214	36	000	1.0	135
00:33:40	7	-94	48	0	0.19	-0.27	-0.12	355	-0.946	15.9	100.0	214	35	000	1.0	135
00:33:50	6	-93	47	0	0.11	-0.25	-0.18	355	-0.409	16.1	100.0	149	28	000	1.0	135
00:34:00	5	-93	48	0	0.01	-0.21	-0.22	355	0.111	14.1	100.0	149	30	000	1.0	135
00:34:10	4	-93	48	0	-0.04	-0.18	-0.24	355	0.387	11.5	100.0	149	35	000	1.0	135
00:34:20	3	-93	47	0	-0.05	-0.19	-0.24	355	0.345	11.1	100.0	103	31	000	1.0	135
00:34:30	2	-94	47	0	-0.15	-0.14	-0.23	355	0.610	8.3	100.0	114	36	000	1.0	135
00:34:40	1	-95	48	0	-0.15	-0.08	-0.20	355	0.809	4.4	51.0	083	38	000	1.0	135
00:34:50	0	-96	48	0	-0.14	-0.06	-0.17	356	0.668	2.3	51.0	058	40	000	1.0	135
00:35:00	0	-96	47	0	-0.19	-0.07	-0.13	356	0.393	2.8	51.0	094	26	000	1.0	135
00:35:10	-1	-98	48	0	-0.25	-0.10	-0.10	356	-0.048	4.7	51.0	066	46	000	1.0	135
00:35:20	-1	-99	47	0	-0.26	-0.11	-0.07	356	-0.253	6.1	99.0	066	35	000	1.0	135
00:35:30	-2	-100	48	0	-0.23	-0.13	-0.06	356	-0.430	8.2	100.0	066	38	000	1.0	135
00:35:40	-2	-101	47	0	-0.24	-0.08	-0.05	356	-0.171	8.2	100.0	066	32	000	1.0	135
00:35:50	-2	-103	48	0	-0.29	0.01	-0.04	356	0.303	6.1	100.0	066	34	000	1.0	135
00:36:00	-2	-104	48	0	-0.34	0.09	-0.02	356	0.658	3.3	100.0	066	40	000	1.0	135
00:36:10	-1	-106	48	0	-0.16	0.13	0.03	356	0.635	-0.8	100.0	066	42	000	1.0	135
00:36:20	-1	-106	47	0	0.09	0.08	0.07	356	0.068	1.5	52.0	066	37	000	1.0	135
00:36:30	-1	-105	48	0	0.13	0.07	0.08	356	-0.091	3.5	52.0	066	34	000	1.0	135
00:36:40	0	-104	48	0	0.17	0.06	0.09	356	-0.179	4.0	52.0	066	34	000	1.0	135
00:36:50	0	-104	47	0	0.18	0.05	0.08	356	-0.213	5.2	52.0	066	35	000	1.0	135
00:37:00	0	-103	48	0	0.17	0.07	0.08	356	-0.054	4.3	52.0	066	47	000	1.0	135
00:37:10	1	-102	48	0	0.22	0.01	0.08	356	-0.433	6.7	52.0	066	25	000	1.0	135
00:37:20	0	-100	48	0	0.26	-0.13	0.05	356	-1.164	11.9	52.0	066	46	000	1.0	135
00:37:30	0	-99	47	0	0.22	-0.12	-0.01	355	-0.720	13.9	52.0	066	41	000	1.0	135
00:37:40	0	-98	48	0	0.14	-0.06	-0.06	355	-0.002	11.3	52.0	142	40	000	1.0	135
00:37:50	-1	-98	47	0	0.10	-0.07	-0.09	355	0.112	10.2	73.0	089	46	000	1.0	135
00:38:00	-1	-97	48	0	0.12	-0.04	-0.10	355	0.331	7.3	73.0	089	45	000	1.0	135
00:38:10	-2	-97	47	0	0.10	-0.04	-0.09	355	0.321	6.3	73.0	089	38	000	1.0	135
00:38:20	-2	-96	48	0	0.06	-0.02	-0.08	356	0.365	3.0	73.0	118	40	000	1.0	135
00:38:30	-2	-96	48	0	0.10	0.00	-0.05	356	0.288	4.0	99.0	118	32	000	1.0	135
00:38:40	-2	-95	48	0	0.03	-0.02	-0.03	356	0.036	7.9	99.0	118	34	000	1.0	135
00:38:50	-2	-96	48	0	-0.12	0.01	-0.07	356	0.555	19.0	99.0	118	40	000	1.0	135
00:39:00	-2	-97	48	0	-0.22	0.07	-0.12	356	1.198	15.1	99.0	118	36	000	1.0	135
00:39:10	-2	-98	48	0	-0.32	0.15	-0.13	356	1.763	10.5	99.0	118	41	000	1.0	135
00:39:20	-2	-100	47	0	-0.32	0.19	-0.11	356	1.879	4.5	99.0	065	32	000	1.0	135
00:39:30	-2	-101	47	0	-0.31	0.21	-0.05	357	1.666	0.0	99.0	065	44	000	1.0	135
00:39:40	-1	-103	48	0	-0.26	0.21	0.02	357	1.205	-3.4	99.0	065	49	000	1.0	135
00:39:50	0	-104	48	0	-0.10	0.20	0.10	357	0.650	-5.4	99.0	041	38	000	1.0	135
00:40:00	0	-104	47	0	0.05	0.22	0.16	357	0.367	-5.0	99.0	041	35	000	1.0	135
00:40:10	2	-103	48	0	0.08	0.24	0.22	357	0.093	-3.9	99.0	359	37	000	1.0	135
00:40:20	3	-103	47	0	0.11	0.20	0.26	357	-0.390	-1.1	99.0	359	34	000	1.0	135
00:40:30	4	-102	48	0	0.28	0.13	0.27	357	-0.938	2.1	99.0	182	37	000	1.0	135
00:40:40	5	-100	47	0	0.29	0.08	0.26	357	-1.169	6.3	99.0	182	37	000	1.0	135
00:40:50	5	-99	48	0	0.22	0.04	0.23	357	-1.199	11.0	99.0	182	34	000	1.0	135
00:41:00	6	-98	48	0	0.15	0.01	0.16	356	-0.976	15.8	99.0	182	32	000	1.0	135
00:41:10	6	-97	47	0	-0.04	0.05	0.08	356	-0.158	14.2	99.0	182	39	000	1.0	135
00:41:20	7	-98	48	0	-0.12	0.11	0.04	356	0.388	7.5	99.0	182	33	000	1.0	135
00:41:30	7	-98	48	0	-0.04	0.05	0.04	356	0.066	8.1	99.0	182	34	000	1.0	135
00:41:40	7	-98	48	0	-0.01	0.00	0.00	356	0.002	11.0	99.0	182	36	000	1.0	135
00:41:50	7	-99	47	0	-0.10	0.01	-0.02	356	0.176	7.5	99.0	182	37	000	1.0	135
00:42:00	7	-100	47	0	-0.19	-0.03	-0.04	356	0.042	8.7	99.0	272	28	000	1.0	135
00:42:10	7	-101	48	0	-0.22	-0.06	-0.06	356	0.002	9.0	99.0	272	38	000	1.0	135
00:42:20	6	-102	48	0	-0.24	-0.12	-0.09	356	-0.245	10.6	99.0	272	39	000	1.0	135
00:42:30	6	-103	47	0	-0.36	-0.21	-0.12	356	-0.627	12.6	99.0	272	44	000	1.0	135
00:42:40	5	-106	48	0	-0.43	-0.24	-0.15	356	-0.571	13.8	99.0	272	36	000	1.0	135
00:42:50	4	-108	47	0	-0.44	-0.26	-0.19	356	-0.441	15.1	99.0	272	30	000	1.0	135
00:43:00	3	-110	48	0	-0.49	-0.27	-0.23	356	-0.250	15.7	99.0	272	40	000	1.0	135
00:43:10	2	-113	47	0	-0.48	-0.27	-0.27	356	0.006	15.8	99.0	272	29	000	1.0	135

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 10:41:18

Start Time [hrs:min:sec]: 00:20:00
End Time [hrs:min:sec]: 00:43:15
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 30
Start Time: 11:37
Length of run [secs]: 1530

Date: 5 February 1999

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	40	Direction: 0
Sea State, Significant wave height [m]:..	8	Direction: 180
Current Speed [knots]:.....	1	Direction: 135

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 2.0

Evaluation:

Mating in the first try.

The captain had a fast approach by holding speed larger and backing down at 150 m from the buoy. First he positioned the moon pool a little on the current side and with an equilibrium heading on the autopilot at 357 degrees and RPM 45, then he made all other maneuvers with the thruster vector.

The simulation ran 15 min too long.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
11:37:17

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: .112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run # 30

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North			Long	Bow	Stern					Knots	Deg	Knots	Deg
00:03:20	12	-581	52	0	4.64	0.30	0.13	356	1.115	-27.3	0.0	180	40	000	1.0 135
00:03:30	12	-557	52	0	4.55	0.18	0.35	355	-1.084	-26.7	100.0	180	32	000	1.0 135
00:03:40	11	-534	52	0	4.42	0.16	0.53	355	-2.325	-21.3	100.0	180	41	000	1.0 135
00:03:50	11	-511	52	0	4.29	0.13	0.64	355	-3.204	-12.6	100.0	180	31	000	1.0 135
00:04:00	11	-489	52	0	4.22	0.12	0.65	354	-3.371	-2.4	100.0	180	36	000	1.0 135
00:04:10	11	-468	52	0	4.19	0.16	0.57	354	-2.614	6.9	100.0	180	45	000	1.0 135
00:04:20	10	-446	52	0	4.09	0.30	0.44	353	-0.879	11.5	100.0	180	35	000	1.0 135
00:04:30	10	-425	52	0	4.05	0.38	0.30	353	0.491	11.7	100.0	180	30	000	1.0 135
00:04:40	9	-404	52	0	4.02	0.48	0.19	354	1.864	7.9	100.0	180	27	000	1.0 135
00:04:50	8	-383	48	0	4.06	0.45	0.15	354	1.922	1.7	100.0	180	36	000	1.0 135
00:05:00	8	-363	48	0	4.03	0.35	0.14	354	1.326	-2.6	100.0	180	34	000	1.0 135
00:05:10	7	-342	48	0	3.89	0.32	0.16	354	1.017	-6.5	100.0	180	32	000	1.0 135
00:05:20	6	-322	30	0	3.75	0.25	0.17	354	0.482	-8.6	100.0	180	34	000	1.0 135
00:05:30	5	-303	29	0	3.63	0.22	0.17	355	0.299	-9.7	100.0	180	37	000	1.0 135
00:05:40	4	-285	29	0	3.42	0.18	0.17	355	0.078	-10.2	100.0	180	40	000	1.0 135
00:05:50	4	-268	29	0	3.29	0.17	0.19	355	-0.140	-25.8	100.0	180	43	000	1.0 135
00:06:00	3	-251	29	0	3.15	0.14	0.26	354	-0.799	-35.0	100.0	180	40	000	1.0 135
00:06:10	3	-236	29	0	3.00	0.10	0.34	354	-1.539	-35.0	100.0	180	36	000	1.0 135
00:06:20	2	-220	29	0	2.83	0.08	0.41	354	-2.100	-35.0	100.0	180	34	000	1.0 135
00:06:30	2	-206	28	0	2.68	0.07	0.48	354	-2.605	-35.0	100.0	180	37	000	1.0 135
00:06:40	2	-193	0	0	2.55	0.03	0.51	353	-3.019	-35.0	100.0	180	29	000	1.0 135
00:06:50	2	-180	0	0	2.38	-0.03	0.49	353	-3.270	-35.0	100.0	180	35	000	1.0 135
00:07:00	1	-168	-21	0	2.19	0.05	0.45	352	-2.597	-35.0	100.0	180	42	000	1.0 135
00:07:10	1	-157	-51	0	1.99	0.16	0.40	352	-1.545	-30.6	100.0	180	37	000	1.0 135
00:07:20	1	-147	-61	0	1.82	0.18	0.33	352	-0.940	-27.0	100.0	180	32	000	1.0 135
00:07:30	1	-138	-62	0	1.66	0.16	0.25	351	-0.608	-24.9	100.0	180	49	000	1.0 135
00:07:40	1	-130	-62	0	1.43	0.21	0.17	351	0.239	-24.9	100.0	180	40	000	1.0 135
00:07:50	1	-123	-62	0	1.22	0.18	0.10	351	0.495	-26.3	100.0	180	46	000	1.0 135
00:08:00	0	-118	-62	0	0.92	0.16	0.03	352	0.866	-29.1	100.0	180	38	000	1.0 135
00:08:10	0	-114	-62	0	0.71	0.09	-0.04	352	0.808	-32.2	100.0	180	33	000	1.0 135
00:08:20	-1	-111	-62	0	0.50	-0.02	-0.11	352	0.576	-33.9	100.0	180	43	000	1.0 135
00:08:30	-1	-109	-49	0	0.22	-0.01	-0.19	352	1.128	-35.0	100.0	180	40	000	1.0 135
00:08:40	-2	-108	-17	0	0.01	-0.05	-0.21	352	0.984	-35.0	100.0	180	45	000	1.0 135
00:08:50	-2	-109	46	0	0.00	-0.10	-0.10	352	-0.030	-35.0	0.0	180	36	000	1.0 135
00:09:00	-3	-108	74	0	0.11	-0.35	0.24	352	-3.775	-18.8	0.0	180	36	000	1.0 135
00:09:10	-3	-107	67	0	0.27	-0.48	0.37	351	-5.451	0.2	0.0	180	40	000	1.0 135
00:09:20	-4	-106	44	0	0.26	-0.48	0.29	350	-4.886	19.2	100.0	180	44	000	1.0 135
00:09:30	-5	-105	46	0	0.21	-0.41	0.12	350	-3.314	35.0	100.0	180	26	000	1.0 135
00:09:40	-6	-104	47	0	0.11	-0.33	-0.08	349	-1.596	35.0	100.0	120	46	000	1.0 135
00:09:50	-7	-104	47	0	0.08	-0.17	-0.25	349	0.535	35.0	100.0	091	32	000	1.0 135
00:10:00	-8	-104	48	0	0.12	0.05	-0.41	349	2.913	35.0	100.0	091	36	000	1.0 135
00:10:10	-9	-103	47	0	0.20	0.13	-0.55	350	4.319	35.0	100.0	091	42	000	1.0 135
00:10:20	-10	-102	47	0	0.23	0.26	-0.67	351	5.910	35.0	100.0	091	40	000	1.0 135
00:10:30	-12	-101	47	0	0.22	0.45	-0.77	352	7.801	35.0	100.0	118	44	000	1.0 135
00:10:40	-12	-100	48	0	0.25	0.50	-0.80	353	8.264	18.4	100.0	145	40	000	1.0 135
00:10:50	-13	-99	47	0	0.28	0.39	-0.71	355	6.988	0.5	100.0	145	36	000	1.0 135
00:11:00	-14	-97	48	0	0.24	0.28	-0.53	356	5.182	-15.8	100.0	145	30	000	1.0 135
00:11:10	-15	-96	48	0	0.22	0.16	-0.33	356	3.127	-21.3	100.0	153	38	000	1.0 135
00:11:20	-15	-95	47	0	0.14	0.08	-0.13	357	1.325	-23.6	100.0	153	32	000	1.0 135
00:11:30	-15	-95	48	0	0.14	0.01	0.03	357	-0.145	-13.1	100.0	121	35	000	1.0 135
00:11:40	-15	-94	48	0	0.20	-0.03	0.12	357	-0.954	-6.9	100.0	154	20	000	1.0 135
00:11:50	-15	-93	47	0	0.20	-0.01	0.18	356	-1.156	-2.9	100.0	136	39	000	1.0 135
00:12:00	-14	-92	46	0	0.13	0.00	0.20	356	-1.260	4.2	100.0	136	39	000	1.0 135
00:12:10	-14	-91	47	0	0.08	0.04	0.19	356	-0.925	6.2	100.0	136	39	000	1.0 135
00:12:20	-13	-91	47	0	0.03	0.06	0.17	356	-0.702	7.4	100.0	136	38	000	1.0 135
00:12:30	-13	-91	47	0	0.00	0.08	0.16	356	-0.475	6.9	100.0	150	37	000	1.0 135
00:12:40	-12	-91	46	0	-0.06	0.11	0.15	356	-0.270	5.6	100.0	118	35	000	1.0 135
00:12:50	-11	-91	46	0	-0.06	0.19	0.15	356	0.239	11.8	100.0	118	35	000	1.0 135
00:13:00	-10	-91	47	0	-0.05	0.28	0.09	356	1.166	12.6	100.0	151	39	000	1.0 135
00:13:10	-9	-92	47	0	-0.03	0.32	0.08	356	1.524	6.3	100.0	151	30	000	1.0 135
00:13:20	-8	-92	46	0	-0.02	0.35	0.09	356	1.662	1.9	100.0	151	34	000	1.0 135
00:13:30	-7	-92	46	0	0.03	0.33	0.13	357	1.288	-0.4	100.0	151	38	000	1.0 135
00:13:40	-6	-91	47	0	0.05	0.29	0.18	357	0.727	-0.9	100.0	151	33	000	1.0 135
00:13:50	-5	-91	47	0	-0.04	0.27	0.21	357	0.409	-0.9	100.0	179	35	000	1.0 135
00:14:00	-3	-91	47	0	-0.07	0.25	0.23	357	0.106	0.0	100.0	179	45	000	1.0 135
00:14:10	-2	-92	46	0	-0.03	0.21	0.25	357	-0.222	1.7	100.0	179	36	000	1.0 135
00:14:20	-1	-92	45	0	-0.05	0.18	0.25	357	-0.445	4.0	100.0	179	34	000	1.0 135
00:14:30	0	-92	45	0	-0.05	0.17	0.24	357	-0.434	5.3	100.0	179	35	000	1.0 135
00:14:40	1	-92	46	0	-0.11	0.20	0.23	357	-0.181	4.9	100.0	179	39	000	1.0 135
00:14:50	2	-93	46	0	-0.14	0.18	0.22	357	-0.215	5.5	77.0	179	46	000	1.0 135
00:15:00	3	-93	46	0	-0.15	0.13	0.20	357	-0.464	8.1	77.0	179	39	000	1.0 135
00:15:10	4	-94	46	0	-0.19	0.13	0.19	357	-0.406	0.4	77.0	179	39	000	1.0 135
00:15:20	5	-95	46	0	-0.26	0.07	0.24	356	-1.072	-4.9	52.0	179	43	000	1.0 135

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current		
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Knots	Deg	Knots	Deg
00:15:30	6	-97	45	0	-0.29	0.06	0.28	356	-1.398	-0.3	0.0	129	36	000	1.0	135
00:15:40	7	-98	45	0	-0.28	0.05	0.28	356	-1.479	4.7	48.0	000	51	000	1.0	135
00:15:50	8	-99	46	0	-0.19	0.09	0.26	356	-1.079	7.8	48.0	000	34	000	1.0	135
00:16:00	9	-100	46	0	-0.12	0.10	0.22	356	-0.772	10.2	48.0	000	30	000	1.0	135
00:16:10	10	-101	46	0	-0.06	0.13	0.18	356	-0.289	9.4	48.0	000	39	000	1.0	135
00:16:20	10	-101	46	0	-0.01	0.16	0.15	356	0.049	7.5	48.0	000	37	000	1.0	135
00:16:30	11	-100	46	0	0.07	0.14	0.13	356	0.044	7.5	48.0	000	34	000	1.0	135
00:16:40	12	-100	45	0	0.08	0.13	0.11	356	0.104	6.5	48.0	000	46	000	1.0	135
00:16:50	12	-99	46	0	0.12	0.10	0.10	356	0.047	6.9	48.0	000	40	000	1.0	135
00:17:00	13	-99	46	0	0.23	0.08	0.08	356	0.018	7.2	48.0	000	43	000	1.0	135
00:17:10	13	-97	46	0	0.25	0.09	0.06	356	0.139	6.1	48.0	000	43	000	1.0	135
00:17:20	13	-96	46	0	0.28	0.08	0.06	356	0.172	5.5	48.0	000	36	000	1.0	135
00:17:30	14	-94	46	0	0.37	0.08	0.05	356	0.173	5.1	48.0	000	47	000	1.0	135
00:17:40	14	-92	45	0	0.43	0.03	0.05	356	-0.104	5.9	48.0	000	31	000	1.0	135
00:17:50	14	-90	45	0	0.45	-0.03	0.04	356	-0.425	7.8	48.0	000	38	000	1.0	135
00:18:00	13	-88	46	0	0.38	-0.02	0.02	356	-0.205	8.5	48.0	000	27	000	1.0	135
00:18:10	13	-86	46	0	0.37	0.02	0.00	356	0.104	7.5	48.0	000	33	000	1.0	135

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

~~00:07:50~~

00:07:50

00:07:20

00:06:50

00:06:20

00:05:50

00:05:20

00:04:50

00:04:20

00:03:50

Start Time [hrs:min:sec]: 00:03:20

End Time [hrs:min:sec]: 00:18:20

00:0 Delta Plot Time [sec]: 30

East-West Scale [m]: 926.

East-West Scale [Nm]: 0.5000

Date: 05-Feb-99 Time: 11:37:17

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 31

Date: 5 February 1999

Start Time: 13:18

Length of run [secs]: 4566

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	40	Direction: 0
Sea State, Significant wave height [m]:..	8	Direction: 180
Current Speed [knots]:.....	1	Direction: 90

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 1.9

Evaluation:

The approach and initial positioning near the buoy was no problem. The same applies to get into the camera view. It took many cycles of ship motion to get small waves when the buoy was near the center of the moon pool.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
13:18:37

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: Run # 31

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Gill Deg	Wind		Current	
	East	North			Long	Bow	Stern						Knots	Deg	Knots	Deg
00:41:40	10	-102	45	0	0.34	-0.14	-0.14	354	-0.046	24.9	53.0	000	36	000	1.0	090
00:41:50	9	-100	45	0	0.29	-0.07	-0.17	354	0.660	21.8	99.0	091	37	000	1.0	090
00:42:00	8	-99	45	0	0.21	-0.02	-0.17	354	0.952	16.6	99.0	091	28	000	1.0	090
00:42:10	8	-98	44	0	0.14	0.04	-0.13	354	1.059	10.3	99.0	089	38	000	1.0	090
00:42:20	7	-98	44	0	0.11	0.02	-0.07	354	0.559	9.8	99.0	089	39	000	1.0	090
00:42:30	7	-97	44	0	-0.02	-0.04	-0.03	354	-0.094	17.8	99.0	089	44	000	1.0	090
00:42:40	7	-98	44	0	-0.11	0.01	-0.04	354	0.289	12.8	99.0	063	36	000	1.0	090
00:42:50	7	-98	45	0	-0.10	0.04	0.00	354	0.265	11.5	99.0	063	30	000	1.0	090
00:43:00	7	-99	45	0	-0.14	0.14	-0.07	354	1.353	19.3	99.0	063	40	000	1.0	090
00:43:10	8	-100	45	0	-0.13	0.25	-0.12	355	2.305	6.5	99.0	088	29	000	1.0	090
00:43:20	8	-100	45	0	-0.14	0.34	-0.11	355	2.832	-1.5	99.0	058	40	000	1.0	090
00:43:30	9	-101	45	0	-0.04	0.40	-0.03	356	2.691	-8.4	99.0	058	30	000	1.0	090
00:43:40	10	-100	45	0	0.11	0.42	0.11	356	1.931	-7.1	99.0	058	29	000	1.0	090
00:43:50	11	-100	44	0	0.16	0.33	0.21	356	0.774	-5.9	99.0	273	37	000	1.0	090
00:44:00	13	-99	44	0	0.17	0.18	0.28	356	-0.638	-0.8	99.0	227	49	000	1.0	090
00:44:10	14	-98	44	0	0.18	0.07	0.30	356	-1.510	6.8	99.0	227	34	000	1.0	090
00:44:20	15	-97	45	0	0.13	0.05	0.29	356	-1.560	13.4	99.0	227	49	000	1.0	090
00:44:30	15	-96	45	0	-0.02	0.04	0.25	355	-1.348	20.0	99.0	227	40	000	1.0	090
00:44:40	16	-97	45	0	-0.06	-0.03	0.19	355	-1.360	24.1	99.0	227	39	000	1.0	090
00:44:50	16	-97	45	0	-0.04	-0.08	0.13	355	-1.319	30.4	99.0	227	41	000	1.0	090
00:45:00	16	-97	45	0	-0.06	-0.09	0.07	355	-1.036	24.2	99.0	227	33	000	1.0	090
00:45:10	16	-97	45	0	0.01	-0.13	0.01	355	-0.841	22.5	99.0	227	44	000	1.0	090
00:45:20	16	-97	44	0	0.01	-0.18	-0.02	355	-1.011	20.4	99.0	292	32	000	1.0	090
00:45:30	15	-97	44	0	-0.11	-0.15	-0.05	354	-0.624	16.6	99.0	292	37	000	1.0	090
00:45:40	15	-98	44	0	-0.10	-0.12	-0.12	354	0.030	11.6	99.0	292	37	000	1.0	090
00:45:50	14	-99	45	0	-0.01	-0.28	-0.11	354	-1.132	20.3	99.0	292	42	000	1.0	090
00:46:00	13	-99	45	0	-0.03	-0.35	-0.12	354	-1.473	24.8	52.0	292	41	000	1.0	090
00:46:10	12	-99	45	0	-0.16	-0.38	-0.17	354	-1.356	27.0	52.0	292	49	000	1.0	090
00:46:20	10	-101	45	0	-0.36	-0.31	-0.28	354	-0.147	25.2	52.0	091	28	000	1.0	090
00:46:30	9	-103	45	0	-0.43	-0.08	-0.36	354	1.733	18.0	99.0	091	40	000	1.0	090
00:46:40	8	-105	45	0	-0.43	-0.02	-0.38	354	2.340	9.9	52.0	091	44	000	1.0	090
00:46:50	8	-108	45	0	-0.43	0.04	-0.37	355	2.614	1.7	99.0	041	40	000	1.0	090
00:47:00	7	-110	44	0	-0.33	0.09	-0.32	355	2.579	-8.0	99.0	000	39	000	1.0	090
00:47:10	7	-111	44	0	-0.24	0.09	-0.23	355	2.026	-16.1	99.0	036	36	000	1.0	090
00:47:20	7	-112	44	0	-0.14	0.11	-0.10	356	1.357	-23.5	99.0	036	40	000	1.0	090
00:47:30	7	-113	45	0	-0.07	0.07	0.05	356	0.109	-17.5	99.0	000	37	000	1.0	090
00:47:40	7	-113	45	0	-0.06	-0.03	0.18	356	-1.376	1.5	99.0	000	41	000	1.0	090
00:47:50	8	-113	45	0	0.03	-0.05	0.20	355	-1.600	17.3	99.0	000	33	000	1.0	090
00:48:00	8	-113	45	0	0.09	-0.02	0.20	355	-1.412	10.3	99.0	000	32	000	1.0	090
00:48:10	8	-112	45	0	0.15	-0.06	0.21	355	-1.696	13.6	99.0	000	32	000	1.0	090
00:48:20	9	-111	45	0	0.26	-0.15	0.19	355	-2.194	17.5	74.0	000	35	000	1.0	090
00:48:30	8	-109	45	0	0.31	-0.16	0.15	354	-1.966	21.7	49.0	000	32	000	1.0	090
00:48:40	8	-108	44	0	0.27	-0.03	0.09	354	-0.801	21.5	27.0	000	39	000	1.0	090
00:48:50	8	-107	44	0	0.30	0.02	0.04	354	-0.156	20.3	52.0	000	41	000	1.0	090
00:49:00	8	-105	45	0	0.39	-0.01	0.01	354	-0.101	20.0	27.0	000	39	000	1.0	090
00:49:10	8	-103	45	0	0.36	-0.05	-0.03	354	-0.136	20.7	27.0	033	33	000	1.0	090
00:49:20	7	-101	45	0	0.37	-0.10	-0.05	354	-0.310	21.8	99.0	086	39	000	1.0	090
00:49:30	7	-99	45	0	0.37	-0.12	-0.08	354	-0.277	22.8	99.0	121	42	000	1.0	090
00:49:40	6	-98	45	0	0.18	-0.10	-0.10	354	-0.023	22.7	99.0	121	30	000	1.0	090
00:49:50	6	-97	45	0	-0.06	-0.03	-0.09	354	0.424	15.2	99.0	090	28	000	1.0	090
00:50:00	5	-98	45	0	-0.11	-0.01	-0.10	354	0.599	14.7	99.0	062	32	000	1.0	090
00:50:10	5	-99	44	0	-0.08	0.00	-0.08	354	0.515	11.5	99.0	062	26	000	1.0	090
00:50:20	5	-99	44	0	0.01	0.01	0.01	354	0.031	-0.9	99.0	062	45	000	1.0	090
00:50:30	5	-99	44	0	0.00	0.01	0.06	354	-0.321	18.1	99.0	062	36	000	1.0	090
00:50:40	6	-99	45	0	-0.11	0.17	0.05	354	0.755	12.3	99.0	091	33	000	1.0	090
00:50:50	6	-99	45	0	-0.07	0.29	0.06	354	1.475	4.3	99.0	091	40	000	1.0	090
00:51:00	7	-99	45	0	-0.02	0.31	0.13	354	1.103	3.6	99.0	059	41	000	1.0	090
00:51:10	9	-99	45	0	0.06	0.30	0.19	355	0.690	4.0	99.0	059	41	000	1.0	090
00:51:20	10	-99	45	0	0.10	0.23	0.25	355	-0.096	6.5	99.0	059	38	000	1.0	090
00:51:30	11	-98	45	0	0.08	0.20	0.27	355	-0.494	9.7	99.0	059	36	000	1.0	090
00:51:40	12	-97	44	0	0.10	0.21	0.27	355	-0.374	10.1	99.0	263	39	000	1.0	090
00:51:50	13	-97	44	0	0.07	0.14	0.25	354	-0.698	13.4	99.0	263	38	000	1.0	090
00:52:00	14	-96	44	0	0.10	0.03	0.21	354	-1.126	21.4	99.0	238	32	000	1.0	090
00:52:10	15	-96	45	0	0.10	0.04	0.14	354	-0.650	21.3	99.0	220	51	000	1.0	090
00:52:20	15	-95	45	0	0.08	0.08	0.10	354	-0.099	17.9	99.0	220	32	000	1.0	090
00:52:30	15	-95	45	0	0.15	0.03	0.07	354	-0.222	18.5	99.0	220	43	000	1.0	090
00:52:40	15	-94	45	0	0.22	-0.08	0.04	354	-0.736	22.3	99.0	205	36	000	1.0	090
00:52:50	15	-93	45	0	0.12	-0.13	-0.02	354	-0.693	26.5	99.0	205	33	000	1.0	090
00:53:00	14	-93	45	0	-0.04	-0.13	-0.08	354	-0.324	25.6	99.0	221	41	000	1.0	090
00:53:10	14	-93	44	0	-0.10	-0.18	-0.11	354	-0.387	25.7	99.0	210	46	000	1.0	090
00:53:20	13	-94	44	0	-0.22	-0.18	-0.22	354	0.268	22.6	99.0	210	36	000	1.0	090
00:53:30	12	-96	44	0	-0.36	-0.26	-0.31	354	0.351	21.6	99.0	261	37	000	1.0	090
00:53:40	11	-98	44	0	-0.36	-0.32	-0.39	354	0.497	20.2	99.0	323	46	000	1.0	090

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North			Long	Bow	Stern				Deg	%	Deg	Knots	Deg	Knots
00:53:50	9	-100	45	0	-0.35	-0.26	-0.45	354	1.218	15.9	99.0	019	45	000	1.0	090
00:54:00	7	-102	45	0	-0.41	-0.10	-0.48	354	2.369	8.0	50.0	019	47	000	1.0	090
00:54:10	6	-104	45	0	-0.45	0.01	-0.45	355	2.897	-1.6	96.0	359	31	000	1.0	090
00:54:20	5	-107	45	0	-0.42	0.00	-0.38	355	2.414	-9.1	100.0	037	41	000	1.0	090
00:54:30	5	-109	45	0	-0.30	0.03	-0.27	356	1.856	-15.8	100.0	037	29	000	1.0	090
00:54:40	4	-110	45	0	-0.15	0.00	-0.13	356	0.836	-19.8	100.0	056	38	000	1.0	090
00:54:50	4	-111	44	0	-0.20	-0.01	-0.02	356	0.027	-14.9	100.0	039	33	000	1.0	090
00:55:00	4	-112	44	0	-0.26	0.01	0.07	356	-0.440	-12.1	100.0	039	35	000	1.0	090
00:55:10	5	-113	44	0	-0.25	-0.01	0.15	356	-1.005	-7.3	100.0	021	35	000	1.0	090
00:55:20	5	-114	42	0	-0.21	0.02	0.18	355	-1.051	-3.2	100.0	021	41	000	1.0	090
00:55:30	6	-115	42	0	-0.07	0.03	0.21	355	-1.125	4.0	100.0	021	40	000	1.0	090
00:55:40	7	-115	42	0	0.04	-0.04	0.22	355	-1.671	18.7	100.0	021	37	000	1.0	090
00:55:50	7	-115	43	0	0.11	0.00	0.21	355	-1.307	14.1	100.0	000	44	000	1.0	090
00:56:00	8	-114	44	0	0.17	0.09	0.20	355	-0.725	10.1	100.0	000	38	000	1.0	090
00:56:10	8	-112	44	0	0.30	0.05	0.20	355	-0.945	11.9	50.0	000	29	000	1.0	090
00:56:20	9	-111	45	0	0.42	0.01	0.19	354	-1.141	14.9	50.0	152	30	000	1.0	090
00:56:30	9	-108	45	0	0.38	-0.01	0.16	354	-1.078	18.5	50.0	152	39	000	1.0	090
00:56:40	9	-107	45	0	0.27	-0.04	0.11	354	-0.969	22.7	50.0	152	31	000	1.0	090
00:56:50	9	-105	45	0	0.29	-0.09	0.06	354	-0.965	25.3	50.0	045	38	000	1.0	090
00:57:00	8	-104	45	0	0.27	-0.17	0.00	354	-1.043	28.5	50.0	133	30	000	1.0	090
00:57:10	8	-103	44	0	0.09	-0.16	-0.07	354	-0.572	31.6	50.0	133	31	000	1.0	090
00:57:20	7	-103	44	0	-0.03	-0.14	-0.13	353	-0.032	28.0	50.0	133	41	000	1.0	090
00:57:30	7	-103	44	0	-0.09	-0.04	-0.16	354	0.731	20.7	50.0	133	37	000	1.0	090
00:57:40	6	-104	45	0	-0.10	0.03	-0.13	354	1.003	13.6	76.0	063	35	000	1.0	090
00:57:50	6	-104	45	0	-0.04	0.01	-0.07	354	0.503	9.0	100.0	063	32	000	1.0	090
00:58:00	6	-104	45	0	0.01	-0.01	-0.02	354	0.055	17.3	100.0	063	33	000	1.0	090
00:58:10	6	-104	45	0	0.00	0.02	0.00	354	0.091	10.1	100.0	035	45	000	1.0	090
00:58:20	6	-104	45	0	-0.03	0.14	0.03	354	0.680	11.0	100.0	058	35	000	1.0	090
00:58:30	7	-104	44	0	-0.07	0.18	0.07	354	0.709	11.6	100.0	058	39	000	1.0	090
00:58:40	7	-105	44	0	-0.13	0.17	0.07	354	0.668	11.4	100.0	037	44	000	1.0	090
00:58:50	8	-105	44	0	-0.01	0.12	0.09	354	0.186	11.8	100.0	037	34	000	1.0	090
00:59:00	9	-105	45	0	0.08	0.11	0.10	354	0.055	13.6	100.0	037	34	000	1.0	090
00:59:10	9	-105	45	0	0.08	0.20	0.12	354	0.486	9.7	100.0	037	41	000	1.0	090
00:59:20	10	-104	45	0	0.16	0.21	0.14	354	0.429	9.1	100.0	325	30	000	1.0	090
00:59:30	11	-103	45	0	0.18	0.18	0.14	354	0.238	9.5	100.0	290	40	000	1.0	090
00:59:40	12	-102	44	0	0.29	0.20	0.14	354	0.386	8.2	100.0	273	35	000	1.0	090
00:59:50	12	-100	44	0	0.45	0.09	0.14	354	-0.296	9.7	100.0	227	33	000	1.0	090
01:00:00	12	-97	44	0	0.50	-0.06	0.13	354	-1.197	14.0	100.0	227	46	000	1.0	090
01:00:10	12	-95	45	0	0.40	-0.08	0.09	354	-1.065	18.3	100.0	207	45	000	1.0	090
01:00:20	12	-93	45	0	0.20	-0.13	0.04	354	-1.053	23.9	100.0	186	51	000	1.0	090
01:00:30	11	-93	45	0	0.15	-0.20	-0.03	354	-1.088	28.3	100.0	237	35	000	1.0	090
01:00:40	11	-92	45	0	0.12	-0.24	-0.10	354	-0.896	29.2	100.0	237	40	000	1.0	090
01:00:50	9	-92	44	0	-0.03	-0.31	-0.17	353	-0.913	31.5	100.0	237	41	000	1.0	090
01:01:00	8	-92	44	0	-0.10	-0.32	-0.23	353	-0.588	31.7	100.0	327	43	000	1.0	090
01:01:10	7	-93	44	0	-0.01	-0.28	-0.27	353	-0.038	30.6	100.0	000	29	000	1.0	090
01:01:20	5	-93	45	0	0.02	-0.18	-0.29	353	0.711	26.4	100.0	058	40	000	1.0	090
01:01:30	4	-93	45	0	0.00	-0.11	-0.28	354	1.065	20.6	100.0	087	31	000	1.0	090
01:01:40	3	-93	45	0	-0.07	-0.07	-0.24	354	1.097	15.8	100.0	138	39	000	1.0	090
01:01:50	3	-94	45	0	-0.19	0.05	-0.25	354	1.904	9.0	100.0	138	43	000	1.0	090
01:02:00	3	-95	45	0	-0.24	0.13	-0.30	354	2.744	17.9	100.0	138	39	000	1.0	090
01:02:10	2	-97	44	0	-0.30	0.16	-0.33	355	3.096	9.5	100.0	138	40	000	1.0	090
01:02:20	2	-98	44	0	-0.38	0.13	-0.31	355	2.806	3.8	100.0	093	37	000	1.0	090
01:02:30	2	-100	44	0	-0.44	0.17	-0.27	356	2.780	-2.9	100.0	039	42	000	1.0	090
01:02:40	2	-103	45	0	-0.44	0.25	-0.20	356	2.858	-12.1	100.0	023	28	000	1.0	090
01:02:50	2	-105	45	0	-0.41	0.28	-0.09	357	2.336	-18.9	100.0	023	44	000	1.0	090
01:03:00	3	-107	45	0	-0.28	0.24	0.05	357	1.204	-22.6	100.0	014	37	000	1.0	090
01:03:10	4	-108	45	0	-0.06	0.18	0.18	357	-0.006	-19.8	100.0	043	36	000	1.0	090
01:03:20	5	-108	45	0	0.02	0.14	0.33	357	-1.207	-11.7	100.0	029	30	000	1.0	090
01:03:30	6	-107	44	0	0.16	0.13	0.44	357	-1.955	-5.8	100.0	029	38	000	1.0	090
01:03:40	8	-106	44	0	0.21	0.08	0.49	356	-2.632	2.5	74.0	302	36	000	1.0	090
01:03:50	9	-105	44	0	0.13	0.04	0.48	356	-2.780	13.6	74.0	302	38	000	1.0	090
01:04:00	10	-104	45	0	0.13	0.00	0.42	355	-2.630	22.5	99.0	274	28	000	1.0	090
01:04:10	11	-103	45	0	0.21	-0.12	0.31	355	-2.747	32.4	99.0	274	29	000	1.0	090
01:04:20	11	-102	45	0	0.22	-0.14	0.18	355	-2.032	35.0	99.0	274	33	000	1.0	090
01:04:30	11	-101	45	0	0.09	-0.12	0.04	354	-1.055	35.0	99.0	274	34	000	1.0	090
01:04:40	11	-101	45	0	-0.03	-0.15	-0.07	354	-0.561	35.0	99.0	274	46	000	1.0	090
01:04:50	10	-101	44	0	-0.01	-0.09	-0.16	354	0.410	29.6	99.0	274	29	000	1.0	090
01:05:00	9	-101	44	0	0.04	-0.09	-0.21	354	0.748	25.7	99.0	274	39	000	1.0	090
01:05:10	8	-101	44	0	-0.03	-0.09	-0.23	354	0.840	23.2	99.0	042	45	000	1.0	090
01:05:20	8	-102	45	0	0.00	-0.10	-0.22	355	0.757	20.9	99.0	000	35	000	1.0	090
01:05:30	7	-102	45	0	-0.02	-0.11	-0.21	355	0.636	20.2	99.0	000	36	000	1.0	090
01:05:40	6	-102	45	0	-0.05	-0.11	-0.20	355	0.591	18.3	99.0	012	38	000	1.0	090
01:05:50	5	-102	45	0	-0.05	-0.11	-0.18	355	0.419	17.6	99.0	072	28	000	1.0	090
01:06:00	5	-103	44	0	-0.18	-0.03	-0.20	355	1.106	13.0	99.0	090	34	000	1.0	090
01:06:10	4	-104	44	0	-0.22	0.07	-0.22	355	1.875	5.3	99.0	032	32	000	1.0	090
01:06:20	4	-105	44	0	-0.16	0.16	-0.20	356	2.242	-7.8	99.0	044	36	000	1.0	090
01:06:30	4	-106	44	0	-0.04	0.15	-0.06	356	1.338	-24.8	99.0	044	44	000	1.0	090
01:06:40	5	-105	45	0	0.08	0.06	0.12	356	-0.386	-5.8	99.0	044	39	000	1.0	090
01:06:50	5	-105	45	0	0.14	0.10	0.19	356	-0.532	6.0	99.0	088	41	000	1.0	090
01:07:00	6	-104	45	0	0.14	0.21	0.23	356	-0.103	4.4	99.0	060	40	000	1.0	090
01:07:10	7	-103	45	0	0.17	0.27	0.28	356	-0.032	4.0	84.0	089	39	000		

Time HH:MM:SS	Position (m)		RPM Port	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind Knots	Wind Deg	Current	
	East	North		Stbd	Long	Bow				%	Deg			Knots	Deg
01:07:40	10	-98	44	0	0.28	0.00	0.25	355	-1.640	19.3	98.0	271	33	000	1.0 090
01:07:50	10	-97	45	0	0.29	-0.05	0.18	355	-1.465	23.7	98.0	243	41	000	1.0 090
01:08:00	11	-96	45	0	0.18	-0.05	0.10	355	-0.909	27.3	98.0	243	41	000	1.0 090
01:08:10	11	-95	45	0	0.05	0.00	0.01	355	-0.109	25.9	98.0	220	40	000	1.0 090
01:08:20	11	-95	45	0	0.06	-0.07	-0.04	355	-0.218	26.3	98.0	249	41	000	1.0 090
01:08:30	10	-94	44	0	0.13	-0.14	-0.10	355	-0.294	26.3	98.0	249	37	000	1.0 090
01:08:40	9	-94	44	0	0.18	-0.09	-0.15	355	0.327	22.4	98.0	297	36	000	1.0 090
01:08:50	9	-93	44	0	0.08	-0.13	-0.17	355	0.223	21.5	98.0	201	42	000	1.0 090
01:09:00	8	-93	45	0	-0.10	-0.14	-0.18	355	0.277	21.0	98.0	177	36	000	1.0 090
01:09:10	7	-94	45	0	-0.20	-0.05	-0.25	355	1.301	14.1	98.0	138	40	000	1.0 090
01:09:20	6	-95	45	0	-0.29	-0.01	-0.28	355	1.705	9.6	98.0	138	35	000	1.0 090
01:09:30	6	-97	45	0	-0.36	0.05	-0.27	355	2.007	3.8	98.0	095	46	000	1.0 090
01:09:40	5	-99	45	0	-0.42	0.06	-0.23	356	1.847	-1.2	98.0	065	33	000	1.0 090
01:09:50	5	-101	44	0	-0.51	0.10	-0.17	356	1.708	-5.1	98.0	065	44	000	1.0 090
01:10:00	5	-104	44	0	-0.47	0.16	-0.10	356	1.638	-10.2	98.0	041	41	000	1.0 090
01:10:10	6	-106	44	0	-0.40	0.19	-0.01	357	1.272	-14.4	98.0	030	41	000	1.0 090
01:10:20	7	-108	45	0	-0.32	0.19	0.09	357	0.613	-15.6	98.0	030	30	000	1.0 090
01:10:30	8	-109	45	0	-0.22	0.17	0.18	357	-0.089	-14.3	98.0	296	27	000	1.0 090
01:10:40	9	-110	45	0	-0.16	0.13	0.23	357	-0.682	-10.2	98.0	296	37	000	1.0 090
01:10:50	9	-111	45	0	-0.01	0.04	0.28	357	-1.469	0.2	98.0	314	31	000	1.0 090
01:11:00	10	-110	45	0	0.11	-0.06	0.29	356	-2.256	12.6	98.0	303	36	000	1.0 090
01:11:10	11	-110	44	0	0.10	-0.09	0.26	356	-2.189	22.5	98.0	304	33	000	1.0 090
01:11:20	11	-110	44	0	-0.04	-0.04	0.15	356	-1.198	30.1	98.0	304	35	000	1.0 090
01:11:30	11	-110	44	0	0.02	-0.03	0.06	355	-0.578	35.0	98.0	326	37	000	1.0 090
01:11:40	11	-109	45	0	0.17	-0.06	0.00	355	-0.342	16.9	98.0	326	52	000	1.0 090
01:11:50	11	-108	45	0	0.20	-0.13	-0.01	355	-0.746	17.1	98.0	326	28	000	1.0 090
01:12:00	10	-107	45	0	0.28	-0.17	-0.03	355	-0.904	19.3	98.0	326	38	000	1.0 090
01:12:10	10	-106	45	0	0.30	-0.14	-0.06	355	-0.511	20.0	51.0	089	33	000	1.0 090
01:12:20	9	-104	45	0	0.23	0.01	-0.06	355	0.434	15.9	100.0	089	32	000	1.0 090
01:12:30	9	-103	44	0	0.20	0.06	-0.04	355	0.633	12.6	100.0	089	35	000	1.0 090
01:12:40	9	-102	44	0	0.21	-0.02	0.00	355	-0.131	15.8	100.0	089	31	000	1.0 090
01:12:50	9	-101	45	0	0.16	-0.02	0.00	355	-0.161	17.5	100.0	089	37	000	1.0 090
01:13:00	9	-100	45	0	0.10	0.02	0.02	355	0.045	15.8	100.0	089	36	000	1.0 090
01:13:10	9	-100	45	0	-0.05	0.04	0.03	355	0.062	15.2	100.0	089	33	000	1.0 090
01:13:20	9	-101	45	0	-0.19	0.15	0.00	355	0.979	9.0	100.0	089	39	000	1.0 090
01:13:30	10	-102	45	0	-0.23	0.22	-0.01	355	1.449	4.0	100.0	089	42	000	1.0 090
01:13:40	10	-103	44	0	-0.24	0.31	0.00	356	1.934	-1.8	100.0	089	35	000	1.0 090
01:13:50	12	-104	44	0	-0.13	0.38	0.05	356	2.100	-10.3	100.0	089	45	000	1.0 090
01:14:00	13	-104	44	0	-0.09	0.39	0.13	356	1.598	-13.1	100.0	089	29	000	1.0 090
01:14:10	14	-105	45	0	-0.09	0.40	0.22	357	1.141	-14.3	100.0	089	37	000	1.0 090
01:14:20	16	-105	45	0	-0.08	0.43	0.31	357	0.764	-15.4	100.0	089	49	000	1.0 090
01:14:30	18	-106	45	0	-0.07	0.42	0.40	357	0.123	-15.0	100.0	089	41	000	1.0 090
01:14:40	20	-106	45	0	0.00	0.36	0.52	357	-1.029	-10.2	100.0	089	37	000	1.0 090
01:14:50	23	-105	45	0	-0.04	0.33	0.61	356	-1.768	-4.6	100.0	089	38	000	1.0 090
01:15:00	25	-106	44	0	-0.10	0.33	0.64	356	-1.951	1.3	100.0	089	39	000	1.0 090
01:15:10	28	-106	44	0	-0.01	0.32	0.65	356	-2.111	8.0	100.0	089	41	000	1.0 090
01:15:20	30	-105	44	0	0.10	0.32	0.63	355	-1.972	13.8	100.0	089	36	000	1.0 090
01:15:30	33	-105	45	0	0.05	0.39	0.59	355	-1.253	17.1	100.0	089	36	000	1.0 090
01:15:40	35	-104	45	0	0.00	0.46	0.54	355	-0.533	18.2	100.0	089	34	000	1.0 090
01:15:50	38	-104	45	0	0.10	0.50	0.49	355	0.062	17.3	100.0	089	40	000	1.0 090
01:16:00	40	-103	45	0	0.16	0.53	0.46	355	0.461	15.8	100.0	089	43	000	1.0 090

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 13:18:37

Start Time [hrs:min:sec]: 00:41:40
End Time [hrs:min:sec]: 01:16:06
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 32

Date: 5 February 1999

Start Time: 14:37

Length of run [secs]: 2760

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 40 Direction: 0

Sea State, Significant wave height [m]:.. 8 Direction: 180

Current Speed [knots]:..... 1 Direction: 90

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 1.5

Evaluation:

This run was very similar to run # 31.

The captain had to wait for a long time for small waves to occur while the buoy was near the center of the moon pool.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
14:37:00

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #32**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern					Deg	Knots	Deg	Knots
00:25:00	13	-115	43	0	-0.21	0.04	0.29	356	-1.559	9.2	99.0	000	34	000	1.0
00:25:10	14	-116	43	0	-0.05	0.06	0.24	356	-1.130	14.6	99.0	340	30	000	1.0
00:25:20	15	-115	43	0	0.09	0.08	0.21	355	-0.879	15.1	99.0	331	41	000	1.0
00:25:30	16	-115	43	0	0.12	0.06	0.19	355	-0.820	17.5	99.0	306	40	000	1.0
00:25:40	16	-114	43	0	0.20	0.00	0.14	355	-0.944	20.0	99.0	306	34	000	1.0
00:25:50	16	-113	43	0	0.34	-0.06	0.10	355	-1.015	21.0	99.0	273	28	000	1.0
00:26:00	16	-111	43	0	0.33	-0.08	0.04	355	-0.735	22.9	99.0	243	38	000	1.0
00:26:10	16	-109	44	0	0.19	-0.12	-0.02	355	-0.654	25.7	99.0	243	36	000	1.0
00:26:20	15	-109	44	0	0.07	-0.20	-0.08	355	-0.729	29.7	99.0	243	44	000	1.0
00:26:30	14	-109	44	0	-0.08	-0.22	-0.14	355	-0.469	28.8	99.0	243	35	000	1.0
00:26:40	13	-110	44	0	-0.10	-0.21	-0.25	355	0.280	25.2	99.0	348	41	000	1.0
00:26:50	12	-110	44	0	-0.04	-0.26	-0.26	355	0.016	25.8	99.0	348	30	000	1.0
00:27:00	11	-110	46	0	-0.07	-0.27	-0.27	355	-0.011	26.0	99.0	348	39	000	1.0
00:27:10	9	-111	46	0	-0.18	-0.10	-0.37	355	1.681	17.6	99.0	308	30	000	1.0
00:27:20	8	-112	46	0	-0.14	0.05	-0.42	355	2.927	2.4	99.0	334	31	000	1.0
00:27:30	8	-113	46	0	-0.04	0.05	-0.30	356	2.241	-12.1	99.0	049	31	000	1.0
00:27:40	7	-113	47	0	0.09	-0.02	-0.10	356	0.515	-4.6	99.0	000	33	000	1.0
00:27:50	7	-112	47	0	0.20	-0.09	-0.02	356	-0.452	6.5	99.0	037	35	000	1.0
00:28:00	7	-111	46	0	0.12	-0.02	0.03	356	-0.315	8.8	99.0	058	30	000	1.0
00:28:10	7	-110	46	0	0.12	0.06	0.08	356	-0.089	6.9	99.0	058	50	000	1.0
00:28:20	7	-110	47	0	0.11	0.05	0.12	356	-0.436	10.4	52.0	085	40	000	1.0
00:28:30	8	-109	47	0	0.08	0.06	0.12	356	-0.428	12.8	100.0	033	37	000	1.0
00:28:40	8	-109	46	0	0.19	0.08	0.14	355	-0.347	10.9	100.0	033	35	000	1.0
00:28:50	8	-107	47	0	0.34	0.08	0.15	355	-0.412	12.0	100.0	000	40	000	1.0
00:29:00	9	-105	46	0	0.49	0.12	0.13	355	-0.062	11.4	100.0	267	33	000	1.0
00:29:10	9	-102	47	0	0.48	0.12	0.11	355	0.079	11.0	100.0	231	44	000	1.0
00:29:20	10	-100	46	0	0.46	0.06	0.10	355	-0.257	11.9	100.0	205	28	000	1.0
00:29:30	10	-97	47	0	0.53	0.05	0.08	355	-0.211	12.9	100.0	205	34	000	1.0
00:29:40	10	-95	45	0	0.51	0.04	0.06	355	-0.149	12.7	100.0	202	42	000	1.0
00:29:50	10	-92	42	0	0.42	-0.06	0.04	355	-0.650	15.3	100.0	269	40	000	1.0
00:30:00	9	-90	43	0	0.37	-0.20	0.02	355	-1.342	20.4	100.0	269	44	000	1.0
00:30:10	9	-89	43	0	0.27	-0.26	-0.03	355	-1.456	26.4	100.0	200	33	000	1.0
00:30:20	8	-88	43	0	0.09	-0.21	-0.09	355	-0.784	29.5	100.0	200	41	000	1.0
00:30:30	7	-88	43	0	-0.03	-0.20	-0.14	355	-0.372	29.1	100.0	154	43	000	1.0
00:30:40	6	-88	43	0	-0.16	-0.10	-0.19	355	0.587	23.5	100.0	154	35	000	1.0
00:30:50	6	-90	42	0	-0.29	0.01	-0.26	355	1.735	16.2	100.0	144	42	000	1.0
00:31:00	5	-91	42	0	-0.25	0.11	-0.28	355	2.440	5.6	100.0	093	47	000	1.0
00:31:10	5	-92	43	0	-0.18	0.15	-0.23	356	2.387	-6.3	100.0	093	35	000	1.0
00:31:20	5	-93	43	0	-0.24	0.16	-0.16	356	1.991	-7.9	100.0	093	44	000	1.0
00:31:30	5	-95	43	0	-0.38	0.22	-0.08	356	1.955	-9.4	100.0	093	39	000	1.0
00:31:40	6	-97	43	0	-0.45	0.26	0.00	357	1.618	-13.1	100.0	036	37	000	1.0
00:31:50	7	-99	42	0	-0.43	0.19	0.08	357	0.723	-14.9	100.0	306	43	000	1.0
00:32:00	7	-101	42	0	-0.28	0.07	0.15	357	-0.505	-11.3	100.0	306	34	000	1.0
00:32:10	8	-102	43	0	-0.27	-0.01	0.19	357	-1.305	-4.7	100.0	333	28	000	1.0
00:32:20	9	-104	44	0	-0.30	0.01	0.21	356	-1.271	-1.5	100.0	333	34	000	1.0
00:32:30	9	-105	47	0	-0.17	0.04	0.20	356	-1.025	3.0	100.0	333	39	000	1.0
00:32:40	10	-106	46	0	-0.06	0.10	0.13	356	-0.231	3.5	100.0	333	45	000	1.0
00:32:50	11	-105	46	0	0.09	0.07	0.18	356	-0.665	6.1	100.0	333	34	000	1.0
00:33:00	11	-104	47	0	0.26	-0.03	0.20	356	-1.417	10.0	100.0	300	40	000	1.0
00:33:10	11	-103	47	0	0.35	-0.11	0.17	355	-1.789	15.0	100.0	234	41	000	1.0
00:33:20	11	-101	46	0	0.31	-0.08	0.13	355	-1.272	18.4	100.0	220	41	000	1.0
00:33:30	11	-100	46	0	0.17	-0.14	0.07	355	-1.309	26.0	100.0	220	36	000	1.0
00:33:40	11	-99	47	0	0.08	-0.21	-0.02	355	-1.208	31.6	100.0	220	35	000	1.0
00:33:50	10	-99	47	0	0.03	-0.22	-0.11	355	-0.674	29.1	100.0	302	28	000	1.0
00:34:00	9	-99	46	0	-0.01	-0.20	-0.17	355	-0.221	26.8	100.0	230	30	000	1.0
00:34:10	8	-99	46	0	-0.05	-0.20	-0.21	355	0.070	25.5	100.0	147	35	000	1.0
00:34:20	7	-100	47	0	-0.05	-0.18	-0.21	355	0.239	23.9	100.0	060	31	000	1.0
00:34:30	6	-100	47	0	-0.10	-0.10	-0.23	355	0.842	19.3	63.0	083	36	000	1.0
00:34:40	5	-101	46	0	-0.10	0.04	-0.27	355	2.004	4.2	99.0	083	38	000	1.0
00:34:50	5	-101	46	0	-0.10	0.09	-0.19	355	1.771	-4.8	99.0	118	40	000	1.0
00:35:00	5	-102	47	0	-0.17	0.14	-0.14	356	1.753	-4.2	99.0	059	26	000	1.0
00:35:10	5	-103	47	0	-0.19	0.14	-0.09	356	1.427	-5.3	99.0	059	46	000	1.0
00:35:20	5	-104	46	0	-0.19	0.14	-0.03	356	1.101	-6.5	99.0	059	35	000	1.0
00:35:30	6	-105	46	0	-0.13	0.11	0.03	356	0.547	-7.3	99.0	022	38	000	1.0
00:35:40	6	-105	47	0	-0.11	0.12	0.07	356	0.275	-6.2	99.0	000	32	000	1.0
00:35:50	7	-106	47	0	-0.13	0.15	0.11	356	0.257	-6.2	99.0	000	34	000	1.0
00:36:00	8	-106	46	0	-0.15	0.17	0.14	356	0.208	-6.8	99.0	337	40	000	1.0
00:36:10	9	-107	46	0	0.06	0.15	0.20	356	-0.324	-3.7	99.0	337	42	000	1.0
00:36:20	9	-106	47	0	0.34	0.07	0.26	356	-1.232	0.4	99.0	297	37	000	1.0
00:36:30	10	-104	47	0	0.38	0.01	0.28	356	-1.713	6.1	99.0	269	34	000	1.0
00:36:40	10	-102	46	0	0.41	-0.03	0.26	356	-1.850	11.8	99.0	269	34	000	1.0
00:36:50	11	-99	46	0	0.39	-0.04	0.22	355	-1.650	16.7	99.0	224	35	000	1.0
00:37:00	11	-98	47	0	0.32	-0.01	0.15	355	-1.043	20.1	99.0	224	47	000	1.0

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill %	Wind		Current	
	East	North			Long	Bow	Stern					Knots	Deg	Knots	Deg
00:37:10	11	-96	45	0	0.32	-0.07	0.09	355	-1.025	22.9	99.0	215	25	000	1.0 090
00:37:20	11	-94	45	0	0.29	-0.23	0.03	355	-1.655	29.4	99.0	215	46	000	1.0 090
00:37:30	10	-93	45	0	0.18	-0.22	-0.07	354	-0.977	32.7	99.0	215	41	000	1.0 090
00:37:40	9	-93	45	0	0.04	-0.15	-0.15	354	0.015	28.7	99.0	215	40	000	1.0 090
00:37:50	8	-93	45	0	-0.05	-0.17	-0.19	354	0.173	27.1	99.0	215	46	000	1.0 090
00:38:00	7	-93	45	0	-0.09	-0.14	-0.22	354	0.522	24.5	99.0	122	45	000	1.0 090
00:38:10	7	-94	45	0	-0.15	-0.05	-0.29	355	1.511	16.8	49.0	122	38	000	1.0 090
00:38:20	6	-95	45	0	-0.18	0.03	-0.33	355	2.263	7.5	49.0	122	40	000	1.0 090
00:38:30	5	-96	44	0	-0.14	0.06	-0.31	355	2.324	-3.1	49.0	122	32	000	1.0 090
00:38:40	5	-97	44	0	-0.20	0.02	-0.26	356	1.759	-3.5	49.0	122	34	000	1.0 090
00:38:50	4	-98	44	0	-0.33	0.00	-0.21	356	1.348	-4.1	49.0	122	40	000	1.0 090
00:39:00	4	-100	45	0	-0.42	0.00	-0.16	356	0.999	-5.6	49.0	122	36	000	1.0 090
00:39:10	4	-102	45	0	-0.48	0.04	-0.09	356	0.821	-7.6	100.0	053	41	000	1.0 090
00:39:20	4	-105	45	0	-0.46	0.07	-0.01	356	0.540	-8.7	100.0	053	32	000	1.0 090
00:39:30	4	-107	50	0	-0.43	0.08	0.06	356	0.151	-8.9	100.0	022	44	000	1.0 090
00:39:40	5	-109	49	0	-0.34	0.08	0.13	356	-0.328	-7.4	100.0	022	49	000	1.0 090
00:39:50	6	-110	49	0	-0.15	0.09	0.18	356	-0.558	-3.5	100.0	022	38	000	1.0 090
00:40:00	6	-111	50	0	0.02	0.12	0.23	356	-0.707	-0.5	100.0	000	35	000	1.0 090
00:40:10	7	-110	49	0	0.07	0.13	0.29	356	-1.015	2.5	100.0	298	37	000	1.0 090
00:40:20	9	-110	50	0	0.08	0.07	0.30	356	-1.433	9.3	100.0	299	34	000	1.0 090
00:40:30	9	-109	48	0	0.28	-0.01	0.28	356	-1.830	12.6	100.0	299	37	000	1.0 090
00:40:40	10	-107	45	0	0.36	-0.08	0.23	355	-2.015	18.2	100.0	269	37	000	1.0 090
00:40:50	10	-105	45	0	0.34	-0.15	0.16	355	-1.996	24.8	100.0	269	34	000	1.0 090
00:41:00	9	-104	46	0	0.29	-0.21	0.06	355	-1.760	30.6	100.0	237	32	000	1.0 090
00:41:10	9	-103	46	0	0.11	-0.17	-0.05	354	-0.736	33.3	100.0	237	39	000	1.0 090
00:41:20	8	-102	46	0	0.04	-0.07	-0.13	354	0.382	24.2	100.0	237	33	000	1.0 090
00:41:30	8	-102	46	0	0.13	-0.15	-0.17	355	0.143	26.1	100.0	237	34	000	1.0 090
00:41:40	6	-101	45	0	0.17	-0.23	-0.22	355	-0.085	27.4	100.0	215	36	000	1.0 090
00:41:50	5	-101	45	0	0.10	-0.14	-0.25	355	0.674	22.9	100.0	090	37	000	1.0 090
00:42:00	4	-101	46	0	0.01	-0.04	-0.28	355	1.491	30.2	100.0	090	28	000	1.0 090
00:42:10	4	-101	46	0	-0.04	0.05	-0.26	355	1.998	15.4	100.0	080	38	000	1.0 090
00:42:20	3	-101	46	0	-0.03	0.04	-0.18	355	1.395	9.5	100.0	056	39	000	1.0 090
00:42:30	3	-101	46	0	-0.13	0.03	-0.18	356	1.309	16.7	100.0	056	44	000	1.0 090
00:42:40	3	-102	46	0	-0.18	0.12	-0.23	356	2.185	8.7	100.0	056	36	000	1.0 090
00:42:50	2	-103	45	0	-0.17	0.18	-0.21	356	2.450	-2.7	100.0	056	30	000	1.0 090
00:43:00	3	-104	45	0	-0.18	0.21	-0.15	357	2.294	-7.9	100.0	033	40	000	1.0 090
00:43:10	3	-105	46	0	-0.13	0.23	-0.07	357	1.912	-13.5	100.0	033	29	000	1.0 090
00:43:20	3	-105	46	0	-0.11	0.24	0.02	357	1.445	-13.9	100.0	340	40	000	1.0 090
00:43:30	4	-106	46	0	0.00	0.21	0.11	357	0.598	-12.0	100.0	275	30	000	1.0 090
00:43:40	5	-105	46	0	0.13	0.14	0.22	357	-0.476	-5.4	100.0	305	29	000	1.0 090
00:43:50	6	-104	46	0	0.21	0.09	0.28	357	-1.202	-0.2	100.0	274	37	000	1.0 090
00:44:00	7	-103	45	0	0.29	0.01	0.31	357	-1.930	6.3	100.0	324	49	000	1.0 090
00:44:10	7	-101	45	0	0.37	-0.05	0.30	357	-2.215	12.4	100.0	289	34	000	1.0 090
00:44:20	8	-99	46	0	0.37	-0.04	0.24	356	-1.832	17.9	100.0	289	49	000	1.0 090
00:44:30	8	-98	46	0	0.27	-0.03	0.17	356	-1.297	22.3	100.0	289	40	000	1.0 090
00:44:40	8	-96	46	0	0.29	-0.07	0.09	356	-1.064	24.6	100.0	289	39	000	1.0 090
00:44:50	8	-94	46	0	0.37	-0.09	0.01	356	-0.686	25.3	100.0	289	41	000	1.0 090
00:45:00	8	-93	45	0	0.41	-0.09	-0.06	356	-0.133	24.6	100.0	289	33	000	1.0 090
00:45:10	7	-90	45	0	0.53	-0.10	-0.13	356	0.235	23.7	100.0	289	44	000	1.0 090
00:45:20	6	-87	46	0	0.54	-0.10	-0.19	356	0.581	21.9	100.0	289	32	000	1.0 090
00:45:30	5	-85	46	0	0.41	-0.05	-0.23	356	1.116	17.4	100.0	289	37	000	1.0 090
00:45:40	4	-83	46	0	0.41	-0.05	-0.23	356	1.163	13.6	100.0	289	37	000	1.0 090
00:45:50	3	-81	46	0	0.50	-0.15	-0.22	356	0.450	13.0	100.0	289	42	000	1.0 090

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 14:37:00

Start Time [hrs:min:sec]: 00:25:00
End Time [hrs:min:sec]: 00:46:00
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 33

Date: 5 February 1999

Start Time: 15:29

Length of run [secs]: 3065

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:.....	40	Direction: 0
Sea State, Significant wave height [m]:..	8	Direction: 180
Current Speed [knots]:.....	2	Direction: 90

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 1.9

Evaluation:

Mating was made in the second try.

Wind and waves caught the bow and blew it to the port close to 20 degrees. The captain used full ahead and reversed the thruster and brought the ship back with no particular problem. Most of the time was used waiting for small waves to occur when the buoy was near the center of the moon pool.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
15:29:38

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 g file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run #33**

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:16:40	-20	-127	74	0	0.12	1.06	-1.11	340	13.786	35.0	98.0	157	46	000	2.0	090
00:16:50	-20	-126	74	0	0.21	1.28	-1.06	343	14.857	35.0	98.0	157	40	000	2.0	090
00:17:00	-19	-125	74	0	0.32	1.46	-0.98	345	15.535	35.0	98.0	157	43	000	2.0	090
00:17:10	-18	-122	64	0	0.48	1.32	-0.82	348	13.560	20.5	98.0	157	43	000	2.0	090
00:17:20	-18	-120	50	0	0.53	1.03	-0.50	350	9.749	1.5	98.0	157	36	000	2.0	090
00:17:30	-17	-117	49	0	0.40	0.87	-0.15	351	6.518	-17.5	98.0	157	47	000	2.0	090
00:17:40	-15	-115	50	0	0.23	0.75	0.26	352	3.136	-35.0	98.0	074	31	000	2.0	090
00:17:50	-12	-113	45	0	0.35	0.56	0.63	352	-0.424	-34.3	98.0	038	38	000	2.0	090
00:18:00	-9	-111	45	0	0.48	0.39	0.90	352	-3.224	-24.6	98.0	038	27	000	2.0	090
00:18:10	-6	-108	45	0	0.48	0.25	1.07	351	-5.226	-9.1	98.0	187	33	000	2.0	090
00:18:20	-3	-105	44	0	0.46	0.16	1.13	350	-6.133	9.7	98.0	180	39	000	2.0	090
00:18:30	0	-102	44	0	0.38	0.25	1.07	349	-5.184	24.1	98.0	180	43	000	2.0	090
00:18:40	3	-100	45	0	0.24	0.43	1.04	348	-3.848	5.1	98.0	180	27	000	2.0	090
00:18:50	6	-98	45	0	0.17	0.33	1.06	348	-4.668	15.3	98.0	180	36	000	2.0	090
00:19:00	9	-96	45	0	0.09	-0.02	1.01	347	-6.531	34.2	98.0	180	39	000	2.0	090
00:19:10	11	-96	45	0	-0.02	-0.02	0.92	346	-5.934	35.0	98.0	127	36	000	2.0	090
00:19:20	14	-95	45	0	-0.15	-0.01	0.83	345	-5.364	35.0	98.0	127	38	000	2.0	090
00:19:30	16	-96	44	0	-0.35	0.02	0.77	344	-4.751	35.0	98.0	127	31	000	2.0	090
00:19:40	19	-98	44	0	-0.50	0.18	0.71	343	-3.365	35.0	98.0	077	37	000	2.0	090
00:19:50	22	-99	44	0	-0.51	0.21	0.65	343	-2.833	35.0	98.0	031	31	000	2.0	090
00:20:00	25	-101	47	0	-0.46	0.46	0.58	342	-0.727	35.0	98.0	031	44	000	2.0	090
00:20:10	28	-102	46	0	-0.31	0.65	0.49	342	0.966	35.0	98.0	031	31	000	2.0	090
00:20:20	31	-103	46	0	-0.28	0.59	0.41	342	1.113	35.0	98.0	269	38	000	2.0	090
00:20:30	34	-103	47	0	-0.28	0.64	0.33	343	1.990	35.0	98.0	269	34	000	2.0	090
00:20:40	37	-104	48	0	-0.23	0.78	0.26	343	3.303	35.0	98.0	359	33	000	2.0	090
00:20:50	40	-104	48	0	-0.14	0.74	0.21	344	3.386	34.5	98.0	359	29	000	2.0	090
00:21:00	42	-104	49	0	-0.01	0.60	0.23	344	2.332	15.5	98.0	359	35	000	2.0	090
00:21:10	44	-103	49	0	-0.01	0.47	0.33	344	0.897	6.2	98.0	359	40	000	2.0	090
00:21:20	46	-103	48	0	0.02	0.32	0.38	345	-0.379	24.1	98.0	268	38	000	2.0	090
00:21:30	47	-102	49	0	0.13	0.16	0.30	344	-0.934	35.0	98.0	268	34	000	2.0	090
00:21:40	48	-101	49	0	0.20	0.11	0.21	344	-0.593	35.0	98.0	268	42	000	2.0	090
00:21:50	48	-100	49	0	0.12	0.23	0.11	344	0.720	35.0	98.0	268	49	000	2.0	090
00:22:00	49	-99	48	0	0.09	0.26	0.04	344	1.396	35.0	98.0	268	38	000	2.0	090
00:22:10	50	-98	48	0	0.18	0.30	-0.02	345	2.001	35.0	98.0	268	45	000	2.0	090
00:22:20	50	-97	48	0	0.23	0.21	-0.03	345	1.549	27.2	98.0	268	31	000	2.0	090
00:22:30	50	-96	48	0	0.25	-0.07	-0.05	345	-0.076	35.0	98.0	268	31	000	2.0	090
00:22:40	49	-95	49	0	0.17	-0.29	-0.08	345	-1.297	35.0	98.0	232	44	000	2.0	090
00:22:50	48	-95	48	0	-0.05	-0.21	-0.10	345	-0.699	35.0	98.0	262	35	000	2.0	090
00:23:00	47	-96	48	0	-0.15	0.05	-0.11	345	1.035	35.0	98.0	324	34	000	2.0	090
00:23:10	47	-96	48	0	-0.13	-0.05	-0.10	345	0.348	35.0	98.0	324	41	000	2.0	090
00:23:20	47	-97	49	0	-0.13	-0.16	-0.10	345	-0.403	35.0	98.0	340	39	000	2.0	090
00:23:30	47	-98	48	0	-0.07	-0.05	-0.10	345	0.317	35.0	98.0	291	46	000	2.0	090
00:23:40	46	-98	48	0	-0.08	0.12	-0.12	345	1.489	30.7	98.0	291	41	000	2.0	090
00:23:50	47	-99	49	0	-0.10	0.45	-0.09	346	3.440	24.5	98.0	301	43	000	2.0	090
00:24:00	48	-99	49	0	-0.02	0.49	-0.02	346	3.233	17.5	98.0	318	43	000	2.0	090
00:24:10	49	-98	49	0	0.02	0.43	0.08	347	2.227	15.3	98.0	318	35	000	2.0	090
00:24:20	51	-98	49	0	0.12	0.48	0.16	347	2.043	12.0	98.0	318	35	000	2.0	090
00:24:30	52	-96	48	0	0.24	0.35	0.26	347	0.571	3.7	98.0	318	44	000	2.0	090
00:24:40	53	-95	49	0	0.25	0.13	0.40	347	-1.684	3.7	98.0	270	33	000	2.0	090
00:24:50	54	-93	49	0	0.21	0.06	0.53	347	-3.013	-2.6	98.0	270	45	000	2.0	090
00:25:00	56	-92	49	0	0.15	-0.01	0.61	346	-3.948	11.5	98.0	270	34	000	2.0	090
00:25:10	57	-91	49	0	0.27	-0.03	0.60	345	-3.998	22.5	98.0	270	30	000	2.0	090
00:25:20	58	-89	48	0	0.36	0.10	0.52	345	-2.641	26.9	98.0	243	41	000	2.0	090
00:25:30	59	-86	49	0	0.33	0.14	0.41	345	-1.730	31.7	98.0	243	40	000	2.0	090
00:25:40	60	-85	48	0	0.35	0.06	0.30	344	-1.536	35.0	98.0	243	34	000	2.0	090
00:25:50	60	-82	49	0	0.46	-0.03	0.21	344	-1.539	26.0	98.0	243	28	000	2.0	090
00:26:00	59	-80	49	0	0.43	-0.02	0.17	344	-1.236	25.8	98.0	221	38	000	2.0	090
00:26:10	59	-78	45	0	0.29	-0.11	0.13	344	-1.543	32.5	98.0	221	36	000	2.0	090
00:26:20	59	-77	46	0	0.16	-0.29	0.08	343	-2.383	35.0	98.0	241	44	000	2.0	090
00:26:30	58	-77	46	0	0.02	-0.31	0.04	343	-2.267	35.0	98.0	241	35	000	2.0	090
00:26:40	57	-77	46	0	-0.06	-0.43	0.02	342	-2.878	35.0	98.0	241	41	000	2.0	090
00:26:50	56	-78	46	0	-0.08	-0.61	0.02	342	-4.006	35.0	98.0	241	30	000	2.0	090
00:27:00	55	-79	52	0	-0.19	-0.65	0.01	341	-4.193	35.0	98.0	208	39	000	2.0	090
00:27:10	54	-81	52	0	-0.37	-0.25	-0.04	341	-1.362	35.0	98.0	208	30	000	2.0	090
00:27:20	54	-83	52	0	-0.42	0.22	-0.08	341	1.897	35.0	98.0	208	31	000	2.0	090
00:27:30	56	-85	51	0	-0.40	0.31	-0.10	341	2.618	35.0	98.0	208	31	000	2.0	090
00:27:40	57	-86	51	0	-0.36	0.25	-0.12	342	2.387	35.0	98.0	208	33	000	2.0	090
00:27:50	57	-88	51	0	-0.35	0.07	-0.13	342	1.267	35.0	98.0	208	35	000	2.0	090
00:28:00	58	-90	51	0	-0.48	0.22	-0.15	342	2.306	35.0	98.0	258	30	000	2.0	090
00:28:10	59	-92	52	0	-0.49	0.41	-0.16	343	3.615	35.0	98.0	295	50	000	2.0	090
00:28:20	60	-95	51	0	-0.46	0.25	-0.13	343	2.449	28.0	98.0	295	40	000	2.0	090
00:28:30	61	-97	51	0	-0.46	0.19	-0.08	343	1.707	23.8	98.0	295	37	000	2.0	090
00:28:40	62	-99	52	0	-0.35	0.14	0.00	344	0.914	21.1	98.0	295	35	000	2.0	090

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn		Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern		Deg/Min	%		Deg	Knots	Deg	Knots	Deg	
00:28:50	63	-100	51	0	-0.20	0.02	0.06	344	-0.218	24.3	98.0	299	40	000	2.0	090	
00:29:00	63	-101	52	0	-0.06	0.15	0.07	344	0.459	19.0	98.0	299	33	000	2.0	090	
00:29:10	64	-100	51	0	-0.01	0.22	0.13	344	0.610	16.5	98.0	299	44	000	2.0	090	
00:29:20	65	-100	52	0	0.06	0.04	0.14	344	-0.658	28.4	98.0	299	28	000	2.0	090	
00:29:30	65	-99	51	0	0.20	0.05	0.11	344	-0.388	25.3	98.0	274	34	000	2.0	090	
00:29:40	65	-98	52	0	0.25	0.04	0.08	344	-0.297	24.9	98.0	274	42	000	2.0	090	
00:29:50	65	-97	51	0	0.21	-0.18	0.04	344	-1.369	33.1	98.0	274	40	000	2.0	090	
00:30:00	64	-96	51	0	0.19	-0.47	-0.03	343	-2.844	35.0	98.0	274	44	000	2.0	090	
00:30:10	62	-96	52	0	0.14	-0.60	-0.08	343	-3.318	35.0	98.0	274	33	000	2.0	090	
00:30:20	60	-96	52	0	0.06	-0.47	-0.13	342	-2.123	35.0	98.0	300	41	000	2.0	090	
00:30:30	59	-96	52	0	0.05	-0.42	-0.18	342	-1.571	35.0	98.0	300	43	000	2.0	090	
00:30:40	57	-96	51	0	0.02	-0.28	-0.22	342	-0.388	35.0	98.0	300	35	000	2.0	090	
00:30:50	56	-97	51	0	-0.01	-0.11	-0.26	342	0.964	35.0	98.0	300	42	000	2.0	090	
00:31:00	55	-97	52	0	0.08	0.01	-0.30	342	1.954	35.0	98.0	300	47	000	2.0	090	
00:31:10	54	-96	51	0	0.19	0.03	-0.33	342	2.327	35.0	98.0	300	35	000	2.0	090	
00:31:20	53	-96	51	0	0.18	0.03	-0.35	343	2.400	28.4	98.0	300	44	000	2.0	090	
00:31:30	53	-95	51	0	0.09	0.20	-0.27	343	2.926	9.9	98.0	300	39	000	2.0	090	
00:31:40	53	-95	51	0	0.06	0.22	-0.06	344	1.807	-0.5	98.0	300	37	000	2.0	090	
00:31:50	53	-94	52	0	0.10	0.17	0.06	344	0.715	15.0	98.0	300	43	000	2.0	090	
00:32:00	53	-93	52	0	0.27	-0.04	0.09	344	-0.836	24.4	98.0	300	34	000	2.0	090	
00:32:10	53	-92	51	0	0.29	-0.14	0.05	344	-1.244	29.9	98.0	300	28	000	2.0	090	
00:32:20	52	-91	51	0	0.21	0.14	0.02	344	0.762	21.6	98.0	243	34	000	2.0	090	
00:32:30	53	-89	52	0	0.29	0.32	0.04	344	1.768	15.2	98.0	243	39	000	2.0	090	
00:32:40	53	-87	52	0	0.33	0.40	0.11	344	1.849	2.2	98.0	243	45	000	2.0	090	
00:32:50	54	-85	51	0	0.42	0.36	0.28	344	0.473	-7.4	98.0	243	34	000	2.0	090	
00:33:00	55	-82	51	0	0.52	0.00	0.42	344	-2.728	2.2	98.0	223	40	000	2.0	090	
00:33:10	55	-79	51	0	0.58	-0.21	0.45	344	-4.185	16.3	98.0	223	41	000	2.0	090	
00:33:20	55	-76	52	0	0.55	-0.05	0.37	343	-2.703	24.1	98.0	223	41	000	2.0	090	
00:33:30	54	-74	52	0	0.42	-0.24	0.27	343	-3.220	35.0	98.0	210	36	000	2.0	090	
00:33:40	53	-72	52	0	0.34	-0.48	0.16	342	-4.070	35.0	98.0	210	35	000	2.0	090	
00:33:50	52	-71	52	0	0.27	-0.45	0.06	341	-3.200	35.0	98.0	210	28	000	2.0	090	
00:34:00	51	-70	52	0	0.17	-0.38	-0.03	341	-2.217	35.0	98.0	210	30	000	2.0	090	
00:34:10	50	-70	52	0	0.13	-0.33	-0.10	341	-1.435	35.0	98.0	210	35	000	2.0	090	
00:34:20	48	-70	52	0	0.11	-0.41	-0.16	340	-1.617	35.0	98.0	210	31	000	2.0	090	
00:34:30	47	-70	51	0	-0.01	-0.29	-0.21	340	-0.491	35.0	98.0	230	36	000	2.0	090	
00:34:40	46	-71	52	0	-0.04	-0.07	-0.26	340	1.196	35.0	98.0	209	38	000	2.0	090	
00:34:50	45	-71	50	0	-0.08	0.09	-0.29	340	2.432	35.0	98.0	209	40	000	2.0	090	
00:35:00	45	-72	49	0	-0.19	0.17	-0.30	341	2.959	35.0	98.0	209	26	000	2.0	090	
00:35:10	45	-73	50	0	-0.30	0.08	-0.28	341	2.283	35.0	98.0	240	46	000	2.0	090	
00:35:20	45	-75	50	0	-0.34	0.00	-0.27	342	1.727	35.0	98.0	271	35	000	2.0	090	
00:35:30	45	-77	50	0	-0.32	-0.12	-0.26	342	0.837	35.0	98.0	297	38	000	2.0	090	
00:35:40	44	-79	49	0	-0.33	-0.07	-0.24	342	1.041	32.1	98.0	297	32	000	2.0	090	
00:35:50	44	-80	49	0	-0.37	0.13	-0.19	342	2.043	24.4	98.0	297	34	000	2.0	090	
00:36:00	45	-82	50	0	-0.40	0.32	-0.10	343	2.647	16.2	98.0	312	40	000	2.0	090	
00:36:10	46	-84	49	0	-0.19	0.36	0.04	343	2.030	7.7	98.0	324	42	000	2.0	090	
00:36:20	47	-84	49	0	0.09	0.19	0.16	343	0.175	11.7	98.0	324	37	000	2.0	090	
00:36:30	48	-83	50	0	0.17	0.14	0.21	343	-0.483	15.8	98.0	324	34	000	2.0	090	
00:36:40	49	-81	50	0	0.21	0.10	0.23	343	-0.850	19.4	98.0	223	34	000	2.0	090	
00:36:50	49	-80	50	0	0.19	0.08	0.22	343	-0.933	23.2	98.0	215	35	000	2.0	090	
00:37:00	50	-79	50	0	0.12	0.16	0.21	343	-0.269	21.7	98.0	215	47	000	2.0	090	
00:37:10	50	-78	50	0	0.14	-0.07	0.19	343	-1.647	32.1	98.0	241	25	000	2.0	090	
00:37:20	50	-78	50	0	0.14	-0.62	0.13	342	-4.737	35.0	98.0	241	46	000	2.0	090	
00:37:30	48	-78	49	0	0.08	-0.61	0.07	341	-4.312	35.0	98.0	241	41	000	2.0	090	
00:37:40	47	-78	50	0	-0.02	-0.39	0.00	341	-2.480	35.0	98.0	241	40	000	2.0	090	
00:37:50	46	-79	49	0	-0.10	-0.44	-0.05	340	-2.467	35.0	98.0	211	46	000	2.0	090	
00:38:00	45	-80	50	0	-0.13	-0.36	-0.09	340	-1.729	35.0	98.0	211	45	000	2.0	090	
00:38:10	44	-81	50	0	-0.19	-0.36	-0.12	340	-1.503	35.0	98.0	211	38	000	2.0	090	
00:38:20	43	-82	49	0	-0.26	-0.23	-0.14	340	-0.564	35.0	98.0	211	40	000	2.0	090	
00:38:30	43	-84	50	0	-0.24	-0.18	-0.16	340	-0.149	35.0	98.0	268	32	000	2.0	090	
00:38:40	43	-85	50	0	-0.29	-0.36	-0.17	340	-1.219	35.0	98.0	268	34	000	2.0	090	
00:38:50	42	-87	50	0	-0.40	-0.46	-0.17	339	-1.838	35.0	98.0	268	40	000	2.0	090	
00:39:00	41	-90	49	0	-0.42	-0.44	-0.17	339	-1.733	35.0	98.0	329	36	000	2.0	090	
00:39:10	41	-93	49	0	-0.44	-0.24	-0.17	339	-0.457	35.0	98.0	329	41	000	2.0	090	
00:39:20	41	-95	50	0	-0.40	-0.12	-0.17	339	0.345	35.0	98.0	322	32	000	2.0	090	
00:39:30	41	-97	49	0	-0.37	-0.01	-0.19	339	1.125	35.0	98.0	345	44	000	2.0	090	
00:39:40	41	-99	49	0	-0.29	0.05	-0.21	339	1.618	35.0	98.0	000	49	000	2.0	090	
00:39:50	41	-100	52	0	-0.13	0.15	-0.23	339	2.399	35.0	98.0	000	38	000	2.0	090	
00:40:00	41	-100	52	0	0.03	0.43	-0.25	340	4.305	22.2	98.0	000	35	000	2.0	090	
00:40:10	42	-100	53	0	0.06	0.64	-0.24	341	5.621	26.0	98.0	272	37	000	2.0	090	
00:40:20	43	-99	52	0	0.08	0.56	-0.17	342	4.659	15.1	98.0	298	34	000	2.0	090	
00:40:30	43	-98	52	0	0.28	0.27	-0.10	342	2.362	21.0	98.0	298	37	000	2.0	090	
00:40:40	43	-96	53	0	0.38	0.02	-0.05	343	0.458	7.8	98.0	298	37	000	2.0	090	
00:40:50	42	-94	52	0	0.38	-0.25	0.04	342	-1.796	15.6	98.0	208	34	000	2.0	090	
00:41:00	41	-93	53	0	0.33	-0.45	0.04	342	-3.150	27.4	98.0	208	32	000	2.0	090	
00:41:10	39	-92	52	0	0.17	-0.31	-0.04	342	-1.724	35.0	98.0	208	39	000	2.0	090	
00:41:20	38	-91	52	0	0.11	0.02	-0.08	341	0.650	21.1	98.0	208	33	000	2.0	090	
00:41:30	38	-91	53	0	0.22	-0.20	-0.08	342	-0.734	30.1	98.0	215	34	000	2.0	090	
00:41:40	36	-90	51	0	0.26	-0.43	-0.14	341	-1.862	35.0	98.0	207	36	000	2.0	090	
00:41:50	35	-89	51	0	0.18	-0.23	-0.21	341	-0.160	35.0	98.0	207	37	000	2.0	090	
00:42:00	33	-89	50	0	0.06	-0.16	-0.23	341	0.487	31.5	98.0	182	28	000	2.0	090	
00:42:10	33	-89	50	0	-0.03	-0.04	-0.20	341	1.014	22.4	98.0	182	38	000	2.0	090	
00:42:																	

Time HH:MM:SS	Position (m)		RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North	Port	Stbd	Long	Bow	Stern				Deg	%	Deg	Knots	Deg	Knots
00:42:40	31	-93	49	0	-0.37	-0.26	-0.12	341	-0.908	35.0	98.0	000	36	000	2.0	090
00:42:50	31	-95	50	0	-0.32	-0.18	-0.12	341	-0.400	35.0	98.0	000	30	000	2.0	090
00:43:00	31	-97	50	0	-0.32	-0.07	-0.12	341	0.302	35.0	98.0	000	40	000	2.0	090
00:43:10	31	-98	49	0	-0.27	0.08	-0.12	341	1.270	30.5	98.0	000	29	000	2.0	090
00:43:20	31	-99	50	0	-0.23	0.27	-0.08	341	2.224	20.1	98.0	000	40	000	2.0	090
00:43:30	33	-100	50	0	-0.13	0.51	0.03	342	3.030	10.8	98.0	002	30	000	2.0	090
00:43:40	34	-100	49	0	0.00	0.62	0.15	342	2.995	4.2	98.0	211	29	000	2.0	090
00:43:50	36	-99	49	0	0.06	0.53	0.29	343	1.558	1.6	98.0	273	37	000	2.0	090
00:44:00	38	-98	50	0	0.14	0.14	0.38	343	-1.520	11.4	98.0	295	49	000	2.0	090
00:44:10	39	-97	49	0	0.23	-0.09	0.36	342	-2.865	25.8	98.0	285	34	000	2.0	090
00:44:20	39	-95	50	0	0.21	-0.01	0.28	342	-1.818	28.9	98.0	246	49	000	2.0	090
00:44:30	39	-94	49	0	0.09	0.04	0.19	342	-0.979	32.0	98.0	246	40	000	2.0	090
00:44:40	39	-94	50	0	0.07	-0.16	0.11	341	-1.707	35.0	98.0	246	39	000	2.0	090
00:44:50	39	-94	50	0	0.11	-0.28	0.03	341	-1.982	35.0	98.0	246	41	000	2.0	090
00:45:00	38	-93	50	0	0.12	-0.27	-0.04	341	-1.462	35.0	98.0	246	33	000	2.0	090
00:45:10	37	-93	49	0	0.20	-0.33	-0.10	341	-1.426	35.0	98.0	246	44	000	2.0	090
00:45:20	35	-92	50	0	0.18	-0.35	-0.16	340	-1.211	35.0	98.0	208	32	000	2.0	090
00:45:30	34	-92	49	0	0.00	-0.09	-0.21	340	0.743	35.0	98.0	208	37	000	2.0	090
00:45:40	34	-93	50	0	-0.05	0.03	-0.20	341	1.479	25.3	98.0	258	37	000	2.0	090
00:45:50	33	-93	49	0	0.02	-0.35	-0.21	341	-0.902	35.0	98.0	272	42	000	2.0	090
00:46:00	31	-93	50	0	0.01	-0.54	-0.23	340	-1.957	35.0	98.0	272	41	000	2.0	090
00:46:10	29	-94	50	0	-0.11	-0.71	-0.25	340	-2.905	35.0	98.0	272	49	000	2.0	090
00:46:20	27	-96	49	0	-0.28	-0.66	-0.24	339	-2.652	35.0	98.0	352	28	000	2.0	090
00:46:30	26	-98	49	0	-0.33	-0.19	-0.22	339	0.159	35.0	98.0	091	40	000	2.0	090
00:46:40	26	-100	50	0	-0.32	-0.09	-0.21	339	0.773	35.0	98.0	091	44	000	2.0	090
00:46:50	26	-102	49	0	-0.34	0.06	-0.20	340	1.677	35.0	98.0	091	40	000	2.0	090
00:47:00	26	-103	50	0	-0.26	0.30	-0.20	340	3.186	35.0	98.0	043	39	000	2.0	090
00:47:10	27	-104	50	0	-0.18	0.49	-0.20	341	4.367	35.0	98.0	038	36	000	2.0	090
00:47:20	28	-105	50	0	-0.06	0.70	-0.21	341	5.790	35.0	98.0	000	40	000	2.0	090
00:47:30	30	-104	50	0	0.02	0.75	-0.18	342	5.904	22.1	98.0	000	37	000	2.0	090
00:47:40	31	-104	50	0	0.05	0.53	-0.05	343	3.699	5.1	98.0	000	41	000	2.0	090
00:47:50	32	-103	49	0	0.15	0.35	0.13	344	1.377	0.9	98.0	269	33	000	2.0	090
00:48:00	33	-102	50	0	0.17	0.33	0.26	344	0.418	2.4	98.0	269	32	000	2.0	090
00:48:10	34	-100	49	0	0.20	0.11	0.36	344	-1.555	10.8	98.0	269	32	000	2.0	090
00:48:20	35	-99	49	0	0.24	-0.21	0.36	343	-3.603	29.1	98.0	220	35	000	2.0	090
00:48:30	34	-98	50	0	0.24	-0.23	0.26	343	-3.115	35.0	98.0	220	32	000	2.0	090
00:48:40	34	-97	50	0	0.16	0.10	0.15	342	-0.339	31.6	98.0	225	39	000	2.0	090
00:48:50	35	-96	50	0	0.17	0.19	0.10	342	0.550	25.7	98.0	269	41	000	2.0	090
00:49:00	35	-94	50	0	0.25	0.06	0.07	342	-0.068	27.8	98.0	223	39	000	2.0	090
00:49:10	35	-93	49	0	0.19	-0.07	0.03	342	-0.628	32.4	98.0	208	33	000	2.0	090
00:49:20	34	-93	50	0	0.16	-0.25	-0.03	342	-1.419	35.0	98.0	208	39	000	2.0	090
00:49:30	33	-92	49	0	0.14	-0.41	-0.08	342	-2.101	35.0	98.0	208	42	000	2.0	090
00:49:40	32	-92	50	0	-0.06	-0.45	-0.11	342	-2.146	35.0	98.0	208	30	000	2.0	090
00:49:50	31	-94	50	0	-0.30	-0.28	-0.12	341	-1.006	35.0	98.0	208	28	000	2.0	090
00:50:00	30	-96	49	0	-0.41	-0.34	-0.11	341	-1.445	35.0	98.0	208	32	000	2.0	090
00:50:10	30	-98	50	0	-0.43	-0.37	-0.09	341	-1.719	35.0	98.0	208	26	000	2.0	090
00:50:20	30	-101	50	0	-0.41	-0.27	-0.09	341	-1.089	35.0	98.0	208	45	000	2.0	090
00:50:30	29	-103	49	0	-0.49	-0.27	-0.09	340	-1.147	35.0	98.0	208	36	000	2.0	090
00:50:40	30	-106	49	0	-0.64	0.10	-0.10	340	1.272	35.0	98.0	208	33	000	2.0	090
00:50:50	31	-109	50	0	-0.63	0.39	-0.10	341	3.111	35.0	98.0	208	40	000	2.0	090
00:51:00	33	-112	49	0	-0.62	0.43	-0.09	341	3.297	35.0	98.0	208	41	000	2.0	090

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 15:29:38

Start Time [hrs:min:sec]: 00:16:40
End Time [hrs:min:sec]: 00:51:05
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

HANDS-ON SIMULATION

SUCTION MOORNG TECHNOLOGY

Simulation Number: 34

Date: 5 February 1999

Start Time: 16:28

Length of run [secs]: 3540

Ship Condition: draft =13.72 m

Environment

Wind Speed [knots]:..... 40 Direction: 0

Sea State, Significant wave height [m]:.. 8 Direction: 180

Current Speed [knots]:..... 2 Direction: 90

Ship Operator: J.A.

Observer: B.K.J

Final Mating, distance between center of buoy and center of moon pool [m]: 1.7

Evaluation:

Mating was made in the first try.

The captain did not decelerate fast enough. Almost at the buoy the captain backed to kill way and in so doing the current took the ship. He ended up using full ahead and hard left. The ship sailed away, and the captain brought it back and then it took long time to wait for small waves while the buoy was near to the center of the moon pool.

During this exercise the captain was able to move the ship sideways with no forward speed. The RPM was set to 47, the rudder 35 degrees starboard, and the thruster about 225 degrees with 100 percent power.

Shiphandling Simulator

Exercise date & time: 05-Feb-99
16:28:24

Ship: 591 150,000 ton, Tanker, partial load
 Exercise number: 754 Suction Mooring System
 Scenario: 112 Open Ocean
 Log file: 999 Dummy tug file based on containership
 Traffic ships: 590 Suction Mooring Buoy
 Initial conditions: 594 150k tanker in partial load - Suction Mooring
 Exercise identification: **Run # 34**

Time HH:MM:SS	Position (m)		Port	RPM		Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North		Stbd	Long	Bow	Stern					Deg	%	Deg	Knots	Deg	Knots
00:33:20	42	-89	45	0	0.32	-0.11	0.06		341	-1.087	31.0	100.0	214	41	000	2.0	090
00:33:30	41	-88	46	0	0.17	-0.35	0.01		340	-2.297	35.0	100.0	214	36	000	2.0	090
00:33:40	40	-88	46	0	0.07	-0.68	-0.02		340	-4.217	35.0	100.0	214	35	000	2.0	090
00:33:50	38	-88	46	0	-0.01	-0.69	-0.04		339	-4.140	35.0	100.0	188	28	000	2.0	090
00:34:00	36	-89	46	0	-0.12	-0.61	-0.04		338	-3.647	35.0	100.0	137	30	000	2.0	090
00:34:10	35	-90	45	0	-0.14	-0.54	-0.04		338	-3.224	35.0	100.0	096	35	000	2.0	090
00:34:20	34	-91	45	0	-0.13	-0.63	-0.03		337	-3.775	35.0	100.0	096	31	000	2.0	090
00:34:30	33	-93	46	0	-0.23	-0.48	-0.04		337	-2.804	35.0	100.0	121	36	000	2.0	090
00:34:40	32	-95	46	0	-0.28	-0.22	-0.05		336	-1.098	35.0	100.0	121	38	000	2.0	090
00:34:50	33	-96	46	0	-0.31	-0.03	-0.07		336	0.222	35.0	100.0	121	40	000	2.0	090
00:35:00	33	-98	47	0	-0.40	0.07	-0.08		336	0.954	35.0	100.0	121	26	000	2.0	090
00:35:10	34	-100	51	0	-0.49	-0.03	-0.10		336	0.447	35.0	100.0	121	46	000	2.0	090
00:35:20	35	-103	51	0	-0.50	-0.08	-0.12		337	0.240	35.0	100.0	031	35	000	2.0	090
00:35:30	35	-105	51	0	-0.43	-0.21	-0.14		337	-0.455	35.0	100.0	031	38	000	2.0	090
00:35:40	35	-107	50	0	-0.42	-0.11	-0.15		336	0.259	35.0	100.0	063	32	000	2.0	090
00:35:50	36	-110	50	0	-0.46	0.22	-0.16		337	2.443	35.0	100.0	063	34	000	2.0	090
00:36:00	37	-112	51	0	-0.50	0.56	-0.18		337	4.682	35.0	100.0	063	40	000	2.0	090
00:36:10	39	-113	51	0	-0.30	0.76	-0.21		338	6.116	35.0	100.0	063	42	000	2.0	090
00:36:20	41	-114	52	0	-0.06	0.65	-0.20		339	5.401	35.0	100.0	063	37	000	2.0	090
00:36:30	42	-113	48	0	-0.02	0.64	-0.18		340	5.199	27.6	100.0	063	34	000	2.0	090
00:36:40	43	-113	48	0	0.01	0.58	-0.10		341	4.311	18.2	100.0	306	34	000	2.0	090
00:36:50	44	-112	47	0	0.05	0.43	-0.01		341	2.832	13.0	100.0	298	35	000	2.0	090
00:37:00	45	-112	48	0	0.06	0.41	0.07		342	2.131	10.4	100.0	298	47	000	2.0	090
00:37:10	46	-111	49	0	0.14	0.07	0.15		342	-0.500	19.1	100.0	298	25	000	2.0	090
00:37:20	45	-110	49	0	0.18	-0.55	0.13		342	-4.320	35.0	100.0	315	46	000	2.0	090
00:37:30	44	-110	49	0	0.19	-0.53	0.06		341	-3.781	35.0	100.0	000	41	000	2.0	090
00:37:40	43	-109	49	0	0.17	-0.27	-0.01		340	-1.695	35.0	100.0	000	40	000	2.0	090
00:37:50	42	-109	49	0	0.18	-0.30	-0.07		340	-1.451	35.0	100.0	000	46	000	2.0	090
00:38:00	40	-108	49	0	0.25	-0.19	-0.13		340	-0.386	35.0	100.0	000	45	000	2.0	090
00:38:10	39	-107	49	0	0.25	-0.13	-0.18		340	0.346	35.0	100.0	060	38	000	2.0	090
00:38:20	38	-106	48	0	0.27	0.06	-0.22		340	1.773	35.0	100.0	033	40	000	2.0	090
00:38:30	37	-104	49	0	0.36	0.16	-0.26		341	2.667	35.0	100.0	355	32	000	2.0	090
00:38:40	36	-103	49	0	0.33	0.00	-0.29		341	1.857	31.0	100.0	329	34	000	2.0	090
00:38:50	35	-102	48	0	0.24	-0.03	-0.26		341	1.496	25.7	100.0	342	40	000	2.0	090
00:39:00	34	-101	48	0	0.18	-0.02	-0.22		341	1.287	21.4	100.0	093	36	000	2.0	090
00:39:10	33	-100	49	0	0.15	0.14	-0.12		342	1.649	10.4	100.0	000	41	000	2.0	090
00:39:20	33	-99	49	0	0.20	0.20	-0.01		342	1.321	12.0	100.0	000	32	000	2.0	090
00:39:30	34	-98	49	0	0.25	0.25	0.07		342	1.105	11.2	100.0	322	44	000	2.0	090
00:39:40	34	-97	48	0	0.29	0.20	0.13		342	0.450	11.2	100.0	274	49	000	2.0	090
00:39:50	34	-95	49	0	0.41	0.18	0.17		342	0.123	12.1	100.0	274	38	000	2.0	090
00:40:00	35	-92	44	0	0.49	0.36	0.19		342	1.038	8.7	100.0	238	35	000	2.0	090
00:40:10	36	-89	45	0	0.43	0.49	0.25		343	1.529	3.6	100.0	213	37	000	2.0	090
00:40:20	37	-87	45	0	0.35	0.40	0.34		343	0.396	2.3	100.0	213	34	000	2.0	090
00:40:30	38	-84	45	0	0.44	0.09	0.45		343	-2.331	-7.2	100.0	213	37	000	2.0	090
00:40:40	38	-82	45	0	0.45	-0.18	0.53		342	-4.543	9.0	100.0	213	37	000	2.0	090
00:40:50	38	-80	44	0	0.37	-0.42	0.51		341	-5.938	28.0	100.0	213	34	000	2.0	090
00:41:00	37	-78	44	0	0.28	-0.63	0.43		340	-6.741	35.0	100.0	192	32	000	2.0	090
00:41:10	37	-77	43	0	0.08	-0.51	0.35		339	-5.473	35.0	100.0	225	39	000	2.0	090
00:41:20	36	-77	43	0	0.00	-0.19	0.26		338	-2.866	35.0	100.0	225	33	000	2.0	090
00:41:30	36	-77	43	0	0.05	-0.45	0.19		338	-4.062	35.0	100.0	225	34	000	2.0	090
00:41:40	35	-77	43	0	0.06	-0.77	0.15		337	-5.835	35.0	100.0	179	36	000	2.0	090
00:41:50	34	-78	43	0	-0.05	-0.59	0.10		336	-4.337	35.0	100.0	179	37	000	2.0	090
00:42:00	33	-79	43	0	-0.18	-0.54	0.07		335	-3.817	35.0	100.0	145	28	000	2.0	090
00:42:10	32	-80	43	0	-0.28	-0.39	0.05		335	-2.779	35.0	100.0	145	38	000	2.0	090
00:42:20	32	-82	43	0	-0.34	-0.48	0.03		334	-3.205	35.0	100.0	111	39	000	2.0	090
00:42:30	32	-85	44	0	-0.49	-0.79	0.02		334	-5.159	35.0	100.0	111	44	000	2.0	090
00:42:40	31	-88	55	0	-0.58	-0.71	-0.02		333	-4.336	35.0	100.0	180	36	000	2.0	090
00:42:50	31	-92	55	0	-0.61	-0.63	-0.08		332	-3.441	35.0	100.0	180	30	000	2.0	090
00:43:00	31	-96	55	0	-0.68	-0.52	-0.14		332	-2.384	35.0	100.0	180	40	000	2.0	090
00:43:10	31	-100	57	0	-0.71	-0.34	-0.20		332	-0.903	35.0	100.0	180	29	000	2.0	090
00:43:20	32	-103	73	0	-0.69	0.01	-0.37		332	2.361	35.0	100.0	180	40	000	2.0	090
00:43:30	33	-107	73	0	-0.57	0.45	-0.54		332	6.260	35.0	100.0	180	30	000	2.0	090
00:43:40	34	-109	73	0	-0.39	0.84	-0.67		334	9.528	35.0	100.0	180	29	000	2.0	090
00:43:50	35	-110	66	0	-0.30	0.92	-0.73		335	10.462	35.0	100.0	180	37	000	2.0	090
00:44:00	36	-111	62	0	-0.25	0.55	-0.71		337	8.054	35.0	100.0	180	49	000	2.0	090
00:44:10	36	-113	62	0	-0.21	0.32	-0.72		338	6.632	35.0	100.0	180	34	000	2.0	090
00:44:20	35	-114	61	0	-0.21	0.41	-0.67		339	6.823	22.1	100.0	180	49	000	2.0	090
00:44:30	35	-115	61	0	-0.30	0.35	-0.46		340	5.158	10.6	100.0	180	40	000	2.0	090
00:44:40	36	-117	72	0	-0.25	0.03	-0.26		341	1.846	12.1	100.0	180	39	000	2.0	090
00:44:50	35	-118	73	0	-0.10	-0.15	-0.17		341	0.125	17.1	100.0	180	41	000	2.0	090
00:45:00	35	-118	74	0	0.02	-0.14	-0.14		341	-0.020	18.1	100.0	180	33	000	2.0	090
00:45:10	34	-118	74	0	0.22	-0.20	-0.15		341	-0.279	19.2	100.0	180	44	000	2.0	090
00:45:20	32	-117	68	0	0.29	-0.21	-0.18		341	-0.170	19.8	100.0	180	32	000	2.0	090

Time HH:MM:SS	Position (m)		Port	RPM Stbd	Speed (Knots)			Heading	Turn Deg/Min	Rudder Deg	Gill		Wind		Current	
	East	North			Long	Bow	Stern				%	Deg	Knots	Deg	Knots	Deg
00:45:30	31	-116	69	0	0.21	0.02	-0.16	341	1.170	12.1	100.0	180	37	000	2.0	090
00:45:40	31	-115	69	0	0.26	0.08	-0.05	341	0.808	10.2	100.0	180	37	000	2.0	090
00:45:50	30	-114	68	0	0.39	-0.27	-0.02	341	-1.623	19.7	100.0	180	42	000	2.0	090
00:46:00	28	-112	62	0	0.39	-0.40	-0.08	341	-2.035	26.6	100.0	180	41	000	2.0	090
00:46:10	26	-111	61	0	0.27	-0.48	-0.18	340	-1.907	32.3	100.0	180	49	000	2.0	090
00:46:20	24	-111	61	0	0.07	-0.34	-0.29	340	-0.312	32.9	100.0	180	28	000	2.0	090
00:46:30	23	-111	62	0	0.01	0.08	-0.31	340	2.455	24.4	100.0	180	40	000	2.0	090
00:46:40	23	-111	62	0	0.05	0.08	-0.21	341	1.849	11.4	100.0	180	44	000	2.0	090
00:46:50	22	-111	68	0	0.07	0.11	-0.10	341	1.292	10.1	100.0	180	40	000	2.0	090
00:47:00	23	-110	68	0	0.17	0.28	-0.06	341	2.152	15.7	100.0	180	39	000	2.0	090
00:47:10	23	-109	71	0	0.27	0.41	-0.02	342	2.727	11.5	100.0	180	36	000	2.0	090
00:47:20	24	-107	71	0	0.41	0.54	0.06	342	3.055	5.8	100.0	180	40	000	2.0	090
00:47:30	25	-104	71	0	0.51	0.52	0.21	343	1.958	0.7	100.0	180	37	000	2.0	090
00:47:40	25	-101	63	0	0.52	0.28	0.35	343	-0.417	3.0	100.0	180	41	000	2.0	090
00:47:50	26	-98	58	0	0.57	0.18	0.41	343	-1.425	8.3	100.0	180	33	000	2.0	090
00:48:00	27	-94	56	0	0.57	0.28	0.42	342	-0.854	10.5	100.0	180	32	000	2.0	090
00:48:10	28	-91	35	0	0.49	0.14	0.44	342	-1.899	16.2	100.0	180	32	000	2.0	090
00:48:20	28	-89	35	0	0.45	-0.19	0.44	342	-3.970	31.2	100.0	180	35	000	2.0	090
00:48:30	28	-86	34	0	0.38	-0.25	0.40	341	-4.088	35.0	100.0	180	32	000	2.0	090
00:48:40	28	-85	34	0	0.24	0.06	0.35	341	-1.816	35.0	100.0	180	39	000	2.0	090
00:48:50	29	-83	34	0	0.15	0.16	0.31	340	-0.912	35.0	100.0	180	41	000	2.0	090
00:49:00	29	-82	34	0	0.13	0.01	0.28	340	-1.720	35.0	100.0	180	39	000	2.0	090
00:49:10	30	-82	30	0	0.01	-0.18	0.28	340	-2.884	35.0	100.0	180	33	000	2.0	090
00:49:20	30	-82	31	0	-0.09	-0.47	0.30	339	-4.882	35.0	100.0	180	39	000	2.0	090
00:49:30	29	-83	46	0	-0.15	-0.71	0.29	338	-6.364	35.0	100.0	180	42	000	2.0	090
00:49:40	28	-84	58	0	-0.32	-0.76	0.20	337	-6.089	35.0	100.0	180	30	000	2.0	090
00:49:50	28	-87	63	0	-0.50	-0.53	0.07	336	-3.763	35.0	100.0	180	28	000	2.0	090
00:50:00	28	-90	64	0	-0.55	-0.55	-0.06	336	-3.067	35.0	100.0	180	32	000	2.0	090
00:50:10	27	-93	61	0	-0.52	-0.53	-0.17	335	-2.314	35.0	100.0	180	26	000	2.0	090
00:50:20	27	-96	65	0	-0.45	-0.36	-0.28	335	-0.524	35.0	100.0	180	45	000	2.0	090
00:50:30	26	-99	65	0	-0.47	-0.31	-0.40	335	0.588	35.0	100.0	180	36	000	2.0	090
00:50:40	26	-102	68	0	-0.55	0.22	-0.50	335	4.591	35.0	100.0	180	33	000	2.0	090
00:50:50	27	-105	68	0	-0.47	0.64	-0.58	337	7.751	35.0	100.0	180	40	000	2.0	090
00:51:00	28	-107	72	0	-0.39	0.75	-0.63	338	8.786	35.0	100.0	180	41	000	2.0	090
00:51:10	29	-108	73	0	-0.28	0.84	-0.71	339	9.811	35.0	100.0	180	41	000	2.0	090
00:51:20	30	-109	73	0	-0.20	0.61	-0.66	341	8.077	19.0	100.0	180	38	000	2.0	090
00:51:30	30	-110	73	0	-0.14	0.36	-0.39	342	4.764	0.0	100.0	180	36	000	2.0	090
00:51:40	30	-110	69	0	-0.03	0.33	-0.03	343	2.287	1.0	100.0	180	39	000	2.0	090
00:51:50	31	-110	38	0	-0.05	0.26	0.11	343	0.917	13.1	100.0	180	38	000	2.0	090
00:52:00	32	-110	49	0	-0.09	0.04	0.19	343	-0.932	27.3	100.0	180	32	000	2.0	090
00:52:10	33	-111	58	0	-0.04	0.14	0.15	343	-0.029	21.9	100.0	330	51	000	2.0	090
00:52:20	34	-110	52	0	0.09	0.32	0.16	343	0.966	15.2	100.0	000	32	000	2.0	090
00:52:30	35	-109	48	0	0.27	0.24	0.21	343	0.172	16.7	100.0	000	43	000	2.0	090
00:52:40	35	-107	48	0	0.45	-0.05	0.22	343	-1.681	24.0	100.0	331	36	000	2.0	090
00:52:50	34	-105	48	0	0.46	-0.14	0.16	343	-1.909	30.8	100.0	331	33	000	2.0	090
00:53:00	34	-102	49	0	0.41	-0.07	0.08	342	-0.931	32.6	100.0	327	41	000	2.0	090
00:53:10	33	-100	49	0	0.43	-0.12	0.00	342	-0.721	34.6	100.0	306	46	000	2.0	090
00:53:20	32	-99	48	0	0.38	-0.20	-0.09	342	-0.675	35.0	100.0	335	36	000	2.0	090
00:53:30	30	-97	49	0	0.31	-0.38	-0.13	342	-1.591	35.0	74.0	063	37	000	2.0	090
00:53:40	28	-96	49	0	0.28	-0.46	-0.16	342	-1.912	35.0	74.0	084	46	000	2.0	090
00:53:50	26	-95	49	0	0.25	-0.31	-0.19	341	-0.740	35.0	99.0	084	45	000	2.0	090
00:54:00	25	-95	53	0	0.15	0.14	-0.24	341	2.419	32.6	99.0	122	47	000	2.0	090
00:54:10	25	-94	56	0	0.10	0.48	-0.20	342	4.318	13.6	99.0	122	31	000	2.0	090
00:54:20	26	-93	56	0	0.10	0.46	-0.03	343	3.108	7.8	99.0	122	41	000	2.0	090
00:54:30	27	-92	56	0	0.20	0.44	0.09	343	2.215	7.1	99.0	237	29	000	2.0	090
00:54:40	28	-91	56	0	0.34	0.28	0.19	343	0.583	8.9	99.0	217	38	000	2.0	090
00:54:50	29	-89	49	0	0.23	0.21	0.24	343	-0.194	11.4	99.0	217	33	000	2.0	090
00:55:00	30	-88	46	0	0.09	0.26	0.30	343	-0.276	12.3	99.0	217	35	000	2.0	090
00:55:10	31	-87	47	0	0.02	0.16	0.34	343	-1.140	18.9	99.0	233	35	000	2.0	090
00:55:20	32	-87	47	0	-0.02	0.24	0.34	343	-0.653	19.0	99.0	210	41	000	2.0	090
00:55:30	34	-86	46	0	0.04	0.21	0.35	343	-0.898	21.6	99.0	235	40	000	2.0	090
00:55:40	35	-86	46	0	0.06	-0.07	0.32	343	-2.458	25.2	99.0	235	37	000	2.0	090
00:55:50	35	-85	47	0	0.08	0.01	0.26	342	-1.548	26.6	99.0	273	44	000	2.0	090
00:56:00	36	-84	47	0	0.06	0.28	0.26	342	0.097	13.7	99.0	236	38	000	2.0	090
00:56:10	37	-84	46	0	0.14	0.13	0.29	342	-1.044	19.3	99.0	268	29	000	2.0	090
00:56:20	38	-82	46	0	0.26	-0.06	0.27	342	-2.059	28.4	99.0	268	30	000	2.0	090
00:56:30	37	-81	47	0	0.22	-0.16	0.19	342	-2.224	35.0	99.0	208	39	000	2.0	090
00:56:40	37	-80	47	0	0.08	-0.27	0.12	341	-2.475	35.0	99.0	208	31	000	2.0	090
00:56:50	36	-80	46	0	0.06	-0.46	0.08	341	-3.454	35.0	99.0	208	38	000	2.0	090
00:57:00	35	-80	46	0	-0.01	-0.74	0.05	340	-5.037	35.0	99.0	208	30	000	2.0	090
00:57:10	33	-82	47	0	-0.20	-0.79	0.05	339	-5.311	35.0	99.0	134	31	000	2.0	090
00:57:20	32	-84	47	0	-0.32	-0.72	0.06	338	-4.951	35.0	99.0	112	41	000	2.0	090
00:57:30	32	-86	53	0	-0.38	-0.39	0.04	338	-2.736	35.0	99.0	112	37	000	2.0	090
00:57:40	32	-88	57	0	-0.37	-0.08	-0.05	337	-0.200	35.0	99.0	112	35	000	2.0	090
00:57:50	32	-90	61	0	-0.31	-0.06	-0.13	337	0.426	35.0	99.0	112	32	000	2.0	090
00:58:00	32	-91	64	0	-0.24	-0.07	-0.24	337	1.103	35.0	99.0	112	33	000	2.0	090
00:58:10	32	-92	63	0	-0.23	0.11	-0.35	338	2.924	35.0	99.0	112	45	000	2.0	090
00:58:20	32	-94	63	0	-0.25	0.58	-0.44	339	6.464	35.0	99.0	112	35	000	2.0	090
00:58:30	33	-95	64	0	-0.27	0.75	-0.47	340	7.690	28.4	99.0	112	39	000	2.0	090
00:58:40	34	-96	64	0	-0.28	0.60	-0.34	341	5.966	14.3	99.0	112	44	000	2.0	090
00:58:50	35	-97	64	0	-0.14	0.35	-0.12	342	2.981							

Simulation Track Plot

Open Ocean

Ship: 150,000 ton, Tanker, partial load

Date: 05-Feb-99 Time: 16:28:24

Start Time [hrs:min:sec]: 00:33:20
End Time [hrs:min:sec]: 00:59:00
Delta Plot Time [sec]: 30
East-West Scale [m]: 926.
East-West Scale [Nm]: 0.5000

Appendix B

REPORT ON APPLICATION TO THE LIVERPOOL BAY PROJECT

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APPENDICES NOT INCLUDED

1.0 Introduction

This report is the result of Service Order SOW/0321 entered into between Hamilton Oil Co. Ltd. and Jens Korsgaard P.E. on April 14, 1994.

The service order relates to the mooring system for the Oil Loading Unit (OLU) for the Liverpool Bay Development Project.

The objectives of the work were:

- o To model test and assess the feasibility of a novel synthetic fiber rope mooring for a submersible mooring buoy
- o To model test and determine the operational limits for the mooring technology developed by Mr. Jens Korsgaard called the Suction Mooring Technology (SMT). SMT consists of mooring a vessel to a submersible buoy by means of a combination of hydrostatic pressure differentials and friction.

The model tests were carried out at the Danish Maritime Institute (DMI) May 8 through May 10 1994 under a contract between Jens Korsgaard and DMI.

2.0 Summary and Conclusions

In a series of communications between Hamilton Oil Co. Ltd. and Jens Korsgaard P.E. in the period September 93 to March 94, conceptual designs for disconnectable moorings for either a shuttle tanker or a Floating Storage Unit (FSU) to be moored in Liverpool Bay for the Liverpool Bay Development Project had been presented. The designs had two novel aspects:

1. The mooring system is a standard submersible Catenary Anchor Leg Mooring (CALM) with a radially deployed anchor line mooring system. However, while the standard system employs only wire rope and/or chain in the anchor line, the anchor line in the new system was comprised of synthetic polyester rope and chain.
2. The mooring is based on the suction mooring technology in which the vessel at least for part of the time is held by a buoy which is forced onto the hull of the tanker by differential hydrostatic pressure, obtained by having a pump take suction in the isolated volume between the top of the buoy and the hull of the vessel.

The first of the above innovations makes it possible to employ submersible CALM buoys in shallow water, it also causes the elastic response of the buoy to become virtually linear in contrast to the strongly non-linear response which is typical for chain or steel wire/chain mooring systems. A secondary benefit of employing synthetic rope is that such rope is nearly weightless in sea water, therefore the synthetic rope exhibits very little catenary action. This factor makes it possible to deploy this type of mooring in wide range of water depths and yet:

- o The elastic characteristics of the mooring changes vary little with water depth. This factor reduces the need for specific water depth related designs and makes it possible to standardize the mooring design and make moorings made up entirely of a few standardized components, capable of being used in wide range of water depths.
- o The mooring may be reused in another project with approximately the same design forces, but with a much different water depth by changing its configuration very little or not at all.

The patented second innovation makes it possible to moor and unmoor in extreme waves at an unprecedented speed. The actual mooring process lasts less than a minute from there being no physical contact or connection between the vessel and the mooring system to the vessel being completely securely moored. Because of this extreme speed of mooring the vessel need not keep station at the point of mooring, it is sufficient that the mooring area on the vessel drifts slowly through the target area. This factor also

contributes to the low cost and reliability of the system.

In the course of the discussions with Hamilton Oil Co. several version were presented including some which have normal structural connections between the buoy and the vessel, however, the systems which were model tested were those in which the vessel is moored solely by the friction between the vessel and the buoy. The buoy is held securely to the bottom of the vessel by differential hydrostatic pressure.

The modeled buoy had 16 mooring legs, represented in the model by 6 legs such that the 6-leg assembly was equivalent in stiffness to the prototype 16 leg system. Although the prototype system will include means to lower the pressure between the buoy and the vessel hull to below atmospheric pressure, the model did not have this capability. In the model the lowest possible pressure at the top of the buoy was atmospheric pressure at a level slightly above the bottom plating elevation of the vessel.

The tests were deliberately planned so that the model set-up would have inferior capabilities to the prototype system with the objective of establishing the capability limits. In spite of this no failure or difficulty occurred in any of the tests.

The tests were conducted in the towing tank at the Danish Maritime Institute in Lyngby, Denmark. The prototype water depth in all tests was 29.8 meters. The scale was 1:50. A stock tanker of 125,000 DWT size was used. The tanker was modified to incorporate the suction mooring technology mooring system. The tanker was used in two loading conditions, fully loaded with a displacement of 149,000 tonnes and in ballasted condition with a displacement of 60,000 tonnes.

The towing tank was too deep for the planned tests and therefore the carriage was fitted with a false bottom to create shallow water. Current was generated in the model by towing the model set-up through the tank at appropriate speeds. Wind was simulated by applying a constant force. All environmental actions were collinear in the tests.

The test report from the Danish Maritime Institute is included in Enclosure D and it describes the test set-up and test results in detail.

The metacentric height of the buoy while being raised without a retrieval line was lower than intended due to a misunderstanding by the model tests laboratory, therefore the rolling and pitching of the buoy while being raised by compressed air is larger than the prototype buoy. While the model buoy performed satisfactorily during all tests without a retrieval line, the corresponding prototype buoy can be expected to perform significantly better. The model buoy being retrieved with a retrieval line always had the proper metacentric height.

The wave conditions used during the tests are given below in table 2-1.

Wave ID	H _s (m)	T _z (sec)
A	6.6	10.1
B	7.7	13.1
C	5.6	9.3
D	5.0	8.9
E	4.7	8.0
F	4.1	7.7

Table 2-1 Test Wave Conditions

A list of all tests with the object of determining the mooring force and main results are given below in table 2-2.

Run No.	Wave ID	Vessel Displacement % of full	Current Speed + head - follow (m/sec)	Wind Force tonnes	Mooring	Maximum Horizontal Mooring Force tonnes
1100	A	100	0	51	Intact	365
1110	A	100	- 1.07	51	Intact	432
1120	A	100	+1.07	51	Intact	389
1200	B	100	0	51	Intact	523
1300	C	100	0	51	Intact	306
1400	D	100	0	51	Intact	365
1410	D	100	- 1.07	51	Intact	295
1420	D	100	+1.07	51	Intact	352
1500	E	100	0	51	Intact	277
1600	F	100	0	51	Intact	172
2100	A	100	0	51	- one leg	210 **
2110	A	100	- 1.07	51	- one leg	178 **
2120	A	100	+1.07	51	- one leg	252 **
5110	A	40	- 1.07	54	Intact	366
5120	A	40	+1.07	54	Intact	377
6100	A	40	0	54	- one leg	202 **
6110	A	40	- 1.07	54	- one leg	191 **
6111	A	40	- 1.07	0	- one leg	203 **
6120	A	40	+1.07	54	- one leg	209 **

** Force in the leg with the largest force (6-leg system)

Table 2-2 Mooring Test Results

A list of all tests with the object of determining the feasibility of the mooring process is given below in table 2-3.

Run No.	Wave Height m	Vessel Displacement % of full	Retrieval Line	Cone	Number of Matings	Largest Impact % of allow.
7100	6.6	40	no	no	3	20
7110	6.6	40	no	no	4	low
7200	7.7	40	no	no	4	58
7400	5.0	40	no	no	5	10
7420	5.0	40	no	no	5	65
7500	4.7	40	no	no	4	low
7520	4.7	40	no	no	3	38
7600	4.1	40	no	no	4	5
8100	6.6	40	yes	yes	5	258
8101	6.6	40	yes	no	8	24
8400	5.0	40	yes	yes	6	low
8401	5.0	40	yes	no	7	11
8500	4.7	40	yes	yes	6	195
8501	4.7	40	yes	no	7	6
8520	4.7	40	yes	yes	4	75
8600	4.1	40	yes	yes	7	123
3100	6.6	100	no	yes	1	43
3600	4.1	100	no	yes	2	46
3601	4.1	100	no	no	2	low
4600	4.1	100	yes	yes	2	low

Table 2-3 Results of Mooring/Unmooring Tests

The main conclusions are the following:

- o A tanker moored solely by differential hydrostatic pressure and the resulting friction between the buoy and the vessel remains safely moored in all tested environmental conditions (waves up to $H_s = 7.7$ meters).

- o An actual full scale system could easily incorporate double the friction compared to that obtained in the model thereby ensuring an adequate safety factor in actual use.

- o The best and safest mooring configuration is one in which the buoy has a flat top and is not fitted with a retrieval line. This configuration performed very well in all mooring tests.

o The next best configuration is a flat top buoy with a retrieval line. This configuration also performed well in all mooring tests and exhibited the lowest impact energies.

o A buoy with an upward pointing male cone, joining a corresponding female cone in the hull, suffered damaging horizontal impacts between the male and female cones in all wave heights tested. This configuration is not recommended. It is probable that a buoy could be constructed of this type which could safely moor in wave heights up to 5 meters.

o The linear characteristics of the tested mooring system causes very substantial reductions in the mooring forces experienced compared to an equivalent non-linear wire rope chain system. Therefore the tested system will require reduced anchor and chain dimensions compared to the traditional wire rope/chain system.

3.0 Mooring Buoy and System of Operations.

The system tested is a mooring system of the suction mooring technology type. The Suction Mooring Technology is described in more detail in enclosure B. The buoy is designed to resist a mooring force of 1200 tonnes and is fitted with 16 anchor legs.

The tested system is near the limit of what can practically be achieved using a submersible buoy. The prototype water depth in the tests was 29.8 meters, leaving only a couple of meters clearance between the buoy and the sea bed when a fully loaded tanker was moored at extreme wave conditions and experienced extreme downward excursions.

3.1 Buoy Configuration.

The tested buoy is shown on figure 3-2. The buoy is comprised of three parts:

A. The part attached to the vessel. This part is cushioned on the top by standard dock fenders acting as, fenders, compression elements, and friction pads. In addition this part is fitted with concentrically deployed pliable fluid seals. Part A is fitted with permanent buoyancy and deballasting tanks are normally not fitted in this part.

B. The part anchored to the sea bed. This part includes all anchor line connections, riser connections, and fluid and signal connections between the vessel and the sea bed. Fluid swivels are not included in the buoy but are located on the vessel. This part is a cylindrical drum which is used routinely as a deballasting chamber. Part B usually also includes compressed air storage tanks.

C. The bearing between parts A and B. This bearing enables the ship to weather vane.

Because of the shallow water depth the buoy would normally descend all the way to the sea bed when not moored to a vessel. This is in contrast to buoys in deeper water which are normally designed to descend to a predetermined water depth rather than all the way to the bottom.

The model test facility had been requested to make the model buoy in accordance with fig 3-1. In reality they made the buoy as indicated on fig 3-2. This deviation resulted in the model buoy having a lower metacentric height when partly ballasted. This had only a practical effect in the cases in which the buoy was deballasted by compressed air. In the case of using retrieval lines to retrieve the buoy there was no internal free water surface, therefore these cases had approximately the intended metacentric height.

Center volume : S. Gr. 1.5 water filled
 S. Gr. 0.8 air filled
 All meas. in mm

Fig. 3-1 Specified Model Buoy

All meas. in mm

Fig. 3-2 Model Buoy Used

Two buoy configurations were tested as indicated on figure 3-1. A configuration with the top conical guide, fitting a corresponding female guide in the vessel was tested, and the alternative configuration with a flat top on the buoy.

3.2 System of Operation

Three ways of mooring the vessel were tested:

- A. Buoy configuration with a male cone retrieved by means of a buoyant retrieval line.
- B. Flat top buoy retrieved by means of a buoyant retrieval line.
- C. Flat top buoy retrieved by deballasting with compressed air.

Three different deballasting systems were used during the tests mentioned under C above:

- 1. Blowing compressed air into the deballasting chamber to force the ballast water out. Ballast water was let back in by removing the compressed air supply.
- 2. Same as one, however, compressed air of equal pressure was applied to both the inlet and outlet to stop the water flow. Ballast water was let back in by removing the compressed air supply.
- 3. A reversible P-D pump was connected to the ballast chamber water connection. The air supply connection was connected to the atmosphere.

System 1 was used in all cases when mooring a fully loaded vessel. System 2 was used for the initial tests with a ballasted vessel, and system 3 was used for the last tests with a ballasted vessel. System 1 could not be properly controlled, whereas systems 2 and 3 could be controlled properly, however, it took too long to reballast the buoy during unmooring using system 2, therefore a switch was made to system 3.

In all cases using systems 2 and 3 the system was tuned to produce a prototype ascent rate of 0.1 m/sec of the buoy in the water column.

In all mooring attempts in the model a dynamic positioning system was approximately emulated by controlling the bow of the vessel by three soft elastic ropes attempting by this means to hold the mooring area of the vessel in proper relations to the buoy.

The actual procedure was equivalent to the planned prototype procedure in which the vessel while still some distance away commands the buoy acoustically to rise to a level about 2 to 3 meters below the keel of the vessel. When the buoy had risen to this level further deballasting is stopped until the movement of the vessel in relation to the buoy is judged to be opportune and the command is issued to resume the ascent. Approximately 30 seconds later (prototype time) the buoy makes contact with the vessel and blocks the bow thruster intake. About 10 seconds later (prototype time) the buoy is securely held onto the vessel by the differential hydrostatic pressure caused by the bow thruster suction.

3.3 Model Vessel Configuration

The model vessel had the following characteristics:

L_{pp} :	258 meters
B:	40.6 meters
Draft:	16.5 meters (fully loaded)
Displacement:	148,950 tonnes (fully loaded)

Additional data on the model vessel is available in enclosure D.

The vessel was equipped with two pumps emulating a bow thruster of the Omnithrusters type or the Elliot Turbo Machinery type. These thrusters take water in at the keel and expel it remotely from the intake area. The prototype pumps would have pumping capacities between 6 and 11 m³/sec whereas the model pumps had a combined capacity corresponding to a prototype pumping rate of 4.5 m³/sec. Thus the model vessel capabilities were significantly below those of the prototype vessel.

A brochure by Elliot Turbo Machinery is enclosed as Enclosure C.

4.0 Impacts between the Buoy and the Vessel

The impacts which were experienced between the buoy and the vessel during the tests depended strongly upon the configuration of the buoy and the method of retrieval. As indicated in the previous chapter three combinations of buoy configuration and retrieval system were tested:

1. Buoy with a conical mating structure and a constant tension winch and a retrieval line.
2. Flat top buoy and a constant tension winch and a retrieval line.
3. Flat top buoy and no retrieval line using compressed air deballasting of the buoy as the means of raising it to the ship's bottom.

System 1 permits horizontal impacts between the conical mating structure on the buoy and the corresponding female cone in the vessel when the male cone enters the female cone in the vessel. All systems permit vertical impacts between the buoy and the bottom of the vessel. Systems 2 and 3 do not permit horizontal impacts between the buoy and the vessel but only vertical impacts.

While the model did not include fendering with the proper stiffness characteristics the model dimensions were based on the provision of specific dock fender units as indicated in figs. 4-1 and 4-2. In the model it was assumed that the fender was already compressed. The model fender was very stiff compared to the prototype fender and therefore only compressed very little during the tests.

The actual performance of the prototype fenders are given in table 4-1.

The performance figures are based on the recommendations by the fender manufacturers and conform to the practice for dock fenders.

For purposes of this report the maximum energy experienced in a test is arbitrarily set to the manufacturer's recommended allowable energy. From this criteria the actual energy experienced in each impact has been calculated as a percentage of the allowable energy.

The actual impact energies experienced during the tests were determined through examination and analysis of the video tapes produced during the tests. An underwater camera had a nearly stationary position relative to the buoy and far removed from the buoy. By examining the video frames from this camera one by one (every 0.02 secs) both the relative angular and translational velocities between the vessel and the buoy can be closely estimated. By analyzing individual frames on the video the impact energies can be estimated with an accuracy of about $\pm 20\%$ from the velocities immediately prior to the impact.

Fig. 4-1 Fenders Buoy with Cone

Fig. 4-2 Fenders Flat Top Buoy

Type of Buoy	Tilt	Maximum Horizontal Impact Velocity (m/sec)	Maximum Vertical Impact Velocity (m/sec)
With cone	N.A.	0.81	see below
Flat Top	0.05	N.A.	2.4
Flat Top	0.10	N.A.	1.95
Flat Top	0.15	N.A.	1.55
Flat Top	0.20	N.A.	1.30
Flat Top	0.25	N.A.	1.15

Table 4-1 Allowable Fender Impact Velocities

All the photos taken from the video tapes are shown in enclosure A. The geometric computations are shown in handwriting on the pictures and the resulting distances and/or angles are shown below each photo. The distances are derived from the known dimensions of the buoy and by using these as scales for the distance measurements.

When a buoy with a male cone as per system 1 impacts the female cone in the vessel both central and eccentric impacts are possible. In consequence all impacts have been conservatively estimated to be central impacts. Vertical central impacts between the buoy and the vessel bottom are possible.

Flat top buoys as per system 2 and system 3 cannot impact the vessel horizontally, only vertical impacts are possible. Central vertical impacts are possible, but cannot cause damage because these impacts are cushioned by the water between the buoy and the vessel hull. The water pressures which would build up would cause large accelerations of the buoy thereby preventing complete compression of the fenders.

Only eccentric impacts with flat top buoys as per systems 2 and 3 can cause damage to the buoy or the vessel.

The analyses of the eccentric impacts were made on the basis that the buoy movement consisted of pure rotation. On the average this assumption is correct, however, for any one specific impact the assumption is conservative if the c.g. of the buoy moves away from the vessel during the impact, and non-conservative if the c.g. of the buoy moves toward the vessel during the impact. The resolution of the photos in general did not permit an evaluation of this factor, it was therefore ignored.

In the analysis of the impacts the reduction in the energy to be absorbed by the fender due to some of the rotational movement being converted to translational movement was ignored. This is a very conservative assumption which in almost all cases leads to an over estimation of forces and energies to be absorbed by the fenders.

In the analysis of the runs a few instances were found in which there is a discrepancy between the second digit in the run number. The confusion only exists between the digits 5 and 6 and therefore the discrepancy may result in the wave heights 4.1 m and 4.7 m being confused in some data. For the purpose of this report this discrepancy has not been resolved, rather the information given in enclosure D (the DMI report) has been assumed to be correct. The discrepancy has no impact on the conclusions to be drawn from the tests.

The results of the tests are given below in table 4-2.

Run No.	Wave Height m	Vessel Displacement % of full	Retrieval Line	Cone	Number of Matings	Largest Impact % of allow.
7100	6.6	40	no	no	3	20
7110	6.6	40	no	no	4	low
7200	7.7	40	no	no	4	58
7400	5.0	40	no	no	5	10
7420	5.0	40	no	no	5	65
7500	4.7	40	no	no	4	low
7520	4.7	40	no	no	3	38
7600	4.1	40	no	no	4	5
8100	6.6	40	yes	yes	5	258
8101	6.6	40	yes	no	8	24
8400	5.0	40	yes	yes	6	low
8401	5.0	40	yes	no	7	11
8500	4.7	40	yes	yes	6	195
8501	4.7	40	yes	no	7	6
8520	4.7	40	yes	yes	4	75
8600	4.1	40	yes	yes	7	123
3100	6.6	100	no	yes	1	43
3600	4.1	100	no	yes	2	46
3601	4.1	100	no	no	2	low
4600	4.1	100	yes	yes	2	low

Table 4-2 Results of Mooring Tests

5.0 Vessel remaining Moored by Differential Pressure and Friction.

A series of tests was carried out in which the vessel was moored and remained moored by the action of differential hydrostatic pressure and friction only. The differential hydrostatic pressure was created by having two pumps with a combined capacity of 4.5 m³/sec take suction in the mooring well. Atmospheric air had free access to the well, therefore the minimum possible absolute pressure inside the well was atmospheric pressure at a level immediately above the keel of the vessel.

The external pressure in the 40% displacement situation was equal to atmospheric pressure plus on the average 4.5 meters head. This modest pressure proved sufficient in all cases to hold the buoy securely attached to the vessel. This was a surprising result because in some cases the bow of the vessel slammed and in at least one case atmospheric air reached the buoy. In this case it would appear that the internal pressure would be the same or larger than the external pressure and therefore the buoy should release immediately. It is believed that the reason it did not happen is that the continuity equation requires that the water filling the expanded volume between the buoy and the vessel be accelerated to move into the void, and the time available did not permit this. For the same reason the friction between the vessel and the buoy hardly diminished either. Since the model laws governing the model tests (Froude's Law) also governs this phenomenon this result would also be obtained in the prototype.

In all the tests the buoy was held by pressure and friction only. In no tests did the buoy ever slip. Considering the very low differential pressure used in all 40% displacement tests it can be concluded that with a pump aboard the vessel capable of lowering the pressure between the buoy and the vessel to say 50 kPa that an adequate safety factor against slipping is assured and this type of mooring is **safe in all wave heights tested.**

The Mooring system modeled is comprised of 16 mooring legs made up of a combination of polyester rope and chain as indicated in Figure 5-1. The mooring rope is almost neutrally buoyant and therefore does not provide any significant catenary action. The elasticity of the system is in consequence derived from a combination of the non-linear elastic extension of the synthetic rope and the non-linear catenary action of the chain legs. The combination of all these elastic elements result in a nearly linear stress-strain curve as indicated on figure 5-2.

Fig. 5-1 Buoy Mooring System

Fig. 5-2 Mooring Force-Deflection Curve

The tests are described in more detail in Enclosure D, the report from the Danish Maritime Institute. The details are not repeated here but the results are summarized below in table 5-1.

Run No.	Wave ID	Vessel Displacement % of full	Current Speed + head - follow (m/sec)	Wind Force tonnes	Mooring	Maximum Horizontal Mooring Force tonnes
1100	A 6.6	100	0	51	Intact	365
1110	A	100	- 1.07	51	Intact	432
1120	A	100	+ 1.07	51	Intact	389
1200	B 7.7	100	0	51	Intact	523
1300	C 5.6	100	0	51	Intact	306
1400	D 5.0	100	0	51	Intact	365
1410	D	100	- 1.07	51	Intact	295
1420	D	100	+ 1.07	51	Intact	352
1500	E 7.7	100	0	51	Intact	277
1600	F 4.1	100	0	51	Intact	172
2100	A	100	0	51	- one leg	**
2110	A	100	- 1.07	51	- one leg	**
2120	A	100	+ 1.07	51	- one leg	**
5110	A	40	- 1.07	54	Intact	366
5120	A	40	+ 1.07	54	Intact	377
6100	A	40	0	54	- one leg	**
6110	A	40	- 1.07	54	- one leg	**
6111	A	40	- 1.07	0	- one leg	**
6120	A	40	+ 1.07	54	- one leg	**

** Not measured

Table 5-1 Mooring Test Results, Maximum Horizontal Buoy Force

In table 5-2 below is given the largest force in the heaviest loaded leg of the 6-leg system tested.

Run No.	Wave ID	Vessel Displacement % of full	Current Speed + head - follow (m/sec)	Wind Force tonnes	Mooring	Maximum Horizontal Force in One Leg tonnes
1100	A	100	0	51	Intact	237
1110	A	100	- 1.07	51	Intact	264
1120	A	100	+1.07	51	Intact	245
1200	B	100	0	51	Intact	308
1300	C	100	0	51	Intact	206
1400	D	100	0	51	Intact	234
1410	D	100	- 1.07	51	Intact	202
1420	D	100	+1.07	51	Intact	222
1500	E	100	0	51	Intact	192
1600	F	100	0	51	Intact	160
2100	A	100	0	51	- one leg	210
2110	A	100	- 1.07	51	- one leg	178
2120	A	100	+1.07	51	- one leg	252
5110	A	40	- 1.07	54	Intact	229
5120	A	40	+1.07	54	Intact	233
6100	A	40	0	54	- one leg	202
6110	A	40	- 1.07	54	- one leg	191
6111	A	40	- 1.07	0	- one leg	203
6120	A	40	+1.07	54	- one leg	209

Table 5-2 Maximum Force in the Heaviest Loaded Leg

Appendix C

MAIN REPORT FROM PHYSICAL MODEL TESTS AT THE DANISH MARITIME INSTITUTE

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APPENDICES:

Appendix A : Video Tapes.

Appendix B : Results.

Appendix C : Waves.

Appendix D : Model Details.

THESE APPENDICES ARE NOT INCLUDED
IN THIS DOCUMENT

1. INTRODUCTION

This report presents the main results obtained from a study of a disconnectable mooring system developed primarily for shuttle tankers. The study has been carried out for Mr. J Korsgaard, U.S.A. by Danish Maritime Institute.

The concept utilizes a moored buoy with a buoyancy chamber enabling the level of the buoy below the surface to be controlled. The buoy is fixed to the vessel by the surrounding water pressure, i.e. once the buoy has made contact with the vessel the water which is in the moonpool and above the buoy is removed, thereby establishing a pressure difference. The water from the moonpool is removed by the bow thruster which has its intake close to the moonpool orifice. Water leaking past the buoy/vessel sealing is removed continuously by a drainage pump. Decoupling is performed by pumping water into the moonpool thereby removing the pressure difference which otherwise holds the buoy to the vessel.

The objective of the study was primarily to investigate the feasibility of the concept from a technical point of view, i.e. if it worked or not when exposed to harsh as well as moderate environmental conditions and to clarify any limiting effects.

Physical model tests with the concept have been carried out with a typical vessel loaded to two different draughts corresponding to fully and partially loaded. Both tests with the vessel moored to the buoy and the mating / decoupling phase have been tested.

The tests were carried out in May 1994 and were supervised by Mr. J. Korsgaard.

2. SUMMARY AND CONCLUSIONS

A series of physical model tests have been carried out with a disconnectable mooring system developed primarily for shuttle tankers. The mooring system consists of a moored buoy which when not in use is kept submerged at a certain level below the sea-surface. Once the shuttle tanker has arrived and is positioned above the buoy, ballast water is removed from the buoy which then rises up under the vessel. At the same time the fore thruster is used to pump water from the moonpool thereby causing the buoy to be sucked to the vessel due to the pressure difference. A large seal at the outer edge of the buoy prevents damage to the vessel and buoy and ensures that a minimum amount of water is able to flood into the moonpool. Water, which enters the moonpool, is continuously removed by drainage pumps. The reverse situation where the vessel is to decouple from the buoy involves pumping water into the moonpool thereby eliminating the holding pressure thus causing the buoy to release.

A number of tests have been carried out with a typical vessel loaded to two different conditions corresponding to fully and partially loaded. The tests encompassed both the condition where the vessel is moored to the buoy and held on station solely by the mooring system as well as the mating / decoupling situations. In both types of tests the vessel was exposed to a range of different environmental conditions covering both moderate and very harsh situations.

The results from the tests are presented in the form of statistical values for each run, time series of e.g. mooring line forces and video tapes of all the tests.

None of the tests with the vessel attached to the buoy showed any indication of the buoy slipping regardless of the environmental conditions which the vessel was exposed to.

Numerous mating and decoupling tests were carried out using either a retrieval line or controlled buoyancy to bring the buoy up under the vessel. The tests showed that this operation could be performed successfully with both methods under both moderate and severe environmental conditions. Tests were carried out with and without the torus fender included. These tests showed that the mating operation is easier to perform without the torus fender as the fender tends to displace the buoy when the fender collides with the moonpool orifice.

3. DESCRIPTION OF EXPERIMENTAL FACILITIES AND MODELS

This Chapter describes the vessel, buoy and various techniques used in this study. Furthermore, the documentation for the anchor system is included in this Chapter, while all other results are presented in Chapter 8 and Appendix B.

3.1 Vessel Particulars and Loading Conditions

The main dimensions of the vessel are listed in Table 3.1 together with the two loading conditions used.

Dimension		100% Loaded	40% Loaded
Displacement	(m ³)	148950	60200
Length (L _{pp})	(m)	258.3	258.3
Breadth	(m)	40.6	40.6
Depth	(m)	21.9	21.9
Draught, fore	(m)	16.5	5.95
Draught, aft	(m)	16.5	7.95
Radii of gyration, r _x (roll)	(m)	16.3	15.6
Radii of gyration, r _y (pitch)	(m)	62.4	63.6
Radii of gyration, r _z (yaw)	(m)	62.4	64.5
Vertical distance to cog V _{cg}	(m)	11.5	12.1
Longitudinal distance to cog L _{cg}	(m)	8.6	6.7

Table 3.1. Vessel Particulars and Loading Conditions.

3.2 Physical Modelling

The model design is based on Froude scaling, which ensures that the gravitational and inertia forces are modelled correctly if the Froude number is the same in the model as in full-scale. Froude's number is defined as:

$$F = \frac{V}{\sqrt{g \cdot L}}$$

where g is the acceleration of gravity, L a characteristic length and V a characteristic velocity.

Froude modelling leads to the following scales from full size to model:

Length	:	1:50
Time	:	$1:50^{1/2}$
Mass	:	$1:(50^3 \cdot 1.025)$
Force	:	$1:(50^3 \cdot 1.025)$

The factor of 1.025 is used to compensate for the different water densities due to the fact that the water in the tank is non-saline.

Froude's model law assumes that the fluid is ideal, i.e. viscous forces are not modelled correctly. Hence its validity is restricted to the potential flow regime. Therefore skin friction and drag forces - depending of the geometry - are not modelled entirely correctly.

3.3 Experimental Models

This section gives a brief description of how the various models were built.

3.3.1 Vessel

A modified stock tanker was used for these tests. The modifications consisted of installing a moonpool (10 m diameter) 40 m from the fore perpendicular.

The moonpool consisted of two tubes inserted into each other. The outer tube was fixed to the vessel by a ring with a curved inner side which was mounted flush with the bottom of the hull. The inner tube which could be moved up and down had a clear ceiling enabling the motion of the buoy relative to the vessel to be monitored. The purpose of the ceiling was primarily to reduce the volume of water which had to be removed. A small air-vent tube was led through the ceiling thus ensuring that the minimum pressure in the chamber above the buoy corresponded to the surrounding atmosphere. This tube was further used for the retrieval line.

Two holes were made side by side and just in front of the moonpool where the curved ring turns into the flat bottom of the vessel. Tubes were glued into the holes and led to pumps which could remove the water in the moonpool and discharge it at the stern. The pumps simulated the intake of the thruster though providing somewhat less capacity than the proposed thruster is capable of. The capacity of the pumps was measured to approximately $4.5 \text{ m}^3/\text{s}$. The design originally called for $6 \text{ m}^3/\text{s}$ which later was revised to $11 \text{ m}^3/\text{s}$.

The principle is illustrated in Figure 3.1 below.

Figure 3.1. Moonpool.

The clear ceiling was for the majority of the tests placed 3 m above the bottom of the hull. However, for the tests where a force gauge was placed in the retrieval line (Run Nos. 8100-8600) the height of the ceiling above the bottom of the hull was increased to 5.2 m.

3.3.2 Buoy

The buoy was designed based on information provided by Mr. J. Korsgaard in fax to DMI dated 1994-04-04. Figure 3.2 shows the main dimensions of the buoy. In order to protect the protruding air / water attachments an additional and neutrally buoyant protection ring was mounted under the buoy. The detachable torus fender mounted on top of the buoy was made of foam-rubber, while the sealing at the outer edge of the buoy was made of a latex hose in order to provide sufficiently soft characteristics.

Various systems were devised to control the amount of water in the internal buoyancy chamber. In the final version a water pump was used to either suck out or pump in the water. This was done by attaching a flexible and submerged hose to the water outlet pipes leading into the chamber while the similar air pipe was attached to the water pump. This set-up provided an efficient control of the buoy level.

Figure 3.2. Buoy with Detachable Fender.

See also Appendix D for further details.

3.3.3 Mooring system

The system as designed utilizes 16 lines. These were for practical reasons represented by 6 lines, i.e. each line corresponds to approximately 2.7 lines. In order to obtain the desired stiffness of the mooring system springs are inserted into the lines. The characteristics of the springs are obtained by measuring the elongation versus load and adjusting the spring length until the desired stiffness has been obtained.

Figure 3.3 shows the target and obtained stiffness for the system (100% loading condition).

Figure 3.3. Desired and Obtained Mooring System Characteristics.

The 6 lines are oriented in a symmetrical layout with 60° between the lines as depicted in Figure 3.4.

Figure 3.4. Mooring System.

A pretension corresponding to 1.04 MN was specified for each line. The pretension in each line was obtained by leading the lines through blocks mounted just over the sea bed to blocks above the water and attaching appropriate clump weights (corresponding to 1.04 MN) to the end of the lines. This system was used to position the buoy correctly with the correct pretension.

Once positioned, the lines were locked at the above-water block, thereby transferring buoy and vessel motion to the stiffness model, i.e. the springs mounted in the lines.

3.4 Tank Facility

The tests were conducted in DMI's large towing and wave generation tank, which is 240 m long, 12 m wide and has a normal water depth of 5.3 m.

The tank is equipped with wave generation facilities at one end and a wave absorbing beach at the opposite end. The wave generator consists of a double hinged paddle which is controlled remotely, enabling either regular or irregular waves to be generated in the tank.

The wave time series were synthesized using a method developed by M.S. Longuet-Higgins (c.f. "On the Joint Distribution of Periods and Amplitudes of Sea Waves", J. Geophysical Research, Vol. 80 pp 2688-2694, 1975). In short the method provides a correct joint distribution of wave heights and periods while at the same time fulfilling the condition that the resulting time series must not contain any regular events which could otherwise occur from an inverse Fourier expansion with regular frequency intervals. In the present case 500 components were used in the generation of each of the wave time-series.

A current is simulated by towing the whole test set-up through the tank. The test set-up is mounted under a carriage running on rails above the tank. Due to the limited water depth required for these tests (29.8 m in full-scale) a 12 x 12 m artificial bed was mounted on the carriage. The size of the bed corresponds to 600 x 600 m in full-scale.

3.5 Instrumentation

Line Forces:

Haul-in line as well as mooring-line forces are measured by inserting a force transducer in each line, i.e. the force is transferred from the vessel/buoy through the gauge to the line. The transducers are calibrated prior to mounting by hanging them vertically and attaching a number of calibrated weights, thus obtaining the relation between signal output and force imposed. During the tests the gauges are kept under water, thus ensuring that no temperature drift, etc., occurs. The integrity of the transducers is checked regularly under calm conditions.

Wave Gauges:

Waves or surface elevation is measured with conductance-type gauges, which are calibrated by immersing the gauges in steps, thus obtaining the relation between water level and conductance.

While calibrating the waves three gauges were placed across the centre of the artificial bed, where the position of the centre gauge corresponds to the position of the moonpool under calm conditions.

The centre wave gauge was moved to a position up front of the vessel and to the port side so as not to interfere with the mooring system and station-keeping system.

3.6 Data Logging

Time series are sampled at 30 Hz using a PC equipped with A/D facilities. Prior to logging the signals are amplified within a range of $\pm 10V$ and filtered by analog low-pass filters to prevent folding of undesired frequency components in the analog/digital data logger.

Data logging consists of three sequences: "zero-check", "span/gain-check" and actual measurement of the instantaneous signal.

The "zero-check", which represents a transducer offset, is logged for 60 seconds before a test and under calm conditions. For all channels the mean value obtained during the "zero-check" is subtracted from the time series during the data processing.

The "span/gain-check" serves as calibration check of amplifiers, filters, transmissions, interface and the data-acquisition computer before a test. The "span/gain-check" is logged for 60 seconds after the "zero-check" has been logged. The obtained values are used in the data processing for calibration or conversion purposes.

Both these checks are performed when the model has been changed or some time has elapsed, thus ensuring that the signals are converted correctly. The checks are, however, not performed when running a number of tests in a rapid succession where the model is not interfered with. In this case the values from the "zero-check" and "span/gain-check" are inherited from one run to the next until these checks are performed again.

3.7 Video

Video recordings are made of all tests using the PAL-VHS system. Four cameras are used:

- Moonpool Camera: Mounted inside the moonpool and giving a view of the buoy from above.
- Underwater Camera: Giving a side view of the buoy and vessel (port side of the vessel).
- Top Camera: Mounted above the vessel. A longitudinal and transversal scale is mounted close to the moonpool giving an approximate indication of the motions. The distance between the marks (from right edge to right edge) is 5 cm corresponding to 2.5 m in full-scale.
- Front/Side Camera: Mounted above water and giving an upfront view of the vessel from the port side.

All video recordings are made in model scale, i.e. $50^{1/2}$ times faster than in full-scale. Once data logging is started, a digital clock is activated. This shows the time in model scale and is in synchronization with the time series of the various parameters presented. The latter are, however, shown with a full-scale time-axis, i.e. $50^{1/2}$ slower than in model scale.

4. TEST SET-UP AND PROCEDURES

4.1 Test Set-Up

The test set-up is depicted in Figure 4.1.

Figure 4.1. Test Set-Up.

4.2 Test Procedures

4.1.1 Moored condition tests

During the moored condition tests the vessel was held by the buoy solely by water pressure, i.e. no measures were taken to ensure that the buoyancy chamber was filled with air. Water leaking past the outer ring seal was removed by the moonpool pumps which ran continuously. The majority of these tests were carried out with the mooring system intact. However, some tests were deliberately carried out with one line missing. In these tests Line No. 1 was removed leaving the buoy moored by Line Nos. 2, 3, 4, 5 & 6.

4.2.2 Mating/decoupling tests

The position of the vessel was controlled manually by hauling in or letting out lines attached to the bow of the vessel while a non-controllable line was attached to the bow. In order to give a reasonably realistic vessel response soft latex springs were mounted in all lines attached to the vessel, thus enabling the vessel to respond to the environmental loads. With no tension on the control lines the vessel was offset downwards and to the starboard side of the buoy. Hence, before the mating procedure was initiated the vessel was hauled into the approximate position using the moonpool video camera and underwater side-view video camera as aids.

Two different methods for mating were tested:

- While submerged in the holding or stand-by position water was removed from the buoyancy chamber and replaced by air causing the buoy to rise upwards towards the vessel.
- While submerged in the holding or stand-by position a near constant tension force was applied to the retrieval line causing the buoy to be pulled up to vessel.

In both cases the moonpool water pumps were activated just prior to mating ensuring that a pressure difference was established quickly. Once mated the continuous removal of water leaking past the seal and into the moonpool was removed thus ensuring that the buoy was kept in place.

Similar, the decoupling procedure was performed as follows:

- Water was led into the buoyancy chamber and through the air-vent tube in the moonpool ceiling thereby increasing the pressure until the buoy was released.
- The tension in the retrieval line was reduced while water was being pumped into the moonpool until the buoy was released.

In both cases the moonpool water pumps were turned off prior to commencing the decoupling procedure. The control lines were only held loosely during the decoupling sequences thus letting the vessel fall back when released.

Mating/decoupling tests were repeated as often as possible within the available one hour (full-scale) test time.

5. TEST PROGRAMME

This chapter describes the environmental conditions and the number system used to identify the individual test.

5.1 Environmental Conditions

5.1.1 Waves

The waves generated in the tank for this particular series of tests are based on the JONSWAP spectrum. Obtained values based on the no current situation are presented in Table 5.1 below:

Wave ID	H _s (m)	T _z (s)	T _p (s)
A	6.6	10.1	12.1
B	7.7	13.1	13.6
C	5.6	9.3	8.7/(12.0) *
D	5.0	8.9	9.1
E	4.7	8.0	8.8
F	4.1	7.7	8.4

* A second peak exists at 12.0 s.

Table 5.1. Obtained Wave Parameters.

The abrupt transition from deep water to shallow water makes it difficult to generate pre-specified wave conditions. The above values were obtained during a number of trial and error tests.

The above conditions are documented in Appendix C.

5.1.2 Wind

A simple pulley and weight system was used to provide a wind load corresponding to 51 t for the 100% load condition and 54 t for the 40% load condition and acting at the stern at deck level.

5.1.3 Current

A head-on and following current corresponding to 1.07 m/s was generated by moving the entire test set-up through the tank while generating waves.

5.1.4 Water depth

A water depth of 29.8 m was maintained over an area of 600 x 600 m during the tests.

5.2 Test Numbers

A four digit number is used to identify the content/configuration of the individual runs. The significance of the individual digit - from left to right - is as follows:

First Digit (Configuration):

- 1 : 100% loaded - intact mooring system
- 2 : 100% loaded - one leg out
- 3 : 100% loaded - mating/decoupling with air assistance
- 4 : 100% loaded - mating/decoupling with retrieval line

- 1 : 40% loaded - intact mooring system
- 2 : 40% loaded - one leg out
- 3 : 40% loaded - mating/decoupling with air assistance
- 4 : 40% loaded - mating/decoupling with retrieval line

- 9 : Other

Second Digit (Waves):

- 1 : A - $H_s = 6.6$ m $T_z = 10.1$ s $T_p = 12.1$ s
- 2 : B - $H_s = 7.7$ m $T_z = 13.1$ s $T_p = 13.6$ s
- 3 : C - $H_s = 5.6$ m $T_z = 9.3$ s $T_p = 8.7/12.0$ s
- 4 : D - $H_s = 5.0$ m $T_z = 8.9$ s $T_p = 9.1$ s
- 5 : E - $H_s = 4.7$ m $T_z = 8.0$ s $T_p = 8.8$ s
- 6 : F - $H_s = 4.1$ m $T_z = 7.7$ s $T_p = 8.4$ s

Third Digit (Current):

- 0 : None
- 1 : Following (1.07 m/s)
- 2 : Head-on (1.07 m/s)

Fourth Digit (Run number):

- 0-9 : Individual run-number. See tables for further information.

Run No.	Waves, current and wind			Comments
1120	A	Head-on	51 t	<i>Mooring system: Intact:</i>
1100	A	None	51 t	
1110	A	Following	51 t	
1200	B	None	51 t	
1300	C	None	51 t	
1420	D	Head-on	51 t	
1400	D	None	51 t	
1410	D	Following	51 t	
1500	E	None	51 t	
1600	F	None	51 t	
2120	A	Head-on	51 t	<i>Mooring system: One leg out (No.1):</i>
2100	A	None	51 t	
2110	A	Following	51 t	

Table 5.2. Load condition: 100% - Vessel Attached to Buoy - Torus Fender Included

Run No.	Waves, current and wind			Comments
3100	A	None	None	<i>Mating/decoupling w/o retrieval line:</i> Torus fender excluded.
3600	F	None	None	<i>Mating/decoupling with retrieval line:</i> Torus fender included
3601	F	None	None	
4600	F	None	None	

Table 5.3. Load Condition: 100% - Mating / Decoupling.

Run No.	Waves, current and wind			Comments
5120	A	Head-on	54 t	<i>Mooring system: Intact:</i> <i>Mooring system: One leg out (No.1):</i>
5110	A	Following	54 t	
6120	A	Head-on	54 t	
6100	A	None	54 t	
6110	A	Following	54 t	
6111	A	Following	None	

Table 5.4. Load Condition: 40% - Vessel Attached to Buoy - Torus Fender Excluded.

Run No.	Waves, current and wind			Comments
7100	A	None	None	<i>Mating/decoupling w/o retrieval line:</i>
7110	A	Following	None	
7200	B	None	None	
7400	D	None	None	
7420	D	Head-on	None	
7500	E	None	None	
7520	E	Head-on	None	
7600	F	None	None	

Table 5.5. Load Condition: 40% - Mating / Decoupling. Torus Fender Excluded.

Run No.	Waves, current and wind			Comments
8100	A	None	None	<i>Mating/decoupling with retrieval line:</i> Torus fender included Torus fender excluded Torus fender included Torus fender excluded Torus fender included Torus fender excluded Torus fender included Torus fender included
8101	A	None	None	
8400	D	None	None	
8401	D	None	None	
8500	E	None	None	
8501	E	None	None	
8520	E	Head-on	None	
8600	F	None	None	

Table 5.6. Load Condition: 40% - Mating / Decoupling with Retrieval Line.

6. DATA ANALYSIS

This Chapter gives a brief description of the how the obtained data is analysed and presented. All values presented have been converted to full-scale if not specifically mentioned otherwise.

6.1 Data Analysis

Based on the logged time series of the various signals, i.e. surface elevation and line forces, the mean, minimum, maximum and rms values are calculated for the various parameters. The minimum and maximum values are relative to zero and represent the extreme values encountered within the duration of a test. The mean and rms values for the various parameters are calculated as:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$$

$$x_{rms} = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2}$$

where:

- N : Total number of data points.
X_i : Value of data point number i.

The various wave cases are further documented in form of wave energy spectra and Weibull plots showing the distribution of the wave heights within each condition.

6.2 Presentation of Results

Results from the tests are presented in the form of time series and tables containing statistical values as outlined in the previous paragraph. All mooring-line forces presented include the pretension of 1.04 MN.

It should be noted that the mooring-line forces presented from the tests where mating / decoupling was performed are influenced by the station-keeping system and therefore do not necessarily represent the actual loads which may be encountered if the vessel is held solely on station by the buoy. The time series from these tests have been included as they very clearly show when the mating/decoupling has occurred.

All tests are further documented by video recordings.

Furthermore, the horizontal force on the buoy is presented as the vectorial sum of the line forces. It should be stressed that this force is only approximate as the instantaneous position of the buoy is not measured, i.e. it is assumed that the angles between the lines remain constant (60°).

7. EVALUATION OF MEASUREMENTS AND RESULTS

It proved difficult to obtain the originally specified wave conditions in the tank due to the abrupt transition from deep to shallow water and back to deep water again. A considerable more elaborate set-up would be required in order to improve the ability of achieving the target values. However, for evaluating the feasibility of the concept the conditions produced in the tank provide ample and valuable information.

In general the equipment used for the tests worked as intended. With the 100% loading condition tests frequent shipping of green water was observed. During these tests the integrity of the vessel was checked regularly and any bilge water was removed.

The buoy had when held by the pretensioned mooring lines not originally sufficient buoyancy to float it to the surface. The available buoyancy was, however, sufficient to perform all the 100% loading conditions tests. In order to perform the 40% loading condition tests the ballast in the buoy was reduced, without changing the outer geometry of the buoy.

The capacity of the moonpool pumps used for the tests was somewhat below what had been anticipated. An increased capacity would have meant a faster discharge rate thereby establishing the necessary pressure difference at an earlier stage.

8. RESULTS

The results are presented in Appendix B which for each run describes the configuration, environmental conditions and obtained results.

8.1 Moored Vessel Tests

In general the vessel responded as expected and no unusual observations were made though frequent shipping of 'green water' occurred during the tests with the vessel loaded to the 100% condition.

In the test cases with a following current the wind load maintained the orientation of the vessel and no abnormal behaviour was observed. It should be noted that no information was readily available as regards the pressure centre of the wind. In these tests the load centre was placed at deck level at the stern.

None of the tests showed any indication that the buoy was unable to hold the vessel as no relative motion between the vessel and buoy was observed regardless of the load condition and environmental conditions.

Similar results were obtained for the tests with one leg out. The missing leg caused the vessel to fall back, thereby occasionally lowering the line force of Line No 4 below the pretension value. Again no relative motion between the vessel and buoy was observed.

Figures 8.1 and 8.2 show the maximum encountered mooring line forces for the 100% and 40% load condition as function of Run Number.

Approximately 35 l/s leaked passed the vessel/buoy seal when then vessel was moored to the buoy.

Figure 8.1. Maximum Mooring Line Forces - Load Condition: 100% .

Figure 8.2. Maximum Mooring Line Forces - Load Condition: 40%.

8.2 Mating / Decoupling Tests

Numerous mating/decoupling tests were made under both moderate and severe conditions. The tendency for the buoy to pitch/roll is reduced significantly as the buoy approaches the vessel and in general the mating was well controlled. The torus fender did at times make it more difficult to perform the mating as it tended to collide with the moonpool orifice thus displacing the buoy before sufficient suction was available. Removing the torus fender speeded up the mating process and in general made it easier to perform the task.

It should be noted that the mooring line forces presented from the tests where mating / decoupling was performed are influenced by the station-keeping system, and therefore do not necessarily represent the actual loads which may be encountered if the vessel is held solely on station by the buoy. A number of these time-series have, however, been included as they very clearly show when the mating / decoupling has occurred.

8.3 Retrieval Line Load Versus Buoy Level

Two indicative tests were carried out where the load in the retrieval line was measured as function of the depth of the buoy below the hull. The results from these tests are presented in Figure 8.3.

Figure 8.3. Retrieval Line Load Versus Depth of Buoy Below Hull.

The Hydrostatic Mooring System

**Final Technical Report
Appendices D, F, G, H, & I
Volume 2 of 2**

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THE HYDROSTATIC MOORING SYSTEM

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SUBMITTAL TO THE AMERICAN BUREAU OF SHIPPING

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The Hydrostatic Mooring - A Brief Overview.

1. Concept

The Hydrostatic Mooring is a single point mooring of the type that attaches to the keel of the vessel. Existing similar concepts comprise the Submerged Turret Loading (STL) provided by Advanced Product Loading and the Turret-Collet type buoy moorings provided by Single Buoy Moorings and SOFEC. These existing systems rely on structural connectors of the hydraulic clamp type to effect the structural connection between the buoy and the vessel. The STL has the structural swivel built into the buoy whereas the turret-collet type buoy mooring has the structural swivel built into the vessel.

The Hydrostatic Mooring has the structural swivel built into the buoy, but in contrast to the other submerged systems relies on a combination of compressive and friction forces between the hull of the vessel and the buoy to transmit the mooring forces from the vessel to the buoy. The Hydrostatic Mooring is shaped like a giant suction cup and reducing the hydrostatic pressure in the volume between the buoy and the hull creates a large compressive force between the buoy and the vessel hull. The mooring is attached to the ship's hull as shown on Figure 1 below.

Figure 1

The volume between the ship's hull and the mooring is isolated from the sea by the circular seal shown on figure 1. The suction pump takes suction within this volume and lowers the absolute pressure to for example 50 kPa within the volume. The exterior pressure is at least atmospheric (100 kPa) thus the disk is pressed upward as indicated by the upward arrows. This upward force is resisted by the compression elements within the volume. The downward pointing arrows illustrate the compressive forces. These compressive forces resist any vertical mooring forces. There is friction between the hull and the compression elements. This friction provides the means to resist horizontal forces between the mooring buoy and the hull. The mooring lines shown in figure 1 provide the means to transmit the mooring forces to the seabed.

The potential of this mooring system is illustrated by the following numerical example:

Ships draft in the mooring area:	5 meters
Sealing ring diameter	20 meters
Mooring pressure:	50 kPa (absolute)
External pressure:	150 kPa (absolute)
Friction coefficient:	20%

Mooring area calculated:	$\pi/4 \cdot 20^2 = 314 \text{ m}^2$
Compressive force calculated:	$314 \cdot (150 - 50) = 31400 \text{ kN}$
Max. horizontal force calculated:	$20\% \cdot 31400 = 6280 \text{ kN}$

The maximum horizontal force in this example is comparable to a normal design force for a FPSO in an extreme ocean environment. Several avenues are available to increase the force capability of the above sample mooring. The sealing ring diameter can in most cases be doubled, the friction coefficient can be increased by proper materials selection and finally ballasting operations can increase the pressure differential. In this manner this mooring can resist even extreme ice forces. Consequently, the hydrostatic mooring has the capability of mooring all large ships in the Arctic or ocean environment.

A more detailed view of the Mooring concept is shown in Figure 2 below:

Figure 2

This more detailed view shows two annular seals between which the hydrostatic pressure is lowered. This reduces the compressive force somewhat, but then permits the maintenance of for example atmospheric pressure in the center area of the buoy. The fluid connection is made within the structural swivel area. The fluid swivel is on the vessel. This is similar to the STL arrangement. Also note the fenders that prevent damaging impacts between the buoy and the vessel.

The Hydrostatic Mooring is under continuous development. One standardized system is sought fitting virtually all situations from the deepest water to depths that are barely enough for the vessel.

2. Application Example.

The application example is for a transport system in which water is transported from Manavgat in Turkey to Ashkelon in Israel. The vessels used are either VLCC or ULCC.

The following describes only the Ashkelon mooring. The mooring in Turkey is similar. A buoy that has an outer sealing ring diameter of 21 m is chosen for either class of vessel. The vessel must have flat bottom plating in the mooring area with a width on the order of 28 m or more for this to work effectively and safely. Tests show that the mooring operation can easily be performed with a precision of 2 meters in conditions with wave heights of $H_s=5$ m or below regardless of cross currents and wind. Mooring is consistently possible on the first attempt in all wave heights up to $H_s=8$ meters regardless of wind and cross current conditions. The accuracy deteriorates to a typical error of 3 meters at 8 meter wave heights. Mooring operations are probably feasible in even higher wave heights, but this may be of theoretical interest only, because operations on the vessel will be curtailed in any event at these extreme conditions.

2.1 Met-Ocean Conditions Ashkelon

The environmental condition in Ashkelon and in Manavgat is described by the following:

- $H_s=2.0$ meters Exceeded 50 days per year
- $H_s=5.0$ meters Exceeded 3.8 days per year
- $H_s=6.0$ meters Exceeded 0.6 days per year
- $H_s=8.0$ meters Return Period 50 years

The current at Ashkelon is reported to be usually north going with a speed of 0.5 knots. For design purposes at this time a design current of 1.5 knots is assumed.

The wind speed is generally quite low at Ashkelon and the maximum-recorded wind speed is 35 knots.

2.2 Mooring Design Conditions.

A system designed for a maximum wave height of $H_s=5.0$ m will have 99% availability and weather delays is not a concern. The required precision for mooring can be set to be 2.0 m in accordance with the results from the maneuvering tests performed. In the actual design a 3.0 meter tolerance will be provided.

For purposes of this document the mooring is designed for a maximum horizontal mooring force of 6000 kN.

The buoy is secured to the ship by differential hydrostatic pressure. The present buoy is designed for water transport. It has two sealing rings, one at 10.5 m radius and another at 4 meter radius. The pressure in the area between the two sealing rings is typically maintained at 50 kPa (absolute). This is done through pumps aboard the moored vessel that take suction within the space between the two sealing rings. The vessels to be moored by this buoy must have a minimum width of flat bottom plate of 28 meters (60,000 DWT). There is no upper limit on ship size other than the limit on force caused by the combination of ship size and environmental conditions and potential water depth limitations.

The submergence of the hull may vary between 4 meters and 25 meters depending on the ship size and the loading condition. This corresponds to absolute hydrostatic pressures at the keel between 140 kPa and 290 kPa. The pressure within the sealing area is 50 kPa. Assuming a 4 meter submergence the differential hydrostatic pressure is 90 kPa. The area is $\pi \cdot (10.5^2 - 4^2) = 295 \text{ m}^2$. The resulting compressive force between the buoy and the vessel is then 27000 kN. The net buoyancy of the combined buoy/mooring system must be added. This is normally negative but close to zero and is ignored. Consequently, a friction coefficient of 0.3 between the keel and the buoy permits a horizontal force of 8100 kN at a draft of 4 meters. At larger drafts the possible horizontal force increases to as much as 18000 kN. In consequence the vessel can control the friction capacity of the buoy and may in principle avoid dangerous combinations of force capability versus possible mooring force by increasing its draft.

The friction coefficient between the ship's bottom and the buoy is believed to be in the 50% to 80% range. Standard ablating anti-fouling paint coats the ship's bottom. The surfaces on the buoy that touch the ship are primarily composed of rubber fender elements. The rubber in these fender elements is specially formulated to have a large friction coefficient relative to wet anti-fouling paint.

The friction coefficient that is assumed for computational purposes is ordinarily in the 10% to 30% range, thereby providing an adequate safety factor against mooring failure. It should be noted that it is possible to determine the actual friction coefficient during unmooring by recording the combination of mooring force and pressure at the time of initiation of the separation process, i.e., when the buoy starts moving on the bottom of the vessel. Therefore, it is possible to monitor the efficacy of the system by measuring the buoy loading condition at initiation of motion upon separation at unmooring. This measurement may be done at each unmooring thereby providing for each ship that uses the mooring a continuous record of the friction coefficient between the buoy and the vessel.

The vessels arriving in Ashkelon are loaded and will discharge their cargo. For purposes of this document it is assumed that the maximum draft of the arriving vessel is 25 meters. The maximum wave condition for approach and mooring is set to $H_s = 5$ meters in this case. A safety margin between the vessel and the buoy of 7.0 m is set. The buoy is 8 meters high requiring a minimum water depth in the mooring area of $25 + 7 + 8 = 40 \text{ m}$.

The water depth in the mooring area is only about 37 m.. Therefore, in order to provide space for the buoy a circular area with a diameter of 100 m will be dredged to a depth of 44 m.. The additional 3 m over depth allows for sedimentation for several years until maintenance dredging is required.

2.3 Cargo Transfer.

The cargo to be transferred in the case at hand is fresh water and therefore unique in the sense that it is nonpolluting and normally can be discharged freely to the sea. This makes it possible to use simpler designs in the cargo transfer system with fewer safeguards against leakage and spills compared to petroleum transfer systems. Later in this section a normal petroleum or gas transfer system will be described.

The proposed water transfer system is shown in Figure 3.

Figure 3

The water is conveyed through the buoy as shown by the "Fluid Path" signature on Figure 3. Consequently, the cargo transfer connection is automatically established as soon as the buoy is securely attached to the ship. One disadvantage of the arrangement shown in Figure 3 is the downward pressure indicated by the arrows in the center of the buoy. This pressure counteracts the suction that presses the buoy onto the ship's keel. However, it acts on a much smaller area than the suction. As an example consider that the suction acts between two sealing circles with diameters 21 m and 8 m respectively. Assume that the differential hydrostatic pressure is -90 kPa, then the compressive force is 27000 kN as previously calculated. Assume further that the differential hydrostatic pressure in the center of the buoy is +200 kPa, then the repulsive force in the center of the buoy is $\pi \cdot 4 \cdot 4 \cdot 200 = 10000$ kN resulting in a minimum net attractive force between the buoy and the vessel of 17000 kN. The latter only occurs at the end of the discharge process or in the beginning of the loading process when the vessel is ballasted. At any other time the compressive force and thereby the mooring capacity is larger.

The vessel monitors the mooring force at all times. This is done by monitoring the mooring buoy position through the GPS positioning system. The known mooring response curve then provides the force. Therefore, the vessel can continuously monitor dangerous combinations of center well pressure and mooring capacity. In the event that such dangerous combination is approached then the vessel may take action by reducing the center well pressure. This would in turn reduce the cargo transfer rate.

3. Petroleum Cargo Transfer.

A more common use of the buoy is for the transfer of oil and/or gas between the vessel and the riser. In this case the pressure in the center well of the buoy would normally be maintained at close to atmospheric pressure. In this case the center of the buoy would provide additional compressive force and thereby assist in the mooring.

Figure 4

The mooring shown in figure 4 is similar to the mooring shown in figure 3 except that the fluids are transferred in separate pipes (Fluid Paths) as shown on Figure 4. In this case a fluid connection is established after mooring by connecting the pipes in the vessel to the pipes in the buoy at the connectors shown on figure 4. Note that the buoy is not centered in the opening in the ship's bottom. Positioning the ship over the buoy for the mooring during the mooring operation cannot be done with complete accuracy. This is particularly so because of the 13 seconds delay between the decision to make the mooring and the actual mating between the buoy and the vessel. Test performed at Nichol's Advanced Marine in Arlington showed that the mating can be consistently performed with an accuracy of about 3 meters in conditions with $H_s = 8$ m. In lower wave heights the operation can be performed with better accuracy. It is expected that experienced operators of the system will consistently be able to perform the mooring with a deviation between the center of the buoy and the center of the hull opening of less than 2 meters.

Assume that the fluid pipe assembly has a diameter of 1.5 m and that the diameter of the inner sealing circle is 10 m. An opening in the bottom of the vessel of 5.8 m then assures that it is possible to make the fluid connection whenever the deviation of the buoy is less than 2.1 m from the centered position. Check calculations: Opening $2 \times 2.1 \text{ m} + 1.5 \text{ m} = 5.7 \text{ m} < 5.8 \text{ m}$, Sealing circle $2 \times 2.1 \text{ m} + 5.8 \text{ m} = 10 \text{ m}$.

A 13.5 m diameter inner sealing circle with 7.5m opening in the bottom of the ship would in this case ensures a 3 m tolerance on the positioning of the buoy on the bottom of the ship.

The fluid paths rotate relative to the ship when the ship changes heading. Therefore, a fluid swivel is required. This is located on the vessel. This fluid swivel may be an ordinary swivel stack permitting unlimited rotation. Alternatively, the fluid swivel may be of the limited number of rotations kind. There are several such types. The limit on the number of revolutions is 1.5 in the case of a drag chain and may be 12 or more in the case of an SMT swivel. Power to turn the swivel must be provided. A powered servomechanism may be used or torque may be transferred from the buoy to the swivel. The system proposed here use torque transfer. A long member of triangular cross section will serve the dual purpose of supporting the fluid paths and to serve as a torque bar. The buoy is placed on the bottom of the ship at random within the mooring area. Therefore, the swivel can be moved such that it is always placed vertically above the center of the buoy.

Figure 5

Figure 5 shows the general arrangement of the fluid transfer system. A fluid swivel on the deck of the ship is connected through a moonpool to the center of the buoy by means of a triangular torsion bar. The torsion bar is mated at the buoy to a triangular female receptacle. The fluid pipes are held to the torsion bar by sleeves. Thus alignment with the

fluid connectors on the buoy is automatically achieved. The torsion bar can be raised and lowered relative to the fluid swivel. The fluid pipes can be raised or lowered relative to the torsion bar. During the mooring operation the torsion bar and the pipes are all in their upper position. Following the mooring the fluid swivel skid is centered above the buoy. Then the torsion bar is turned to align with the buoy orientation. The torsion bar is then guided into and seated in the torsion bar receptacle on the buoy. The fluid pipes are now lowered individually to each connector and connected. Each pipe is pressurized with nitrogen and the seal integrity is tested. Following the seal integrity test the nitrogen pressure is increased further. The sealing area is in fluid communication with the valve actuator in the corresponding valve in the buoy. The nitrogen pressure actuates the valve to open. The valve is equipped with spring return for automatic closure upon loss of sealing pressure.

At disconnect the operation is reversed. Instead of the testing of seal integrity the pipes are flushed and cleaned such that no product escapes upon disconnect.

The fluid pipes are shown to be located on the exterior surface of the torsion bar in Figure 5. However, they would ordinarily be located inside the torsion bar. This location inside the torsion bar creates several advantages:

- The fluid pipes are shielded from impact damage
- The atmosphere inside the torsion bar may be maintained inert at low cost and with high reliability.
- Any leaking fluid is contained within the torsion bar. This provides a double barrier against escape.
- The torsion bar may have a larger cross section for the same overall assembly diameter. This enhances the structural capacity of the torsion bar.

The fluid pipes are equipped with several safety devices that ensure against all but minimal spills during emergency and/or accidental disconnect. Controlled emergency disconnect is initiated if:

- The buoy moves on the bottom of the ship. This is detected two ways, optically by an automatic monitoring system and/or mechanically by a continuous comparison between tilt sensors within the torsion bar and on deck.
- The mooring maintenance pressure rises to above a preset level. This pressure is recorded continuously at all 3 pressure maintenance pumps.
- The vessel has an excessive excursion, either due to chain failure or due to excessive weather conditions. This is detected by the differential GPS system, which determines buoy deflection. Back-up systems may consist of acoustic systems detecting movement relative to beacons on the seabed or electronic triangulation systems such as for example Motorola Miniranger.
- Emergency conditions aboard the vessel such as fire or collision.

Controlled emergency disconnect comprises the following steps::

- Reducing nitrogen seal pressure. This causes closure of the valves on both sides of the connector, because these valves are maintained open by the seal pressure.
- If time permits purging of the fluid paths by nitrogen
- Blow down of Seal nitrogen and release of couplers

The vessel may now disconnect the mooring. In the event of accidental violent moves of the mooring buoy the nitrogen seal pressure maintenance system will automatically release all pressure and automatically cause closure of both the automatic valves on both sides of the coupler and the release of the coupler. This is automatic upon loss of sealing pressure. The content of approximately 20 m of pipe will be released within the torsion bar. Please note that all or nearly all this liquid will be trapped within the mooring moonpool and may be cleaned up by the ship's crew before the next mooring.

Uncontrolled disconnect is forced by the release of the seal pressure, either through rupture of the nitrogen piping or through the activation of emergency blowdown systems. The seal pressure release causes automatic valve closure (7 – 10 sec) and automatic release of couplers. The pipes within the torsion bar may optionally be equipped with break-away couplers that are actuated by the torsion bar being let down below a preset level. If so equipped, the actuation causes a short time release of the fluids (7 – 10 sec), closure of valves on both sides of the coupler and release of the couplers. All couplers will likely be lost in this event, the torsion bar will likely be damaged, and there may be some superficial hull damage in the moonpool area. The buoy will in this case drop to its storage position well clear of the vessel.

1. Mooring System

The present mooring system is a single point mooring attached to the keel of the moored vessel. The mooring buoy is held firmly to the bottom of the vessel by differential hydrostatic pressure. A structural swivel is built into the mooring buoy that permits the moored ship to weathervane in relation to the mooring chains.

Pressure maintenance pumps aboard the vessel maintain the differential pressure. These pumps take suction within the volume isolated by the top of the buoy and the hull of the vessel.

1.1 General Arrangement

The function and basic general arrangement is explained in the previous section. Single point moorings are typically moored to the seabed through a series of radial deployed catenary mooring lines terminating in drag anchors or stake piles in the seabed. This standard arrangement is illustrated on Figure 1-2 (Hydrostatic Mooring General Arrangement – 2).

A special mooring system has been developed that takes advantage of the unique properties inherent in the present mooring system as shown on figure 1-1 (Hydrostatic Mooring General Arrangement – 1). This system is comprised of a series of heavy weights that are lifted by the excursions of the mooring buoy. When the buoy deflects horizontally the connecting chain is bent over a fairlead in the top of the stake pile. In the proposed system that is specifically designed for the water transport system at Askelon Israel six stake piles are provided. This system maintains a higher fraction of its initial capabilities than the traditional system shown in Figure 1-2 when one mooring line fails.

Because of the small amount of chain that is used in mooring concept 1 it is not a significant economic penalty to oversize the mooring chains to compensate for the wear that will occur at the fairlead. It is the intent to frequently inspect the system and to replace chain and fairleads when significant wear has occurred.

This is the preferred system partly because of significant cost reductions and partly due to its much superior force deflection characteristics as illustrated in figure 1-4.

The graph in Figure 1-3 depicts the chain force as a function of the horizontal excursion of the vessel. Because the chain force is supplied by a hanging weight it is nearly constant. It is, however, modified above the fairlead by the friction in the fairlead. The present calculation is based on a friction coefficient of 10% as being the steel on steel friction coefficient. Figure 1-4 shows the resulting component of the chain force for a single chain. There are six chains, therefore the actual mooring force is six times the force shown on Figure 1-4.

The principal buoyancy is provided in an exterior near toroidal shaped ring beam. This ring beam serves three main purposes:

1. It protects the mooring surface of the buoy against vessel impact
2. It serves as the main buoyancy and trim volume in the buoy
3. It provides low-pressure air storage tanks for the rapid ascent system used in the mooring process.

This is shown in more detail in figure 1-5. The ring beam is in the shape of a 12-sided polygon. Each side of the polygon is protected against ship impact by a 2 meter long standard cylindrical ship fender 1400 mm by 700 mm as shown in more detail on Figure 1-6. Later in this section an analysis is presented showing that this level of fendering is sufficient to protect both the ship and the buoy against damaging impact during the mooring and the unmooring processes.

The metacentric height of the buoy in concept 1 is obviously strongly positive. The vertical loads of the mooring weights are applied at the bottom of the buoy and therefore bring the apparent center of gravity down in the lower third of the buoy. The center of buoyancy is about at the mid point of the buoy. A detailed analysis has not been made however it is believed that concept 1 has a positive metacenter height in all conditions.

Concept 2 was used in the model tests in Denmark. Ballasting in the bottom of the buoy is always possible, however, for the model tested buoy it was necessary to keep the diameter of the rapid ascent volume at 6 meters in order to keep the metacentric height positive during the ascent.

1.2 Compression Elements

Figure 1-5 also shows the main compression elements between the buoy surface and the vessel hull. These are comprised of a series of Trellex Morse Fender bar units deployed in a radial pattern as shown. Because of the density of fender bars they may for computational purposes be treated as a continuous surface. The force capacity of the fender bars is 54 tonnes or 530 kN per meter. There are a total of 360 meters of fender bars on the buoy surface. The total theoretical capacity of these units are to resist a total compressive force of 191,000 kN (19,500 tonnes). The maximum possible compression is obtained when absolute vacuum exists above the buoy while submerged to its deepest submergence. The area within the outer seal ring is 346 m².

In the case that the pressure above the buoy is 0 absolute the maximum possible differential load is 35 tonnes/m² resulting in a total load of 12,100 tonnes. The mooring load is at most applied 8 meters below the fender surface. Assume 600 tonnes horizontal load, then the resulting moment is 4800 tonnes meters. The fendering circle ring has an OD of 18.5 m and an ID of 10.5 m. The section modulus of this ring is $\frac{\pi}{32}(18.5^3 - 10.5^3) = 508 \text{ m}^3$. The resulting pressure differential is $4800/508 = 9.45 \text{ tonnes/m}^2$. The

allowable is the difference between the stress resulting from 12,100 tonnes and 19,500 tonnes or 21.4 tonnes per m².

This margin is required to cope with the ship's bottom being out plane. The total allowable stress is $19,500/346 = 56.4$ tonnes/m². The allowable margin is $21.4 - 9.45 = 11.9$ tonnes/m² or 21 % of the fully allowed deflection. Since the allowable deflection is 150 mm the system can cope with $2 \times 0.21 \times 150 = 63$ mm out plane deviation within the mooring area. Note, however, that from a practical point of view significantly higher out of plane deviation would at most cause some minor damage to the fender bars, and then only in the event that full vacuum, maximum submergence, and full horizontal mooring force all occur simultaneously.

Figures 1-9 through 1-12 shows catalogue cuts of the various fendering elements were selected for this application.

1.3 Sealing Units

The sealing units contact the keel plating in the ship and impede the flow of water from the sea to the volume in which the low pressure is maintained. There are two annular seals an inner and an outer as for example illustrated in Figure 2 in the Brief overview.

Because the pressure is maintained low above the buoy through continuous removal of water by pumps aboard the ship the seals need not be perfect. Rather, their function is to impede the water flow sufficiently that the pumps may reliably maintain the pressure low above the buoy.

Figure 1-6 shows an outer sealing element. This sealing elements must be capable of the following:

- To maintain contact with the hull for all pressure differentials ranging from a low 50 kPa to a high of 350 kPa.
- To maintain sealing pressure in the presence of unevenness of the hull.
- To be able to deflect without damage when a maximum impact between the buoy and the vessel deflects the exterior fenders fully.
- To be able to slide on the bottom plating of the vessel without damage.
- To resist safely all possible levels of differential pressure
- To provide the highest practical level of sealing.

A range of materials were investigated and the result was that the steel unit shown on figures 1-6, 1-7, and 1-8 was the only unit that was able to fulfill all criteria. Figure 1-7 shows in more detail how the unit pivots. Figure 1-8 shows the structural make-up of an exterior sealing unit. The structural design of the unit is presented later in this document.

The sealing units are seated in "boxes" at the edge of the buoy. Each "box" holds one sealing unit. The sealing unit fits loosely in its "box" and is prevented from sliding out by

a tab on the underside. The curved surface shown on the top of the unit is bolted on after the unit is placed in the "box". The units are spaced some 25 mm apart along the perimeter. A special Trellex Morse extruded fender is placed in a continuous ring above the units and is bolted onto each unit and is held securely by bolted on angle irons. On the exterior and below the sealing element there is a continuous rubber sheet made from conveyor belting. This rubber sheet seals the gaps between the sealing elements. It also seals the gap between the hull of the buoy and the sealing element.

The conveyor belting would typically be capable of resisting differential pressures in excess of 1000 kPa in this application. Thus there is no issue with the structural strength of the rubber sheet. Both the rubber sheet and the extruded fender will be stretched when the sealing ring is depressed. However the stretch is less than 5%, which is well within the capabilities of these elements.

The sealing elements are cantilevered. The purpose of the cantilever is to make it possible for the sealing element to deflect vertically and also to have the hydrostatic pressure differential increase the sealing pressure as the pressure differential increases.

Figure 1-8 shows an exterior sealing element. The interior sealing element is similar, however, the taper is in the opposite direction. In consequence the interior seal "box" design is with parallel sides and the unit also has parallel sides for the part that is placed within the "box"

1.4 Structural Bearing

The structural bearing is continually submerged. However, because of the use of compressed air to regulate the buoyancy during the rapid ascent to effect the mooring it is possible to have the bearing in air if it is placed in a volume in the buoy that is only open downward.

Because the bearing will be at least occasionally immersed in seawater a standard large diameter roller bearing is not practical. The strongly varying hydrostatic pressure will almost certainly drive salt water into such a bearing with rapid failure being the result.

A separate problem is the marine growth that will accumulate in continuously immersed areas. This may also be a problem for friction bearings such as Lubron bearings.

Therefore a bearing based on the technology used to move heavy objects on endless track roller units has been adopted (Hillman Rollers). These roller units are highly resistant to dirt. By placing the bearing most of the time within an air pocket with only occasional wetting, marine growth problems are avoided. The roller units will be manufactured from relatively noble materials such as stainless steel or Monel. The roller units will roll on a 3 sided circular track with one vertical and two horizontal surfaces.

The roller units are mounted that they may be individually removed and mounted while the buoy is surfaced for maintenance. The units are backed by Belleville springs that have a maximum deflection of 19 mm. This feature reduces the accuracy required on the bearing rolling surfaces, permitting a relatively primitive manufacturing process.

1.5 Rapid Ascent Buoyancy

Rapid ascent of the mooring buoy is achieved by introducing air into a downward facing "can" with a volume of 120 m³. By filling this volume with air the buoyancy increases by approximately 1200 kN.

The rapid ascent buoyancy is only needed for 13 seconds. Therefore there is no need that the rapid ascent buoyancy be airtight. Indeed it is undesirable that the rapid ascent buoyancy be airtight because of the danger that gases developed by biological processes accumulate in this volume and thereby cause that the buoy surfaces unexpectedly. In consequence the rapid ascent buoyancy is equipped with bleed holes that causes the air to bleed out in approximately 15 minutes.

The rapid ascent buoyancy is also equipped with ports that can be opened that bleed the air out in 20 seconds. These are actuated automatically in the event that the stay-closed signal is lost or in the event that an active "open" signal is received. This system is actuated in case the vessel fails to capture the buoy. In this case the buoy will descend again within 20 seconds which will normally be before the vessel moves sufficiently that the buoy would surface and thereby potentially impact the vessel on the side.

The normal process is that the ascent signal serves, as the stay-closed signal is well. When the mooring is secure this signal is shut off and the rapid descent system is automatically actuated and the rapid ascent air is released. Thus following the mooring the buoy is immediately ready to be released. Even in the event that this fails the buoy is ready for release 15 minutes later.

Suction Mooring Technology			
TITLE			
Hydrostatic Mooring General Arrangement - 1			
SIZE	CAGE CODE	DWG NO	REV
A4			
SCALE	1:500	SHEET	

Figure 1-1

Suction Mooring Technology			
TITLE			
Hydrostatic Mooring General Arrangement - 2			
SIZE	CAGE CODE	DWG NO	REV
A4			
SCALE	1:500	SHEET	

Figure 1-2

SAWM Line force Askelon

Figure 1-3

Horizontal Mooring Force Askelon (1/6 of force)

Legend

A - Low Pressure Tank No. 1

B - Low Pressure Tank No. 2

C- Buoyancy and Trim Tank

Suction Mooring Technology

TITLE

Hydrostatic Mooring
Buoyancy Tank Distribution

SIZE

A4

CAGE CODE

DWG NO

REV

0

SCALE

1:200

SHEET

Bridgestone Fender
1400 * 700

Undelected Position

Trellex Morse
Fender Bar 200 * 300

Fully Deflected
Position

Suction Mooring Technology

TITLE

Hydrostatic Mooring Outer Seal

SIZE

A4

CAGE CODE

DWG NO

REV

SCALE

SHEET

Figure 1-6

Suction Mooring Technology

TITLE

Hydrostatic Mooring
Outer Seal Mounting

SIZE

A4

CAGE CODE

DWG NO

REV

SCALE

SHEET

Figure 1-8

800⁺ - 1200⁺

(Length = 1 m)

Deflection Performance Size (mm)	40%		45%		50%		*(70%)	
	R	E	R	E	R	E	R	E
900 ϕ x 450 ϕ	18.6	3.40	22.3	4.30	27.3	5.40	(546)	(40.50)
1000 ϕ x 500 ϕ	20.6	4.20	24.8	5.30	30.3	6.70	(606)	(50.25)
1100 ϕ x 550 ϕ	22.7	5.10	27.3	6.50	33.3	8.10	(666)	(60.75)
1200 ϕ x 600 ϕ	24.8	6.10	29.8	7.70	36.3	9.70	(726)	(72.75)

R: Reaction force (tons) E: Energy absorption (ton-m)

* Figures at 70% deflection are for reference.

Tolerance: $\pm 10\%$

REACTION FORCE

ENERGY ABSORPTION

F.g 1-9

(Length = 1 m)

Deflection Performance Size (mm)	40%		45%		50%		*(70%)	
	R	E	R	E	R	E	R	E
1300φ x 650φ	26.8	7.10	32.2	9.00	39.4	11.40	(788)	(85.50)
1400φ x 700φ	28.9	8.30	34.7	10.50	42.4	13.20	(848)	(99.00)
1500φ x 750φ	31.0	9.50	37.2	12.10	45.4	15.10	(908)	(113.25)
1600φ x 800φ	33.0	10.75	39.7	13.57	48.4	17.18	(968)	(128.85)

R: Reaction force (tons) E: Energy absorption (ton-m)

* Figures at 70% deflection are for reference.

Tolerance. ±10%

REACTION FORCE

ENERGY ABSORPTION

CYLINDRICAL WING EXTRUSION

LENGTHS UP TO 20 FT. OTHER
SIZES AVAILABLE ON REQUEST.

PART N°	A	BORE	C	D	E	Wt./Ft.	R/E
UNITS	INCHES					lbs	Kip _{Ft} Kip
F7-0000	3	1	6	.75	1.5	4.3	25
F7-8000	4	2	7.5	1.0	2.25	10	19.5
F7-1000	6	3	9	1.5	3	15.5	13.5
FB-1000	8	4	12	2.0	4	30	11
FB-4000	10	5	15	2.5	5	44	9
F7-3000	12	6	18	3.0	6	58.5	6.3

APPROXIMATE LOAD/ENERGY, DEFLECTION CURVES FOR MORSE STANDARD
CYLINDRICAL WING

*Note Special soft rubber
will be used*

*Hydrostatic Mooring Seal
3 Kacira 50% of the above
Fig 1-6*

FENDER BAR SELECTION

RATED PROPERTIES				DIMENSIONS IN MM		
ENERGY ABSORBED		REACTION FORCE		FENDER TYPE ML W×H×L	ANCHOR	QTY
TONNE M	FT-KIPS	TONNES	KIPS			
1.7	12.3	65	143	150×150×1000	M 24	2
2.5	18.4	98	216	150×150×1500		3
1.7	12.3	45	99	150×200×1000	M 24	2
2.5	18.4	68	150	150×200×1500		3
2.7	19.5	84	185	200×200×1000	M 30	2
4.1	29.7	126	278	200×200×1500		3
2.7	19.5	67	148	200×250×1000	M 30	2
4.1	29.7	101	223	200×250×1500		3
2.7	19.5	54	119	200×300×1000	M 30	2
4.1	29.7	81	179	200×300×1500		3

Selected
unit

Fig 1-12

Hydrostatic mooring with one main weight
origin of coordinate system is at seabed vertically under main weight
Spread sheet only applicable to single Stakepile anchor

leg length t 45 meters
Top of Stakepile elevation z -40 meters
Elevation Top of chain a -10 meters
Weight elevation e -55 meters
water chain lght c 30 meters
Main weight submerged w 1000 kN
friction coefficient f 0.1

Point number meters	Elevation of weight e	Length of chain in water c	Legal points. Top of stakepile above weight e>z	Angle to attach point from horizontal alfa	chain force extending kN	Chain Force retracting kN	Horizontal force Extending kN	Horizontal Force retracting kN
0	-55.00	30.00	yes		1000	1000	0	0
1	-54.98	30.02	yes	1.537475	1003.338	996.6734	33.42602	33.20401
2	-54.93	30.07	yes	1.504228	1006.679	993.3653	66.96329	66.07768
3	-54.85	30.15	yes	1.471128	1010.017	990.0826	100.5004	98.5169
4	-54.73	30.27	yes	1.438245	1013.343	986.8323	133.9272	130.4234
5	-54.59	30.41	yes	1.405648	1016.652	983.6208	167.1366	161.7063
6	-54.41	30.59	yes	1.373401	1019.936	980.454	200.0258	192.2828
7	-54.19	30.81	yes	1.341564	1023.188	977.3375	232.4986	222.08
8	-53.95	31.05	yes	1.310194	1026.403	974.2764	264.4657	251.0346
9	-53.68	31.32	yes	1.27934	1029.575	971.275	295.8461	279.0938
10	-53.38	31.62	yes	1.249046	1032.698	968.3371	326.5679	306.2151
11	-53.05	31.95	yes	1.219352	1035.769	965.4659	356.5684	332.3661
12	-52.69	32.31	yes	1.19029	1038.784	962.6642	385.7946	357.5245
13	-52.30	32.70	yes	1.161888	1041.738	959.934	414.2029	381.6769
14	-51.89	33.11	yes	1.134169	1044.63	957.2768	441.7588	404.8184
15	-51.46	33.54	yes	1.107149	1047.456	954.6937	468.4367	426.952
16	-51.00	34.00	yes	1.080839	1050.216	952.1852	494.2192	448.0871
17	-50.52	34.48	yes	1.055247	1052.907	949.7515	519.0964	468.2394
18	-50.01	34.99	yes	1.030377	1055.529	947.3924	543.0651	487.4293

19	-49.49	35.51 yes	1.006227	1058.081	945.1072	566.1285	505.6816
20	-48.94	36.06 yes	0.982794	1060.563	942.8951	588.2947	523.0241
21	-48.38	36.62 yes	0.96007	1062.976	940.7549	609.5768	539.4875
22	-47.80	37.20 yes	0.938047	1065.32	938.6854	629.9913	555.1044
23	-47.20	37.80 yes	0.916714	1067.595	936.685	649.5584	569.9087
24	-46.58	38.42 yes	0.896055	1069.803	934.7519	668.3004	583.9349
25	-45.95	39.05 yes	0.876058	1071.944	932.8845	686.2418	597.2181
26	-45.30	39.70 yes	0.856706	1074.02	931.0809	703.4088	609.7933
27	-44.64	40.36 yes	0.837981	1076.033	929.3392	719.8284	621.6951
28	-43.96	41.04 yes	0.819867	1077.984	927.6573	735.5284	632.9575
29	-43.27	41.73 yes	0.802346	1079.875	926.0333	750.5368	643.6136
30	-42.57	42.43 yes	0.785398	1081.706	924.4653	764.8819	653.6956
31	-41.86	43.14 yes	0.769006	1083.481	922.9511	778.5918	663.2346
32	-41.14	43.86 yes	0.753151	1085.2	921.4889	791.6939	672.2605
33	-40.40	44.60 yes	0.737815	1086.866	920.0768	804.2155	680.8017
34	-39.66	45.34	0.722979				
35	-38.90	46.10	0.708626				
36	-38.14	46.86	0.694738				
37	-37.37	47.63	0.681298				
38	-36.59	48.41	0.668289				
39	-35.80	49.20	0.655696				
40	-35.00	50.00	0.643501				
41	-34.20	50.80	0.631691				
42	-33.39	51.61	0.620249				
43	-32.57	52.43	0.609163				
44	-31.75	53.25	0.598419				
45	-30.92	54.08	0.588003				
46	-30.08	54.92	0.577902				
47	-29.24	55.76	0.568105				
48	-28.40	56.60	0.558599				
49	-27.55	57.45	0.549374				
50	-26.69	58.31	0.54042				
51	-25.83	59.17	0.531724				
52	-24.97	60.03	0.523278				
53	-24.10	60.90	0.515073				
54	-23.23	61.77	0.507099				
55	-22.35	62.65	0.499347				
56	-21.47	63.53	0.491809				
57	-20.59	64.41	0.484478				
58	-19.70	65.30	0.477345				
59	-18.81	66.19	0.470404				

Hydrostatic mooring with one main weight
 origin of coordinate system is at seabed vertically under main weight
 Spread sheet only applicable to single Stakepile anchor

leg length t 45 meters
 Top of Stakepile elevation z -40 meters
 Elevation Top of chain a -32 meters
 Weight elevation e -77 meters
 water chain lght c 8 meters
 Main weight submerged w 1000 kN

friction coefficient f 0.1

Point number meters	Elevation of weight e	Length of chain in water c	Legal points. Top of stakepile above weight e>z	Angle to attach point from horizontal alfa	chain force extending kN	Chain Force retracting kN	Horizontal force Extending kN	Horizontal Force retracting kN
0	-77.00	8.00	yes		1000	1000	0	0
1	-76.94	8.06	yes	1.446441	1012.513	987.6415	125.5868	122.5019
2	-76.75	8.25	yes	1.325818	1024.8	975.7998	248.5506	236.6662
3	-76.46	8.54	yes	1.212026	1036.528	964.7589	363.9494	338.7495
4	-76.06	8.94	yes	1.107149	1047.456	954.6937	468.4367	426.952
5	-75.57	9.43	yes	1.012197	1057.45	945.6716	560.4471	501.2049
6	-75.00	10.00	yes	0.927295	1066.466	937.6767	639.8794	562.606
7	-74.37	10.63	yes	0.851966	1074.53	930.6398	707.5827	612.8306
8	-73.69	11.31	yes	0.785398	1081.706	924.4653	764.8819	653.6956
9	-72.96	12.04	yes	0.726642	1088.081	919.0494	813.2417	686.9061
10	-72.19	12.81	yes	0.674741	1093.743	914.2918	854.0696	713.9419
11	-71.40	13.60	yes	0.628796	1098.779	910.1007	888.6226	736.0313
12	-70.58	14.42	yes	0.588003	1103.271	906.3956	917.9769	754.1668
13	-69.74	15.26	yes	0.551655	1107.288	903.1071	943.0314	769.1387
14	-68.88	16.12	yes	0.519146	1110.894	900.176	964.526	781.5716
15	-68.00	17.00	yes	0.489957	1114.141	897.5523	983.0658	791.9579
16	-67.11	17.89	yes	0.463648	1117.076	895.194	999.1435	800.6858
17	-66.21	18.79	yes	0.439843	1119.739	893.0655	1013.161	808.0623
18	-65.30	19.70	yes	0.418224	1122.162	891.1369	1025.445	814.3312

19	-64.38	20.62 yes	0.398522	1124.375	889.3829	1036.264	819.6868
20	-63.46	21.54 yes	0.380506	1126.403	887.7821	1045.839	824.2849
21	-62.53	22.47 yes	0.363979	1128.266	886.316	1054.351	828.2514
22	-61.59	23.41 yes	0.348771	1129.983	884.9691	1061.951	831.6882
23	-60.65	24.35 yes	0.334737	1131.57	883.728	1068.764	834.6783
24	-59.70	25.30 yes	0.321751	1133.04	882.5811	1074.896	837.29
25	-58.75	26.25 yes	0.309703	1134.406	881.5185	1080.436	839.5795
26	-57.80	27.20 yes	0.298499	1135.678	880.5314	1085.457	841.5934
27	-56.84	28.16 yes	0.288055	1136.865	879.6123	1090.024	843.3706
28	-55.88	29.12 yes	0.2783	1137.974	878.7545	1094.189	844.9435
29	-54.92	30.08 yes	0.269167	1139.014	877.9524	1098.001	846.3396
30	-53.95	31.05 yes	0.260602	1139.99	877.2008	1101.498	847.582
31	-52.98	32.02 yes	0.252554	1140.908	876.4951	1104.715	848.6903
32	-52.02	32.98 yes	0.244979	1141.772	875.8313	1107.682	849.6812
33	-51.04	33.96 yes	0.237836	1142.588	875.206	1110.424	850.569
34	-50.07	34.93 yes	0.231091	1143.359	874.6158	1112.965	851.366
35	-49.10	35.90 yes	0.224711	1144.089	874.058	1115.325	852.0829
36	-48.12	36.88 yes	0.218669	1144.78	873.5301	1117.52	852.7287
37	-47.15	37.85 yes	0.212938	1145.437	873.0296	1119.566	853.3115
38	-46.17	38.83 yes	0.207496	1146.06	872.5546	1121.477	853.8381
39	-45.19	39.81 yes	0.202322	1146.653	872.1032	1123.265	854.3147
40	-44.21	40.79 yes	0.197396	1147.218	871.6737	1124.94	854.7464
41	-43.23	41.77 yes	0.192701	1147.757	871.2646	1126.513	855.138
42	-42.24	42.76 yes	0.188222	1148.271	870.8744	1127.991	855.4935
43	-41.26	43.74 yes	0.183943	1148.763	870.5019	1129.383	855.8166
44	-40.28	44.72 yes	0.179853	1149.232	870.146	1130.695	856.1105
45	-39.29	45.71	0.17594				
46	-38.31	46.69	0.172191				
47	-37.32	47.68	0.168597				
48	-36.34	48.66	0.165149				
49	-35.35	49.65	0.161837				
50	-34.36	50.64	0.158655				
51	-33.38	51.62	0.155595				
52	-32.39	52.61	0.152649				
53	-31.40	53.60	0.149812				
54	-30.41	54.59	0.147078				
55	-29.42	55.58	0.144442				
56	-28.43	56.57	0.141897				
57	-27.44	57.56	0.13944				
58	-26.45	58.55	0.137066				
59	-25.46	59.54	0.134771				

Content of chapter 2.

Section 1: This is the structural calculation of the sealing units.

Section 2: This is the structural calculation of the buoy and the bearing system performed by Han Padron Associates.

Subsequent to this design a number of changes was made that have only negligible impact on the structural system. These were:

- The watertight plate was moved from the underside of the buoy to the top of the buoy. The reason for this was to improve the structural force transfer between the fenders and the structure. The timber in-fill now serves the prevention of trapping air below the buoy rather than the function of preventing the accumulation of sediments on top of the buoy, which was the previous function..
- The center 8-meter diameter plate was changed to be able to resist the maximum physically possible hydrostatic pressure differential of 350 kPa.
- The bearing was changed from a Lubron bearing to a Hillman roller bearing. A revised bearing design is presented in section 3.

Section 3: This is the final concept for the mooring chain attachments and the bearing.

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12. April 2000

Preliminary calculations of float units

Design Loads:

1. Hydraulic pressure on outer side of cylindrical fender and rubber sheet: 350 kPa
2. Horizontal friction force on top of cylindrical fender: 50% of vertical force

Material and design stress:

All steel parts are made from hot rolled sheets with $f_y = 36$ ksi ($f_y = 248$ Mpa)

Design stress in bending: $248/1.67 =$

149 Mpa

Design stress in shear: $248/2.50 =$

99 Mpa

Assumptions:

1. Own weight and buoyancy are not considered. They are assumed small in comparison with forces from hydraulic pressure.
2. Leak between fender elements is not considered. Hydraulic pressure is assumed constant from top of fender to lower fixation of rubber sheet.
3. Friction forces in points of contact between float unit and pocket are not considered.
4. Height of rubber fender is 300 mm unloaded. At maximum load the height is 150mm. In between height is assumed to vary linearly with load.
5. Approximate geometry is used in the calculations.

Load Cases:

Three load cases governs:

1. Float unit in top position (fender support slab is horizontal), friction force from ship on fender in the direction of the centre of the buoy. External pressure 350 kPa.
2. Float unit in bottom position (top side of float unit is horizontal), friction force from ship in the direction away from the center of the buoy. External pressure 350 kPa.
3. Float unit in top position (fender support slab is horizontal), friction force from ship on fender in tangential direction. External pressure 350 kPa.

Calculation of Reactions:

Load case 1:

Horizontal projection:

$$350 \times 0.648 \times 0.672 + 350 \times 0.615 \times 0.271 + \frac{1}{2}V_1 + V_2 \times \sin(13.508^\circ) = H \times \cos(2.54^\circ)$$

Vertical projection:

$$350 \times 0.609 \times 0.929 = V_1 - V_2 \times \cos(13.508^\circ) - H \times \sin(2.54^\circ)$$

Moment (point of contact with ship):

$$350 \times 0.648 \times 0.672^2 \times \frac{1}{2} + 350 \times 0.615 \times 0.271 \times 0.805 + 350 \times 0.609 \times 0.929 \times 0.458 = -V_2 \times (0.929 \times \cos(13.508^\circ) + 0.943 \times \sin(13.508^\circ)) + H \times (0.985 \times \cos(2.54^\circ) - 1.867 \times \sin(2.54^\circ))$$

Results:

$$V_1 = 424 \text{ kN}$$

$$V_2 = 211 \text{ kN}$$

$$H = 472 \text{ kN}$$

Load case 2:

Horizontal projection:

$$350 \times 0.658 \times 0.565 = \frac{1}{2}V_1 + H \times \cos(22.101^\circ)$$

Vertical projection:

$$350 \times 0.618 \times 1.235 = V_1 + V_2 + H \times \sin(22.101^\circ)$$

Moment (point of contact with ship):

$$350 \times 0.658 \times 0.565^2 \times \frac{1}{2} + 350 \times 0.618 \times 1.235 \times 0.606 = V_2 \times 1.235 + H \times (0.227 \times \cos(22.101^\circ) + 2.105 \times \sin(22.101^\circ))$$

Results:

$$V_1 = 136 \text{ kN}$$

$$V_2 = 106 \text{ kN}$$

$$H = 67 \text{ kN}$$

Load case 3:

Horizontal projection:

$$350 \times 0.648 \times 0.747 + 350 \times 0.615 \times 0.271 = -V_2 \times \sin(13.508^\circ) + H \times \cos(2.54^\circ)$$

Vertical projection:

$$350 \times 0.609 \times 0.929 = V_1 - V_2 \times \cos(13.508^\circ) - H \times \sin(2.54^\circ)$$

Moment (point of contact with ship): $350 \times 0.648 \times 0.747^2 \times \frac{1}{2} + 350 \times 0.615 \times 0.271 \times 0.880 + 350 \times 0.609 \times 0.929 \times 0.458 = -V_2 \times (0.929 \times \cos(13.508^\circ) + 1.018 \times \sin(13.508^\circ)) + H \times (1.060 \times \cos(2.54^\circ) - 1.867 \times \sin(2.54^\circ))$

Results: $V_1 = 227 \text{ kN}$
 $V_2 = 19 \text{ kN}$
 $H = 232 \text{ kN}$

Horizontal projection: $\frac{1}{2} \times 227 = Q_1 - Q_2 - Q_3$

Moment, vertical axis: $\frac{1}{2} \times 227 \times 0.929 = 0.9375 \times Q_3$

Moment, horizontal axis: $\frac{1}{2} \times 227 \times 1.018 = 0.4995 \times Q_1 + 0.0415 \times Q_3$

Results: $Q_1 = 222 \text{ kN}$
 $Q_2 = -4 \text{ kN}$
 $Q_3 = 112 \text{ kN}$

Pressure Design:

Curved panel: Membrane stress: $f_n = p \times R/t = 0.35 \times 300/12 = 8.8 \text{ MPa}$
 $R/t = 300/12 = 25$, no stability problem.

Bottom sheet: Area between stiffeners: $231 \times 598 \text{ mm}$. Carrying capacity only considered in one direction. $M = p \times l^2/12 = 0.35 \times 231^2/12 = 1556 \text{ N}$
 $f_b = 6 \times 1556/12^2 = 65 \text{ Mpa}$

Stiffener 75 x 12 mm: Area: $219 \times 12 + 87 \times 12 = 2628 + 1044 = 3672 \text{ mm}^2$
Center of gravity: $a = (2628 \times 6 + 1044 \times 43.5)/3672 = 16.7 \text{ mm}$
 $I = 2628 \times 10.7^2 + 1044 \times 26.8^2 + 2628 \times 12^2/12 + 1044 \times 87^2/12 = 1.741 \text{ E}6 \text{ mm}^4$
 $S_b = 1.741 \text{ E}6/70.3 = 24.77 \text{ E}3 \text{ mm}^3$
 $S_t = 1.741 \text{ E}6/16.7 = 104.3 \text{ E}3 \text{ mm}^3$
Moment in stiffener: $M = 0.35 \times 231 \times 598^2/8 = 3.614 \text{ E}6 \text{ Nmm}$
 $f_{bb} = 3.614 \text{ E}6/24.77 \text{ E}3 = 146 \text{ Mpa} < 149$.
 $f_{bt} = 3.614 \text{ E}6/104.3 \text{ E}3 = 35 \text{ Mpa}$.

External sheet: Area between stiffeners: $280 \times 628 \text{ mm}$. Carrying capacity only considered in one direction. $M = p \times l^2/12 = 0.35 \times 280^2/12 = 2287 \text{ N}$
 $f_b = 6 \times 2287/12^2 = 95 \text{ Mpa}$
Moment in stiffener: $M = 0.35 \times \frac{1}{2} \times 280 \times 628^2/8 = 2.416 \text{ E}6 \text{ Nmm} < 3.614 \text{ E}6$

Support plate for fender: Hydraulic pressure + reaction on fender (load case 1)
 $p = 0.35 + 424000/(400 \times 628) = 2.038 \text{ MPa}$
Area between stiffeners: $161 \times 628 \text{ mm}$. Carrying capacity only considered in one direction. $M = p \times l^2/8 = 2.038 \times 161^2/10 = 5283 \text{ N}$
 $f_b = 6 \times 5283/20^2 = 79 \text{ Mpa} < 149$.

Stiffener 140 x 20 mm: Area: $141 \times 20 + 160 \times 20 = 2820 + 3200 = 6020 \text{ mm}^2$
Center of gravity: $a = (2820 \times 10 + 3200 \times 80)/6020 = 47.2 \text{ mm}$
 $I = 2820 \times 37.2^2 + 3200 \times 32.8^2 + 2820 \times 20^2/12 + 3200 \times 160^2/12 = 14.27 \text{ E}6 \text{ mm}^4$
 $S_b = 14.27 \text{ E}6/112.8 = 126.5 \text{ E}3 \text{ mm}^3$
 $S_t = 14.27 \text{ E}6/47.2 = 302.3 \text{ E}3 \text{ mm}^3$
Moment in stiffener: $M = 2.038 \times 161 \times 1.1 \times 628^2/8 = 17.79 \text{ E}6 \text{ Nmm}$
 $f_{bb} = 17.79 \text{ E}6/126.5 \text{ E}3 = 141 \text{ Mpa} < 149$.
 $f_{bt} = 17.79 \text{ E}6/302.3 \text{ E}3 = 59 \text{ Mpa}$.

SIZE	CAGE CODE	DWG NO	REV
A4			
SCALE	1:20		SHEET

Detail 1,

1:1

Detail 2, 1:2.5

top position
Load case 1.

Section A-A

TITLE			
SIZE	CAGE CODE	DWG NO	REV
A4			
SCALE 1:20		SHEET	

top position
Load case 3

Section A-A

SIZE A4	CAGE CODE	DWG NO	REV
SCALE: 1:20		SHEET

PROJECT Buoy
SUBJECT STEEL STRUCTURE
PRELIM. CALCS

SHEET NO. 1 OF 6
JOB NO. 869.01
MADE BY LL DATE 05/07/00
CHKD. BY _____ DATE _____

DESIGN LOADS

1. SHIP RESISTING LOADS

HORIZONTAL COMPONENT — 600.0T (METRIC)
VERTICAL COMPONENT — 400.0T (METRIC)

2. HYDRAULIC PRESSURE ON 5M ± PLATE UNIT RING (UP) — 35.0T/M²

ASSUMPTIONS

1. ALL LOADS FROM SHIP ARE TRANSFERRED BY FRICTION AS FUNCTION OF HYDRAULIC PRESSURE TO THE PLATE UNIT. FROM THE PLATE UNIT LOADS ARE TRANSFERRED TO THE ANCHOR UNIT BY SLIDING RING BELONGING TO PLATE UNIT TO SUPPORTS BELONGING TO ANCHOR UNIT. ANCHOR UNIT IS KEEPING IN PLACE BY CHAINS.
2. ASSUMPTION FOR COMPUTER MODEL OF THE ANCHOR UNIT
 - 2.1. HORIZONTAL AND VERTICAL LOADS FROM PLATE UNIT IS TAKEN BY TWO $\frac{1}{2}$ SUPPORTS, EVERY ONE TAKES $\frac{1}{2}$ OF TOTAL HORIZONTAL OR VERTICAL LOAD.
 - 2.2. ALL MEMBERS WAS TAKEN AS HOT ROLLED ELEMENTS WITH $F_y = 36 \text{ ksi}$ (5000 kg/cm^2). ALL MEMBER ON DESIGN STAGE SHALL BE TAKEN AS WELDED ELEMENTS WITH CHARACTERISTICS (A, I, S) CLOSE TO TAKEN FOR RUNS "BOUY" AND 3D MODEL SHALL BE BUILT.
 - 2.3. MEMBER 17 IS TAKEN CONDITIONALLY TO INDICATE THAT THE SYSTEM (UNDER SHIP) CAN NOT MOVE UP UNDER APPLIED LOADS.

HAN-PADRON ASSOCIATES
CONSULTING ENGINEERS

PROJECT Buoy
SUBJECT PLATE UNIT. STEEL STRUCTURE
PRELIM. CALCS.

SHEET NO. 2 OF 6
JOB NO. 864.02
MADE BY LL DATE 03/07/03
CHKD. BY _____ DATE _____

MAIN GIRDER

SUPPORT REACTIONS 660.0 KIPS & 415.56 KIPS
SEE RUN "BUOY1" (*)

AT SLIDING RING
LEVEL

$$\left. \begin{aligned} R_c &= -213.6k \\ H_c &= 660.0k \\ R_D &= 628.6k \end{aligned} \right\}$$

(*) THIS CASE GOVERNS

PROJECT Buoy
 SUBJECT PLATE UNIT. STEEL STRUCTURE.
PRELIM. CALCS.

SHEET NO. 3 OF 6
 JOB NO. 864.02
 MADE BY LL DATE 03/07/00
 CHKD. BY _____ DATE _____

MOMENT AT SECTION BB'

$$M_L = 660 \times 0.35 \times 3.28 + 213 \times 2.25 \times 3.28 = 2330 \text{ KFT}$$

FOR LEFT GIRDER AND FOR RIGHT GIRDER

$$M_R = 628.6 \times 2.25 \times 3.28 = 4640 \text{ KFT} - \text{GOVERNS}$$

$$I = \frac{0.625 \times 80.7^3}{12} + 23.6 \times 41^2 \times 2$$

$$I = 106,716 \text{ IN}^4$$

$$S = \frac{106,716}{41.35} = 2580.8 \text{ IN}^3$$

BENDING STRESS

$$f_B = \frac{4640 \times 12}{2580.8} = 21.6 \text{ ksi} < 24.0$$

O.K.

FROM HYDRAULIC PRESSURE.

$$\text{AVER. } q = 35 \text{ T/M}^2 \times \frac{5+2.5}{2} = 131.25 \text{ T/M} \quad \text{OR}$$

$$q = 88.0 \text{ K/FT}$$

$$M = \frac{88 \times (6 \times 3.28)^2}{8} = 4260.0 \text{ KFT} < 4640 \text{ KFT}$$

SEE ABOVE.

O.K.

$$\text{SHEAR} - V = 628.6 \text{ K} - A = 0.625 \times 80.7 + 2 \times 23.6 = 97.6 \text{ IN}^2$$

$$f_v = \frac{628.6}{97.6} = 6.4 \text{ ksi} < 14.4 \text{ ALLOW.}$$

PROJECT Buoy
 SUBJECT PLATE UNIT. STEEL STRUCTURE.
PRELIM. CALCS.

SHEET NO. 4 OF 6
 JOB NO. 864.02
 MADE BY LL DATE 03/07/00
 CHKD. BY _____ DATE _____

DECKING

ASSUME THAT TIMBER BLOCKS WITHSTAND HYDRAULIC PRESSURE IN SPAN BETWEEN BEAMS, SO THICKNESS OF STEEL PLATE CAN BE TAKEN W/O CALCULATIONS OF 14 TO 16 MM.

DECK BEAM.

LONGEST BEAM HAS LENGTH $\frac{\pi \times 19}{12} - 0.3 = 4.67 \text{ M}$
 SPACING - 1.0 M
 DISTR. LOAD PER BEAM IS 35.0 T/M OR 23.5 K/FT

$$M = \frac{23.5 \times (4.67 \times 3.28)^2}{8} = 689.2 \text{ KFT}$$

$$S_{REQ} = \frac{689.2 \times 12}{24} = 344.6 \text{ IN}^3$$

USE W30x124 - S=355 IN³ FOR LONGESTS AND
 W30x116 FOR ALL THE OTHERS

SLIDING RING

V IS $\frac{1}{2}$ OF TOTAL VERTICAL LOAD

$$V = 400 \times 2.2 / 2 = 440 \text{ KIPS}$$

$$\text{STIFF PL @ } \frac{3.14 \times 5.5}{36} \times 3.28 = 1.6 \text{ FT}$$

VERTICAL LOAD IS DISTR. TO TWO STIFF. PL'S, PER ONE

$$V_1 = 440 / 2 = 220.0 \text{ KIPS}$$

PROJECT

Buoy

SUBJECT

PLATE UNIT. STEEL STRUCTURE

PRELIM. CALCS

SHEET NO. 5 OF 6
 JOB NO. 864.01
 MADE BY LL DATE 03/07/03
 CHKD. BY _____ DATE _____

SECTION a-a

$$I = \frac{0.75 \times 18^3}{12} + 19 \times 0.75^2 \times 2 = 3790 \text{ in}^4$$

$$S = \frac{3790}{10} = 379 \text{ in}^3$$

$$M = 220 \text{ KFT}$$

$$f_b = \frac{220 \times 12}{379} = 7.0 \text{ ksi}$$

O.K.

VERTICAL WELD FOR STIFF. PL

$$L = 18 \times 2 = 36", \text{ ASSUMING } \frac{5}{8}" (16 \text{ mm}) \text{ WELD}$$

$$\text{CAPACITY } 0.927 \times 10 = 9.27 \text{ k/in}$$

$$\text{WELD CAPACITY } P_w = 9.27 \times 36 = 334 \text{ kips} > 220$$

O.K.

PROJECT

Buoy

SUBJECT

PLATE UNIT. STEEL STRUCTURE.
PRELIM. CALCS

SHEET NO. 6 OF 6
JOB NO. 864.02
MADE BY LL DATE 03/07/00
CHKD. BY DATE

TIMBER BLOCKS UNDER HYDRAULIC PRESSURE

$$q = 35 \text{ T/H}^2 \text{ OR } 7.16 \text{ KSF}$$

ASSUME 3 TIMBER BLOCKS
SPACE WITHSTAND UPLIFT
PRESSURE

SAY 12" x 12" TIMBERS

$$\text{TOTAL } M = \frac{7.16 \times (1 \times 3.28)^2}{8} = 9.62 \text{ KFT/FT}$$

$$V = 7.16 \times \frac{3.28}{2} = 11.7 \text{ KIPS - SHEAR}$$

MOMENT PER ONE BLOCK — 3.21 KFT

$$S \approx 0.9 \times \frac{12^3}{6} \approx 259.2 \text{ IN}^3$$

$$f_b = \frac{3.21 \times 12}{259.2} = 0.15 \text{ KSI O.K.}$$

$$\text{SHEAR } f_v = \frac{3}{2} \times \frac{11700}{28 \times 12} = 52 \text{ PSI} < 100 \text{ PSI, O.K.}$$

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*****
*
*           S T A A D - I I I
*       Revision 22.3
*       Proprietary Program of
*       Research Engineers, Inc.
*       Date=      MAR   6, 2000
*       Time=      14: 1: 5
*
*       USER ID: HAN-PADRON ASSOCIATES
*****
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1. STAAD PLANE ANALYSIS
2. *BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL LOAD OF 660 KIPS
3. *PRELIMINARY CALCULATION
4. *RUN NAME-BUOY1
5. UNIT KIP FT
6. JOINT COORDINATES
7. 1 0 0; 2 21.6 0; 3 0 10.8; 4 7.2 10.8; 5 14.4 10.8
8. 6 21.6 10.8; 7 5.6 10.8; 8 5.6 13.6; 9 5.6 15.5
9. 10 3.1 15.5; 11 7.2 0; 12 14.4 0; 13 21.6 35
10. *
11. MEMBER INCIDENCES
12. 1 3 7; 2 7 4; 3 4 5; 4 11 12; 5 5 6; 6 1 12
13. 7 12 2; 8 7 8; 9 8 9; 10 9 10; 11 1 4; 12 5 2
14. 13 1 3; 14 2 6; 15 4 11; 16 5 12; 17 6 13
15. *
16. MEMBER RELEASE
17. 13 TO 16 START MY MZ
18. 13 TO 16 END MY MZ
19. 17 START MY MZ
20. 17 END MY MZ
21. *
22. UNIT INCHES
23. MEMBER PROPERTIES
24. 1 2 5 TA ST W36X439
25. 3 TA ST W36X300
26. 4 6 7 TA ST W33X387
27. 8 9 TA ST W40X593
28. 10 TA ST W14X455
29. 11 TO 16 TA ST PIPE OD 20 ID 18.25
30. 17 PRISMATIC AX 120 IZ 91000 IY 91000
31. *
32. CONSTANT
33. E 29000 ALL
34. *
35. SUPPORTS
36. 1 13 PINNED
37. UNIT FT
38. LOAD 1
39. JOINT LOAD
40. 10 FY 0
41. LOAD 2
```

ANALISYS

*BUOY,ANCHOR UNIT SECTION UNDER HORIZONTAL L
42. 8 FX 660
43. *
44. LOAD COMBINATION 3
45. 1 1.0 2 1.0
46. PERFORM ANALYSIS

P R O B L E M S T A T I S T I C S

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 13/ 17/ 2
ORIGINAL/FINAL BAND-WIDTH = 11/ 4
TOTAL PRIMARY LOAD CASES = 2, TOTAL DEGREES OF FREEDOM = 35
SIZE OF STIFFNESS MATRIX = 455 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE = 12.03/ 1293.9 MB, EXMEM = 1963.8 MB

++ Processing Element Stiffness Matrix.	13:12:39
++ Processing Global Stiffness Matrix.	13:12:39
++ Processing Triangular Factorization.	13:12:39
++ Calculating Joint Displacements.	13:12:39
++ Calculating Member Forces.	13:12:40

47. PARAMETER
48. RATIO 1.0 ALL
49. TRACK 1.0 ALL
50. CHECK CODE ALL

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

STAAD-III CODE CHECKING - (AISC)

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
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1	ST W36 X439	PASS .00	AISC- H1-3 .00	.067 213.67	2 5.60
---	-------------	-------------	-------------------	----------------	-----------

MEM= 1, UNIT KIP-INCH, L= 67.2 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 17.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.77 FT= 21.60 FV= 14.40					

2	ST W36 X439	PASS 660.00 C	AISC- H1-2 .00	.748 -1634.33	2 .00
---	-------------	------------------	-------------------	------------------	----------

MEM= 2, UNIT KIP-INCH, L= 19.2 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 4.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.39 FT= 21.60 FV= 14.40					

3	ST W36 X300	PASS 377.08 C	AISC- H1-2 .00	.992 -1737.01	2 .00
---	-------------	------------------	-------------------	------------------	----------

MEM= 3, UNIT KIP-INCH, L= 86.4 AX= 88.30 SZ=1105.1 SY= 156.1					
KL/R-Y= 22.5 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.44 FT= 21.60 FV= 14.40					

4	ST W33 X387	PASS .00	AISC- H1-3 .00	.242 647.57	2 7.20
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MEM= 4, UNIT KIP-INCH, L= 86.4 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 22.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.42 FT= 21.60 FV= 14.40					

5	ST W36 X439	PASS .00 C	AISC- H1-3 .00	.116 371.24	2 .00
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MEM= 5, UNIT KIP-INCH, L= 86.4 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 21.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.48 FT= 21.60 FV= 14.40					

6	ST W33 X387	PASS 377.08 T	AISC- H2-1 .00	.224 -186.11	2 .00
---	-------------	------------------	-------------------	-----------------	----------

MEM= 6, UNIT KIP-INCH, L= 172.8 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 45.6 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 18.72 FT= 21.60 FV= 14.40					

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
=====					
7	ST W33 X387	PASS 377.08 T	AISC- H2-1 .00	.336 484.69	2 .00

MEM= 7, UNIT KIP-INCH, L= 86.4 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 22.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.42 FT= 21.60 FV= 14.40					

8	ST W40 X593	PASS .00 T	SHEAR -Y .00	.596 1848.00	2 .00

MEM= 8, UNIT KIP-INCH, L= 33.6 AX=174.00 SZ=2344.7 SY= 302.0					
KL/R-Y= 8.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.21 FT= 21.60 FV= 14.40					

9	ST W40 X593	PASS .00 C	AISC- H1-3 .00	.000 .00	1 .00

MEM= 9, UNIT KIP-INCH, L= 22.8 AX=174.00 SZ=2344.7 SY= 302.0					
KL/R-Y= 6.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.34 FT= 21.60 FV= 14.40					

10	ST W14 X455	PASS .00 C	AISC- H1-3 .00	.000 .00	1 .00

MEM= 10, UNIT KIP-INCH, L= 30.0 AX=134.00 SZ= 756.0 SY= 304.1					
KL/R-Y= 6.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.30 FT= 21.60 FV= 14.40					

11	ST PIP E	PASS 469.61 T	AISC- H2-1 .00	.804 186.11	2 .00

MEM= 11, UNIT KIP-INCH, L= 155.8 AX= 52.57 SZ= 240.9 SY= 240.9					
KL/R-Y= 23.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.41 FT= 21.60 FV= 14.40					

12	ST PIP E	FAIL 633.74 C	AISC- H1-2 .00	1.029 224.56	2 .00

MEM= 12, UNIT KIP-INCH, L= 155.8 AX= 52.57 SZ= 240.9 SY= 240.9					
KL/R-Y= 23.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.41 FT= 21.60 FV= 14.40					

13	ST PIP E	PASS 38.16 T	AISC- H2-1 .00	.034 .00	2 .00

ANALYSIS

*BUOY ANCHOR UNIT SECTION UNDER HORIZONTAL L

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
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=====
| MEM=      13, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
|-----|
| 14 ST PIPE PASS AISC- H2-1 .411 2 |
| 467.12 T .00 .00 .00 |
|-----|
| MEM=      14, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
|-----|
| 15 ST PIPE PASS AISC- H1-3 .083 2 |
| 89.94 C .00 .00 .00 |
|-----|
| MEM=      15, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
|-----|
| 16 ST PIPE PASS AISC- H2-1 .119 2 |
| 134.71 T .00 .00 .00 |
|-----|
| MEM=      16, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
|-----|

```

51. PRINT ANALYSIS RESULTS

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.000000	.000000	.000000	.000000	.000000	-.00052
	3	.000000	.000000	.000000	.000000	.000000	-.00052
2	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.02983	-.07438	.000000	.000000	.000000	-.00049
	3	.02983	-.07438	.000000	.000000	.000000	-.00049
3	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.22548	.00324	.000000	.000000	.000000	-.00113
	3	.22548	.00324	.000000	.000000	.000000	-.00113
4	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.22206	-.09038	.000000	.000000	.000000	-.00082
	3	.22206	-.09038	.000000	.000000	.000000	-.00082
5	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.20934	-.03252	.000000	.000000	.000000	.00019
	3	.20934	-.03252	.000000	.000000	.000000	.00019
6	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.20934	-.03468	.000000	.000000	.000000	-.00003
	3	.20934	-.03468	.000000	.000000	.000000	-.00003
7	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.22548	-.07171	.000000	.000000	.000000	-.00123
	3	.22548	-.07171	.000000	.000000	.000000	-.00123
8	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.29238	-.07171	.000000	.000000	.000000	-.00148
	3	.29238	-.07171	.000000	.000000	.000000	-.00148
9	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.32623	-.07171	.000000	.000000	.000000	-.00148
	3	.32623	-.07171	.000000	.000000	.000000	-.00148
10	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.32623	-.02717	.000000	.000000	.000000	-.00148
	3	.32623	-.02717	.000000	.000000	.000000	-.00148
11	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.01988	-.08273	.000000	.000000	.000000	.00047
	3	.01988	-.08273	.000000	.000000	.000000	.00047
12	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.01988	-.04397	.000000	.000000	.000000	-.00001
	3	.01988	-.04397	.000000	.000000	.000000	-.00001
13	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.000000	.000000	.000000	.000000	.000000	.000000

ANALISYS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

SUPPORT REACTIONS -UNIT KIP FEET STRUCTURE TYPE = PLANE

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
1	1	.00	.00	.00	.00	.00	.00
	2	-660.00	-415.56	.00	.00	.00	.00
	3	-660.00	-415.56	.00	.00	.00	.00
13	1	.00	.00	.00	.00	.00	.00
	2	.00	415.56	.00	.00	.00	.00
	3	.00	415.56	.00	.00	.00	.00

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	3	.00	.00	.00	.00	.00	.00
		7	.00	.00	.00	.00	.00	.00
	2	3	.00	-38.16	.00	.00	.00	.00
		7	.00	38.16	.00	.00	.00	-213.67
	3	3	.00	-38.16	.00	.00	.00	.00
		7	.00	38.16	.00	.00	.00	-213.67
2	1	7	.00	.00	.00	.00	.00	.00
		4	.00	.00	.00	.00	.00	.00
	2	7	660.00	-38.16	.00	.00	.00	-1634.33
		4	-660.00	38.16	.00	.00	.00	1573.28
	3	7	660.00	-38.16	.00	.00	.00	-1634.33
		4	-660.00	38.16	.00	.00	.00	1573.28
3	1	4	.00	.00	.00	.00	.00	.00
		5	.00	.00	.00	.00	.00	.00
	2	4	377.08	-324.00	.00	.00	.00	-1737.01
		5	-377.08	324.00	.00	.00	.00	-595.81
	3	4	377.08	-324.00	.00	.00	.00	-1737.01
		5	-377.08	324.00	.00	.00	.00	-595.81
4	1	11	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	2	11	.00	-89.94	.00	.00	.00	.00
		12	.00	89.94	.00	.00	.00	-647.57
	3	11	.00	-89.94	.00	.00	.00	.00
		12	.00	89.94	.00	.00	.00	-647.57
5	1	5	.00	.00	.00	.00	.00	.00
		6	.00	.00	.00	.00	.00	.00
	2	5	.00	51.56	.00	.00	.00	371.24
		6	.00	-51.56	.00	.00	.00	.00
	3	5	.00	51.56	.00	.00	.00	371.24
		6	.00	-51.56	.00	.00	.00	.00
6	1	1	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	2	1	-377.08	-1.61	.00	.00	.00	-186.11
		12	377.08	1.61	.00	.00	.00	162.88
	3	1	-377.08	-1.61	.00	.00	.00	-186.11
		12	377.08	1.61	.00	.00	.00	162.88
7	1	12	.00	.00	.00	.00	.00	.00
		2	.00	.00	.00	.00	.00	.00

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	12	-377.08	43.15	.00	.00	.00	484.69
		2	377.08	-43.15	.00	.00	.00	-173.99
	3	12	-377.08	43.15	.00	.00	.00	484.69
		2	377.08	-43.15	.00	.00	.00	-173.99
8	1	7	.00	.00	.00	.00	.00	.00
		8	.00	.00	.00	.00	.00	.00
	2	7	.00	660.00	.00	.00	.00	1848.00
		8	.00	-660.00	.00	.00	.00	.00
	3	7	.00	660.00	.00	.00	.00	1848.00
		8	.00	-660.00	.00	.00	.00	.00
9	1	8	.00	.00	.00	.00	.00	.00
		9	.00	.00	.00	.00	.00	.00
	2	8	.00	.00	.00	.00	.00	.00
		9	.00	.00	.00	.00	.00	.00
	3	8	.00	.00	.00	.00	.00	.00
		9	.00	.00	.00	.00	.00	.00
10	1	9	.00	.00	.00	.00	.00	.00
		10	.00	.00	.00	.00	.00	.00
	2	9	.00	.00	.00	.00	.00	.00
		10	.00	.00	.00	.00	.00	.00
	3	9	.00	.00	.00	.00	.00	.00
		10	.00	.00	.00	.00	.00	.00
11	1	1	.00	.00	.00	.00	.00	.00
		4	.00	.00	.00	.00	.00	.00
	2	1	-469.61	26.95	.00	.00	.00	186.11
		4	469.61	-26.95	.00	.00	.00	163.73
	3	1	-469.61	26.95	.00	.00	.00	186.11
		4	469.61	-26.95	.00	.00	.00	163.73
12	1	5	.00	.00	.00	.00	.00	.00
		2	.00	.00	.00	.00	.00	.00
	2	5	633.74	30.71	.00	.00	.00	224.56
		2	-633.74	-30.71	.00	.00	.00	173.99
	3	5	633.74	30.71	.00	.00	.00	224.56
		2	-633.74	-30.71	.00	.00	.00	173.99
13	1	1	.00	.00	.00	.00	.00	.00
		3	.00	.00	.00	.00	.00	.00
	2	1	-38.16	.00	.00	.00	.00	.00
		3	38.16	.00	.00	.00	.00	.00
	3	1	-38.16	.00	.00	.00	.00	.00
		3	38.16	.00	.00	.00	.00	.00
14	1	2	.00	.00	.00	.00	.00	.00
		6	.00	.00	.00	.00	.00	.00

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	2	-467.12	.00	.00	.00	.00	.00
		6	467.12	.00	.00	.00	.00	.00
	3	2	-467.12	.00	.00	.00	.00	.00
		6	467.12	.00	.00	.00	.00	.00
15	1	4	.00	.00	.00	.00	.00	.00
		11	.00	.00	.00	.00	.00	.00
	2	4	89.94	.00	.00	.00	.00	.00
		11	-89.94	.00	.00	.00	.00	.00
	3	4	89.94	.00	.00	.00	.00	.00
		11	-89.94	.00	.00	.00	.00	.00
16	1	5	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	2	5	-134.71	.00	.00	.00	.00	.00
		12	134.71	.00	.00	.00	.00	.00
	3	5	-134.71	.00	.00	.00	.00	.00
		12	134.71	.00	.00	.00	.00	.00
17	1	6	.00	.00	.00	.00	.00	.00
		13	.00	.00	.00	.00	.00	.00
	2	6	-415.56	.00	.00	.00	.00	.00
		13	415.56	.00	.00	.00	.00	.00
	3	6	-415.56	.00	.00	.00	.00	.00
		13	415.56	.00	.00	.00	.00	.00

***** END OF LATEST ANALYSIS RESULT *****

52. FINISH

***** END OF STAAD-III *****

**** DATE= MAR 6,2000 TIME= 13:12:40 ****

 * For questions on STAAD-III, contact: *
 * Research Engineers, Inc at *
 * West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
 * East Coast: Ph- (508) 688-3626 Fax- (508) 685-7230 *

```
*****
*
*           S T A A D - I I I
*       Revision 22.3
*       Proprietary Program of
*       Research Engineers, Inc.
*       Date=      MAR  6, 2000
*       Time=      13:58:51
*
*       USER ID: HAN-PADRON ASSOCIATES
*****
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1.  STAAD PLANE ANALYSIS
2.  *BUOY.ANCHOR UNIT SECTION UNDER VERTICAL LOAD OF 440 KIPS
3.  *PRELIMINARY CALCULATION
4.  *RUN NAME-BUOY2
5.  UNIT KIP FT
6.  JOINT COORDINATES
7.  1 0 0; 2 21.6 0; 3 0 10.8; 4 7.2 10.8; 5 14.4 10.8
8.  6 21.6 10.8; 7 5.6 10.8; 8 5.6 13.6; 9 5.6 15.5
9.  10 3.1 15.5; 11 7.2 0; 12 14.4 0; 13 21.6 35
10. *
11. MEMBER INCIDENCES
12. 1 3 7; 2 7 4; 3 4 5; 4 11 12; 5 5 6; 6 1 12
13. 7 12 2; 8 7 8; 9 8 9; 10 9 10; 11 1 4; 12 5 2
14. 13 1 3; 14 2 6; 15 4 11; 16 5 12; 17 6 13
15. *
16. MEMBER RELEASE
17. 13 TO 16 START MY MZ
18. 13 TO 16 END MY MZ
19. 17 START MY MZ
20. 17 END MY MZ
21. *
22. UNIT INCHES
23. MEMBER PROPERTIES
24. 1 2 5 TA ST W36X439
25. 3 TA ST W36X300
26. 4 6 7 TA ST W33X387
27. 8 9 TA ST W40X593
28. 10 TA ST W14X455
29. 11 TO 16 TA ST PIPE OD 20 ID 18.25
30. 17 PRISMATIC AX 120 IZ 91000 IY 91000
31. *
32. CONSTANT
33. E 29000 ALL
34. *
35. SUPPORTS
36. 1 13 PINNED
37. UNIT FT
38. LOAD 1
39. JOINT LOAD
40. 10 FY -440
41. LOAD 2
```

ANALISYS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L
42. 8 FX 0
43. *
44. LOAD COMBINATION 3
45. 1 1.0 2 1.0
46. PERFORM ANALYSIS

P R O B L E M S T A T I S T I C S

NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS = 13/ 17/ 2
ORIGINAL/FINAL BAND-WIDTH = 11/ 4
TOTAL PRIMARY LOAD CASES = 2, TOTAL DEGREES OF FREEDOM = 35
SIZE OF STIFFNESS MATRIX = 455 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE = 12.03/ 1292.7 MB, EXMEM = 1963.6 MB

++ Processing Element Stiffness Matrix.	13:31: 7
++ Processing Global Stiffness Matrix.	13:31: 7
++ Processing Triangular Factorization.	13:31: 7
++ Calculating Joint Displacements.	13:31: 7
++ Calculating Member Forces.	13:31: 7

47. PARAMETER
48. RATIO 1.0 ALL
49. TRACK 1.0 ALL
50. CHECK CODE ALL

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

STAAD-III CODE CHECKING - (AISC)

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
=====					
1	ST W36 X439	PASS .00	AISC- H1-3 .00	.423 -1358.11	1 5.60

MEM= 1, UNIT KIP-INCH, L= 67.2 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 17.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.77 FT= 21.60 FV= 14.40					

2	ST W36 X439	PASS .00 C	SHEAR -Y .00	.264 -258.11	1 .00

MEM= 2, UNIT KIP-INCH, L= 19.2 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 4.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.39 FT= 21.60 FV= 14.40					

3	ST W36 X300	PASS 71.50 C	AISC- H1-3 .00	.136 210.99	1 7.20

MEM= 3, UNIT KIP-INCH, L= 86.4 AX= 88.30 SZ=1105.1 SY= 156.1					
KL/R-Y= 22.5 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.44 FT= 21.60 FV= 14.40					

4	ST W33 X387	PASS .00	AISC- H1-3 .00	.092 245.72	1 7.20

MEM= 4, UNIT KIP-INCH, L= 86.4 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 22.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.42 FT= 21.60 FV= 14.40					

5	ST W36 X439	PASS .00 T	AISC- H2-1 .00	.050 161.20	1 .00

MEM= 5, UNIT KIP-INCH, L= 86.4 AX=128.00 SZ=1620.5 SY= 234.6					
KL/R-Y= 21.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.48 FT= 21.60 FV= 14.40					

6	ST W33 X387	PASS 71.50 T	AISC- H2-1 .00	.081 -139.13	1 14.40

MEM= 6, UNIT KIP-INCH, L= 172.8 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 45.6 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 18.72 FT= 21.60 FV= 14.40					

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
=====					
7	ST W33 X387	PASS 71.50 T	AISC- H2-1 .00	.069 106.59	1 .00

MEM= 7, UNIT KIP-INCH, L= 86.4 AX=113.00 SZ=1351.9 SY= 200.0					
KL/R-Y= 22.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 20.42 FT= 21.60 FV= 14.40					

8	ST W40 X593	PASS 440.00 C	AISC- H1-3 .00	.356 -1100.00	1 .00

MEM= 8, UNIT KIP-INCH, L= 33.6 AX=174.00 SZ=2344.7 SY= 302.0					
KL/R-Y= 8.8 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.21 FT= 21.60 FV= 14.40					

9	ST W40 X593	PASS 440.00 C	AISC- H1-3 .00	.355 -1100.00	1 .00

MEM= 9, UNIT KIP-INCH, L= 22.8 AX=174.00 SZ=2344.7 SY= 302.0					
KL/R-Y= 6.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.34 FT= 21.60 FV= 14.40					

10	ST W14 X455	PASS .00 T	SHEAR -Y .00	.797 1100.00	1 .00

MEM= 10, UNIT KIP-INCH, L= 30.0 AX=134.00 SZ= 756.0 SY= 304.1					
KL/R-Y= 6.9 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 27.00 FTY= 27.00 FA= 21.30 FT= 21.60 FV= 14.40					

11	ST PIPE	PASS 146.77 C	AISC- H1-3 .00	.338 -96.16	1 12.98

MEM= 11, UNIT KIP-INCH, L= 155.8 AX= 52.57 SZ= 240.9 SY= 240.9					
KL/R-Y= 23.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.41 FT= 21.60 FV= 14.40					

12	ST PIPE	PASS 118.85 C	AISC- H1-3 .00	.215 49.79	1 .00

MEM= 12, UNIT KIP-INCH, L= 155.8 AX= 52.57 SZ= 240.9 SY= 240.9					
KL/R-Y= 23.0 CB= 1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76					
FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.41 FT= 21.60 FV= 14.40					

13	ST PIPE	PASS 242.52 C	AISC- H1-1 .00	.223 .00	1 .00

ANALYSIS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

ALL UNITS ARE - KIP FEET (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
--------	-------	---------------	----------------------	--------------	----------------------

```

=====
| MEM=      13, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
=====

```

14	ST PIPE	PASS	AISC- H2-1	.075	1
		85.54 T	.00	.00	.00

```

=====
| MEM=      14, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
=====

```

15	ST PIPE	PASS	AISC- H1-3	.031	1
		34.13 C	.00	.00	.00

```

=====
| MEM=      15, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
=====

```

16	ST PIPE	PASS	AISC- H2-1	.034	1
		38.16 T	.00	.00	.00

```

=====
| MEM=      16, UNIT KIP-INCH, L= 129.6 AX= 52.57 SZ= 240.9 SY= 240.9 |
| KL/R-Y=   19.1 CB=   1.00 YLD= 36.00 ALLOWABLE STRESSES: FCZ= 23.76 |
| FTZ= 23.76 FCY= 23.76 FTY= 23.76 FA= 20.65 FT= 21.60 FV= 14.40 |
=====

```

51. PRINT ANALYSIS RESULTS

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	.000000	.000000	.000000	.000000	.000000	-.000020
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.000000	.000000	.000000	.000000	.000000	-.000020
2	1	.005666	-.01254	.000000	.000000	.000000	-.000001
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.005666	-.01254	.000000	.000000	.000000	-.000001
3	1	.032666	-.02062	.000000	.000000	.000000	-.000033
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.032666	-.02062	.000000	.000000	.000000	-.000033
4	1	.032666	-.03980	.000000	.000000	.000000	.000031
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.032666	-.03980	.000000	.000000	.000000	.000031
5	1	.03025	-.01074	.000000	.000000	.000000	.000015
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.03025	-.01074	.000000	.000000	.000000	.000015
6	1	.03025	-.00527	.000000	.000000	.000000	.000006
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.03025	-.00527	.000000	.000000	.000000	.000006
7	1	.032666	-.05060	.000000	.000000	.000000	.000028
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.032666	-.05060	.000000	.000000	.000000	.000028
8	1	.01811	-.05353	.000000	.000000	.000000	.000058
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.01811	-.05353	.000000	.000000	.000000	.000058
9	1	.00243	-.05552	.000000	.000000	.000000	.000079
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.00243	-.05552	.000000	.000000	.000000	.000079
10	1	.00243	-.12198	.000000	.000000	.000000	.00174
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.00243	-.12198	.000000	.000000	.000000	.00174
11	1	.00377	-.03690	.000000	.000000	.000000	.000027
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.00377	-.03690	.000000	.000000	.000000	.000027
12	1	.00377	-.01398	.000000	.000000	.000000	.000009
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.00377	-.01398	.000000	.000000	.000000	.000009
13	1	.000000	.000000	.000000	.000000	.000000	.000000
	2	.000000	.000000	.000000	.000000	.000000	.000000
	3	.000000	.000000	.000000	.000000	.000000	.000000

ANALISYS

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

SUPPORT REACTIONS -UNIT KIP FEET STRUCTURE TYPE = PLANE

JOINT	LOAD	FORCE - X	FORCE - Y	FORCE - Z	MOM - X	MOM - Y	MOM Z
1	1	.00	376.85	.00	.00	.00	.00
	2	.00	.00	.00	.00	.00	.00
	3	.00	376.85	.00	.00	.00	.00
13	1	.00	63.15	.00	.00	.00	.00
	2	.00	.00	.00	.00	.00	.00
	3	.00	63.15	.00	.00	.00	.00

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	3	.00	242.52	.00	.00	.00	.00
		7	.00	-242.52	.00	.00	.00	1358.11
	2	3	.00	.00	.00	.00	.00	.00
		7	.00	.00	.00	.00	.00	.00
	3	3	.00	242.52	.00	.00	.00	.00
		7	.00	-242.52	.00	.00	.00	1358.11
2	1	7	.00	-197.48	.00	.00	.00	-258.11
		4	.00	197.48	.00	.00	.00	-57.85
	2	7	.00	.00	.00	.00	.00	.00
		4	.00	.00	.00	.00	.00	.00
	3	7	.00	-197.48	.00	.00	.00	-258.11
		4	.00	197.48	.00	.00	.00	-57.85
3	1	4	71.50	-34.62	.00	.00	.00	-38.31
		5	-71.50	34.62	.00	.00	.00	-210.99
	2	4	.00	.00	.00	.00	.00	.00
		5	.00	.00	.00	.00	.00	.00
	3	4	71.50	-34.62	.00	.00	.00	-38.31
		5	-71.50	34.62	.00	.00	.00	-210.99
4	1	11	.00	-34.13	.00	.00	.00	.00
		12	.00	34.13	.00	.00	.00	-245.72
	2	11	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	3	11	.00	-34.13	.00	.00	.00	.00
		12	.00	34.13	.00	.00	.00	-245.72
5	1	5	.00	22.39	.00	.00	.00	161.20
		6	.00	-22.39	.00	.00	.00	.00
	2	5	.00	.00	.00	.00	.00	.00
		6	.00	.00	.00	.00	.00	.00
	3	5	.00	22.39	.00	.00	.00	161.20
		6	.00	-22.39	.00	.00	.00	.00
6	1	1	-71.50	5.60	.00	.00	.00	-58.42
		12	71.50	-5.60	.00	.00	.00	139.13
	2	1	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	3	1	-71.50	5.60	.00	.00	.00	-58.42
		12	71.50	-5.60	.00	.00	.00	139.13
7	1	12	-71.50	9.63	.00	.00	.00	106.59
		2	71.50	-9.63	.00	.00	.00	-37.24

ANALYSIS

*BUOY,ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	12	.00	.00	.00	.00	.00	.00
		2	.00	.00	.00	.00	.00	.00
	3	12	-71.50	9.63	.00	.00	.00	106.59
		2	71.50	-9.63	.00	.00	.00	-37.24
8	1	7	440.00	.00	.00	.00	.00	-1100.00
		8	-440.00	.00	.00	.00	.00	1100.00
	2	7	.00	.00	.00	.00	.00	.00
		8	.00	.00	.00	.00	.00	.00
	3	7	440.00	.00	.00	.00	.00	-1100.00
		8	-440.00	.00	.00	.00	.00	1100.00
9	1	8	440.00	.00	.00	.00	.00	-1100.00
		9	-440.00	.00	.00	.00	.00	1100.00
	2	8	.00	.00	.00	.00	.00	.00
		9	.00	.00	.00	.00	.00	.00
	3	8	440.00	.00	.00	.00	.00	-1100.00
		9	-440.00	.00	.00	.00	.00	1100.00
10	1	9	.00	440.00	.00	.00	.00	1100.00
		10	.00	-440.00	.00	.00	.00	.00
	2	9	.00	.00	.00	.00	.00	.00
		10	.00	.00	.00	.00	.00	.00
	3	9	.00	440.00	.00	.00	.00	1100.00
		10	.00	-440.00	.00	.00	.00	.00
11	1	1	146.77	11.91	.00	.00	.00	58.42
		4	-146.77	-11.91	.00	.00	.00	96.16
	2	1	.00	.00	.00	.00	.00	.00
		4	.00	.00	.00	.00	.00	.00
	3	1	146.77	11.91	.00	.00	.00	58.42
		4	-146.77	-11.91	.00	.00	.00	96.16
12	1	5	118.85	6.71	.00	.00	.00	49.79
		2	-118.85	-6.71	.00	.00	.00	37.24
	2	5	.00	.00	.00	.00	.00	.00
		2	.00	.00	.00	.00	.00	.00
	3	5	118.85	6.71	.00	.00	.00	49.79
		2	-118.85	-6.71	.00	.00	.00	37.24
13	1	1	242.52	.00	.00	.00	.00	.00
		3	-242.52	.00	.00	.00	.00	.00
	2	1	.00	.00	.00	.00	.00	.00
		3	.00	.00	.00	.00	.00	.00
	3	1	242.52	.00	.00	.00	.00	.00
		3	-242.52	.00	.00	.00	.00	.00
14	1	2	-85.54	.00	.00	.00	.00	.00
		6	85.54	.00	.00	.00	.00	.00

*BUOY.ANCHOR UNIT SECTION UNDER HORIZONTAL L

MEMBER END FORCES STRUCTURE TYPE = PLANE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	2	.00	.00	.00	.00	.00	.00
		6	.00	.00	.00	.00	.00	.00
	3	2	-85.54	.00	.00	.00	.00	.00
		6	85.54	.00	.00	.00	.00	.00
15	1	4	34.13	.00	.00	.00	.00	.00
		11	-34.13	.00	.00	.00	.00	.00
	2	4	.00	.00	.00	.00	.00	.00
		11	.00	.00	.00	.00	.00	.00
	3	4	34.13	.00	.00	.00	.00	.00
		11	-34.13	.00	.00	.00	.00	.00
16	1	5	-38.16	.00	.00	.00	.00	.00
		12	38.16	.00	.00	.00	.00	.00
	2	5	.00	.00	.00	.00	.00	.00
		12	.00	.00	.00	.00	.00	.00
	3	5	-38.16	.00	.00	.00	.00	.00
		12	38.16	.00	.00	.00	.00	.00
17	1	6	-63.15	.00	.00	.00	.00	.00
		13	63.15	.00	.00	.00	.00	.00
	2	6	.00	.00	.00	.00	.00	.00
		13	.00	.00	.00	.00	.00	.00
	3	6	-63.15	.00	.00	.00	.00	.00
		13	63.15	.00	.00	.00	.00	.00

***** END OF LATEST ANALYSIS RESULT *****

52. FINISH

***** END OF STAAD-III *****

**** DATE= MAR 6,2000 TIME= 13:31: 7 ****

 * For questions on STAAD-III, contact: *
 * Research Engineers, Inc at *
 * West Coast: Ph- (714) 974-2500 Fax- (714) 921-2543 *
 * East Coast: Ph- (508) 688-3626 Fax- (508) 685-7230 *

STRUCTURE DATA

TYPE = PLANE

$$Z_3 = 13$$

MM = 17

NE = 0

$$N_S = 0$$

NRJ= 2

21 3

XMAX= 2

YMAX= 31

ZMAX=

MN/ELEM

J=13, M=17

UNIT FEE KIP

STAAD POST - PLOT (REV: 22.3)
TITLE: ANALYSIS

DATE: MAR 5, 2000

PROJECT

SUBJECT.

Bouy ANCHOR UNIT STEEL STRUCTURE

SHEET NO. 1 OF 5
JOB NO. 869.02
MADE BY LL DATE 03/05/00
CHKD. BY _____ DATE _____

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

ANCHOR UNIT

STEEL STRUCTURE

SECTION 21

SHEET NO. 2 OF 5
JOB NO. 864.02
MADE BY LL DATE 03/05/00
CHKD. BY _____ DATE _____

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

ANCHOR UNIT

STEEL STRUCTURE

SHEET NO. 3 OF 5
JOB NO. 864.02
MADE BY LL DATE 03/05/00
CHKD. BY _____ DATE _____

SECTION 3 / 1

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

ANCHOR UNIT

STEEL STRUCTURE

SHEET NO. 4 OF 5
JOB NO. 864,02
MADE BY LL DATE 02/29/00
CHKD. BY _____ DATE _____

SECTION 4 / 1
SCALE 1:25

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

ANCHOR UNIT

STEEL STRUCTURE

SHEET NO. 5 OF 5
JOB NO. 864.02
MADE BY LL DATE 02/29/00
CHKD. BY _____ DATE _____

SECTION 5 / 1

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

PLATE UNIT

STEEL STRUCTURE

A
2A

SHEET NO. 1A OF 4
JOB NO. 864.02
MADE BY LL DATE 03/02/00
CHKD. BY _____ DATE _____

PLAN. TOP OF UNIT
SCALE 1:75

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT Buoy
SUBJECT PLATE UNIT
STEEL STRUCTURE

SECTION

SCALE 1:50

A
1A

SHEET NO. 2A OF 4
JOB NO. 864, 0L
MADE BY LL DATE 03/02/00
CHKD. BY _____ DATE _____

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT

Buoy

SUBJECT

PLATE UNIT

STEEL STRUCTURE

A
2A

SHEET NO. 3A OF 4
JOB NO. 864.02
MADE BY LC DATE 03/03/00
CHKD. BY DATE

SLIDING
RING

SIMILAR C
4A

C
4A

B
2A

SECTION
SCALE 1:75

HAN-PADRON ASSOCIATES

CONSULTING ENGINEERS

PROJECT Buoy
SUBJECT PLATE UNIT
STEEL STRUCTURE

SHEET NO. 4A OF 4
 JOB NO. 864.01
 MADE BY LL DATE 03/03/00
 CHKD. BY _____ DATE _____

0x116)

JOINT
 SCALE 1:25 (1)

1. July 2000

Preliminary calculations of bearings and anchor unit

Alternative Design

Design Loads:

Horizontal load from chains:	6000
kN	
Differential pressure on water pipe:	200kPa

Material and design stress:

All steel parts are made from hot rolled sheets with $f_y = 36$ ksi ($f_y = 248$ MPa)	
Design stress in bending: $248/1.67 =$	149
MPa	
Design stress in shear: $248/2.50 =$	99 MPa
Bolt quality 8.8 (tensile strength = 800 MPa, yield stress = 640 MPa)	
M54, effective cross section in tension: 1890 mm^2	
Prestress: $1890 \times 800 \times 0.7 \times 10^{-3} =$	1058
kN	
Design strength: $1890 \times 800 \times 10^{-3} / 2 =$	756 kN

Bearings:

Bearings between plate unit and anchor unit are Mammoth rollers from Hilman Equipment Co., New Jersey.

Bearing for horizontal load is a modified type 7X with a capacity of 500 US tons = 4448 kN

Bearing for vertical load is a modified type 6X with a capacity of 300 US tons = 2669 kN

Bearings between chains and anchor unit are LUBRON AQ flange bushings. Lubron alloy 862 is used with a recommended bearing load of 6000 psi = 41.4 MPa. Stainless steel is intended as material in mating surface.

Assumptions:

1. 6 parallel chains are connected to weights. The submerged weight of each is 1000 kN. The weights are moving in vertical tubes sunk into the sea bed.
2. Horizontal force is assumed evenly distributed between the chains.
3. Vertical loads are only considered in the design of the lubron bearings.
4. Approximate geometry is used in the calculations.

Extent of design:

Only the lower part of the anchor unit is considered. The upper part is not different from the "standard" design.

Calculation of bearing loads on Lubon bushings:

Horizontal load: $R = 1000 \text{ kN}$
Moment at center of bearing : $M = 1000 \times 0.475$
 $= 475 \text{ kNm}$
Bearing stress on bushing: $f = 1.000 / (0.55 \times 0.275) + 0.475 \times 6 / (0.275 \times 0.550^2) =$
 $40.9 \text{ MPa} < 41.4 \text{ MPa}$
Vertical load: $N = 1000 \text{ kN}$
Bearing stress on flange: $f = 1.000 \times 4 / (\pi (0.375^2 - 0.325^2)) = 36.4 \text{ MPa} < 41.4 \text{ MPa}$

Design of bottom ring beam:

Horizontal forces: The ring is loaded with six parallel forces of 1000 kN each. The ring must redistribute the forces as a sinus distributed shear force in the cylindrical wall. Diagonal beams are not considered.

From Roark's Formulas for Stress & Strain, 6th. edition, table 17, case 1, case 4 and case 20:

Moment around vertical axis: $M = W \times R (3^{1/2}/2 - 3/\pi) = 1000 \times 3.175 (3^{1/2}/2 - 3/\pi) =$

-282 kNm

$N = 3 \times W/\pi = 3 \times 1000/\pi = 955 \text{ kN}$

Shear: $V = 1000/2 = 500 \text{ kN}$

Excentricity of chain force: $e = 550/2 + 200 = 475 \text{ mm}$

Moment around horizontal axis: $M = 1000 \times 0.475/2 = 138 \text{ kNm}$

Torsional moments are carried by the diagonal beams.

Cross sectional properties: $A = 550 \times 550 - 510 \times 510 = 42400 \text{ mm}^2$
 $I = 550 \times 550^3/12 - 510 \times 510^3/12 = 1988 \times 10^6$
 mm^4

$S = I/275 = 7.229 \times 10^6 \text{ mm}^3$

Stress: $f = 955/42.4 + (282 + 138)/7.229 = 81 \text{ MPa} < 149 \text{ MPa}$

Shear stress: $\tau = 500000 / (20 \times 2 \times 550) = 23 \text{ MPa}$

Design of diagonal beam in bottom ring:

Moment: $M = 1000 \times 0.475 = 475 \text{ kNm at edge}$
Shear force: $Q = 475 / 3.5 = 136 \text{ kN}$
Cross sectional properties: $A = 2 \times 300 \times 20 + 510 \times 15 = 19650 \text{ mm}^2$
 $I = \frac{1}{2} \times 300 \times 20 \times 530^2 + 15 \times 510^3 / 12 = 1009 \times 10^6 \text{ mm}^4$
 $S = I / 275 = 3.667 \times 10^6 \text{ mm}^3$
Normal stress: $f = 475 / 3.667 = 130 \text{ MPa} < 149 \text{ MPa}$
Shear stress: $\tau = 136000 / (550 \times 15) = 16.5 \text{ MPa}$

Design of exterior cylindrical shell:

Shear stress: $f = W / (\pi \times R \times t) = 6000 \times 10^3 / (\pi \times 3500 \times 20)$
 $= 27 \text{ MPa}$
Moment: $M = 6000 \times 2.650 = 15900 \text{ kNm}$
Bending stress (neglecting vertical stiffeners): $f = M / (\pi \times R^2 \times t) = 15900 \times 10^6 / (\pi \times 3500^2 \times 20) = 21 \text{ MPa}$
Critical elastic shear stress according to ECCS: "Buckling of Steel Shells"
 $f = 0.75 \times E \times (R/t)^{0.5} \times (t/R)^{1.25} = 0.75 \times 2.1 \times 10^5 \times (3500/1950)^{0.5} \times (20/3500)^{1.25} = 332 \text{ MPa} \gg 99 \text{ MPa} > 27$
Critical elastic compression stress according to API RP 2A:
 $f_{xc} = 2 \times 0.3 \times E \times t/D = 0.6 \times 2.1 \times 10^5 \times 20/7000 = 360 \text{ MPa}$
Design compression stress: $f_{xc} = 149 (1.64 - 0.23 \times (7000/20)^{0.25}) = 96 > 21 \text{ MPa}$

1. July 2000

Preliminary calculations of bearings and anchor unit

Design Loads:

Horizontal load from chains: 6000
kN
Differential pressure on water pipe: 200kPa

Material and design stress:

All steel parts are made from hot rolled sheets with $f_y = 36$ ksi ($f_y = 248$ MPa)
Design stress in bending: $248/1.67 =$ 149
MPa
Design stress in shear: $248/2.50 =$ 99 MPa
Bolt quality 8.8 (tensile strength = 800 MPa, yield stress = 640 MPa)
M54, effective cross section in tension: 1890 mm^2
Prestress: $1890 \times 800 \times 0.7 \times 10^{-3} =$ 1058
kN
Design strenght: $1890 \times 800 \times 10^{-3} / 2 =$ 756 kN

Bearings:

Bearings between plate unit and anchor unit are Mammoth rollers from Hilman Equipment Co., New Jersey.
Bearing for horizontal load is a modified type 7X with a capacity of 500 US tons = 4448 kN
Bearing for vertical load is a modified type 6X with a capacity of 300 US tons = 2669 kN

Assumptions:

1. 6 chains are spread out radial from the buoy, each of them anchored to a concrete block on the sea bed.
2. The horizontal force is assumed transmitted by only one chain.
3. Vertical loads from chains are neglected. On the safe side, as vertical chain load reduces moment at level of bearings.
4. Approximate geometry is used in the calculations.

Calculation of bearing loads:

Horizontal load: $R = 6000 / (1 + 2 \times \cos(60^\circ)^2) = 4000 \text{ kN} < 4448$
kN
Vertical load: Moment at level of bearings : $M = 6000 \times 3.81 =$ 22860 kNm
Diameter of centerline of bearings : 6.69 m
 $R = M / (1.5 \times 6.69) = 2278 \text{ kN} < 2669 \text{ kN}$

Design of bottom ring beam:

Horizontal forces:

6000 kN.
distributed
diagonal beam
considered.

The ring is loaded with one horizontal force of
The ring must redistribute the force as a sinus
shear force in the cylindrical wall. Only the
in the direction of the force is

From Roark's Formulas for Stress & Strain, 6th. edition, table 17, case 1 and case 20:

$$M = W \times R / (4 \times \pi) = 6000 \times 3.175 / 12.566 =$$

1516 kNm

$$N = 0.75 \times W / \pi = 0.75 \times 6000 / \pi = 1432 \text{ kN}$$

Cross sectional properties:

$$A = 900 \times 650 - 840 \times 600 = 81000 \text{ mm}^2$$

$$I = 900 \times 650^3 / 12 - 840 \times 600^3 / 12 = 5477 \times 10^6$$

mm⁴

$$S = I / 325 = 16.85 \times 10^6 \text{ mm}^3$$

Stress:

$$f = 1432 / 81 + 1516 / 16.85 = 108 \text{ MPa} < 149$$

MPa

Design of diagonal beam in bottom ring:

connection is

Moment from the excentricity of the chain
carried by the diagonal beams

Normal force:

$$N = \frac{1}{2} \times 6000 = 3000 \text{ kN}$$

Moment:

Excentricity of horizontal chain force: 900/2 -

200 =

250 mm

$$M = 6000 \times 0.250 = 1500 \text{ kNm at edge}$$

$$M = 1500 \times 6350 / 7000 = 1361 \text{ kNm at inner beam}$$

edge of ring

Differential pressure on water pipe: $200 \times 2.2^2 \times$

$\pi / 4 =$

760 kN

$$M = 760 \times 7.0 / (3 \times 4) + \frac{1}{2} \times 1500 = 1193 <$$

1361 at center

Shear force:

$$Q = 1500 / 7.0 + 760 / 6 = 341 \text{ kN}$$

Cross sectional properties:

$$A = 2 \times 500 \times 30 + 840 \times 25 = 51000 \text{ mm}^2$$

$$I = \frac{1}{2} \times 500 \times 30 \times 870^2 + 25 \times 840^3 / 12 = 6912 \times$$

10⁶ mm⁴

$$S = I / 450 = 15.36 \times 10^6 \text{ mm}^3$$

Normal stress:

$$f = 3000 / 51.00 + 1361 / 15.36 = 147 \text{ MPa} < 149$$

MPa

Shear stress:

$$f = 341000 / (900 \times 25) = 15 \text{ MPa}$$

Design of exterior cylindrical shell:

Shear stress: $f = W/(\pi \times R \times t) = 6000 \times 10^3 / (\pi \times 3500 \times 25)$
= 22 MPa

Moment: $M = 6000 \times 2.650 = 15900 \text{ kNm}$

Bending stress (neglecting vertical stiffeners): $f = M/(\pi \times R^2 \times t) = 15900 \times 10^6 / (\pi \times 3500^2 \times 25) = 17 \text{ MPa}$

Critical elastic shear stress according to ECCS: "Buckling of Steel Shells"
 $f = 0.75 \times E \times (R/t)^{0.5} \times (t/R)^{1.25} = 0.75 \times 2.1 \times 10^5 \times (3500/1950)^{0.5} \times (25/3500)^{1.25} = 438 \text{ MPa} \gg 99 \text{ MPa}$

Critical elastic compression stress according to API RP 2A:
 $f_{xc} = 2 \times 0.3 \times E \times t/D = 0.6 \times 2.1 \times 10^5 \times 25/7000 = 450 \text{ MPa}$

Design compression stress: $f_{xc} = 149 (1.64 - 0.23 \times (7000/25)^{0.25}) = 104 > 17 \text{ MPa}$

Design of upper flat plate:

The part of the plate between the radial stiffeners is approximated with a circular plate with clamped edges, $R = 650 \text{ mm}$.

Moment per unit length: $m = p R^2 / 8 = 200 \times 0.65^2 / 8 = 10.56 \text{ kN}$
 $f = 6 \times 10560/30^2 = 70 \text{ MPa} < 149 \text{ MPa}$

Design of beam over bearings:

Vertical load from bearing: 2278 kN

Tension in bolts: $N_t = 2278 \times 2000/1515 = 3007 \text{ kN}$

Vertical reaction at inner end of beam: $N_c = 3007 - 2278 = 729 \text{ kN}$

Tension in one bolt: $N = 3007/4 = 752 \text{ kN} < 756 \text{ MPa}$

Shear in beam: $Q = 2278 \text{ kN}$

Moment in beam: $M = 2278 \times 0.380 = 866 \text{ kNm}$

Shear stress: $f = 2278 \times 10^3 / (40 \times 600) = 95 \text{ MPa} < 99 \text{ MPa}$

Cross sectional properties:
 $A = 400 \times 40 + 520 \times 40 + 300 \times 40 = 16000 + 12000 = 48800 \text{ mm}^2$

Depth of Center of gravity:
 $\eta = (16000 \times 20 + 20800 \times 300 + 12000 \times 580) / 48800 = 277.0 \text{ mm}$

$I = 16000 \times 257^2 + 20800 \times 23^2 + 12000 \times 303^2 + 20800 \times 520^2 / 12 = 2638 \times 10^6 \text{ mm}^4$

$S = I/323 = 8167 \times 10^3 \text{ mm}^3 \text{ (top)}$
 $S = I/277 = 9524 \times 10^3 \text{ mm}^3 \text{ (bottom)}$

Bending stress, top: $f = 866/8.167 = 106 \text{ MPa} < 149 \text{ MPa}$

Bending stress, bottom: $f = 866/9.524 = 91 \text{ MPa}$

Considering holes for bolts: $f = 91 \times 400/280 = 130 \text{ MPa} < 149 \text{ MPa}$

Anchor Unit, 1:25

26.06.2000

D-D, 1:25

26.06.2000

E-E, 1:25

26.06.2000

F-F, 1:25

26.06.2000

Beam over bearing

A-A, 1:25

B-B, 1:10

C-C, 1:10

Content of Chapter 3

The content of this chapter is the design by Han-Padron Associates of the rapid ascent system. The high-pressure tanks are not detailed. They consist of standard 10-inch pipe that are coiled at convenient locations on the underside of the buoy.

The capacity to perform multiple mooring attempts is ensured by making the 10-inch tanks long enough. A standard pressure of 3000 psi is used for these tanks. 50 meters of pipe contain sufficient air for one mooring attempt. Thus 2* 200 meters of piping is adequate to give the buoy the capability to perform 8 mooring attempts without having the high-pressure air replenished.

The electrical system has not been detailed. However it is based on 24 volt DC maintained by battery packs that are recharged each time a ship is present. The charging power is provided through an electromagnetic coupler surrounding the coupling for the high-pressure air supply from the ship.

The electrical system is duplicated (A system and B system) These systems have no common parts and are connected to their respective buoyancy control system. Each system has an acoustic receiver that "wakes the system up" when the ship approaches and sends the signal. An acoustic confirmation signal is repeatedly emitted in response. Following wake-up vertical lights are lit to assist in centering the buoy.

Following wake-up PLCs initiate a series of events as follows:

- Pressure in the low pressure tank is raised if required to 700 kPa above ambient external pressure
- The leak proof valve is opened
- The pilot for the rapid opening valve is energized

The command to ascend rapidly is received as a modulated infrared signal from the ship. This causes actuation of the rapid opening valve. If this signal is lost for more than 30 seconds then the rapid descent system is automatically activated. This will for example be the case each time the mooring is successfully moored and the vessel shuts off the signal.

Rapid descent is also activated by an acoustic signal received by the wake-up unit.

The unit automatically goes into sleeping mode one hour after "wake up" or when battery charging starts.

January 14, 2000
Job No. 864-01

Mr. Jens Korsgaard
Suction Mooring Technology
318 North Post Road
Princeton, NJ 08550

Dear Jens,

Han-Padron Associates LLP is pleased to submit the attached report in conclusion of the design/analysis work of the SMT Pneumatic Deployment (Ascend)/Rapid Descend System. The report consists of a summary of the process data, simplified P&ID, detailed calculations, valve catalog cuts and model numbers, and a budgetary estimate by Daniel Valve Company.

We appreciate the opportunity to carry out this work and we look forward to performing any subsequent work on the subject matter. Please call me should you have any question or comment.

Very truly yours,

HAN-PADRON ASSOCIATES, LLP

Yehoshua Gilad, P.E.
Mechanical Department Manager
Project Manager

YG/yg

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c: M. Faeth

SMT Pneumatic Deployment (Ascend)/Rapid Descend System

Process Data and Description

1. General Description

The suction mooring pneumatic system consists of three compressed air tanks interconnected with pipes and valves to provide the mooring deployment motion (ascend), the emergency disengagement motion (rapid descend), and all associated compressed air services (refill, pressure maintenance, control functions, etc.). The three tanks include a high-pressure tank (HPT), a low-pressure tank (LPT), and a bottomless buoyancy tank (BBT).

The LPT supplies the necessary compressed air to purge the water from the BBT during deployment (ascend) and to purge the air from the BBT during rapid descent. Both operations are performed separately and by separate pipelines and control valves. The HPT serves as a reservoir used to replenish the LPT. All operations are controlled remotely from the moored vessel.

Compressed air is supplied to the mooring system by the vessel through a quick-connect coupling. It is assumed that periodic maintenance will be performed on the mooring system. Thus, the air lines feeding the valve pilots, where instrument air is needed, are equipped with a filter/regulator/lubricator and a desiccant cartridge.

2. Deployment System

The LPT is designed to provide compressed air to the BBT for four separate deployment attempts. It has a design operating pressure range of 80.5 psia to 175 psia. Compressed air is transferred to the BBT through a 6 inch pipeline equipped with an 8 inch control valve. The volumes of the LPT and BBT are 140 cu-m and 150 cu-m, respectively. The control valve is fully open/close within 2 seconds, and remains open continuously for 8 seconds (per deployment attempt). The incoming compressed air drives the water out of the BBT causing the mooring system to ascend to the vessel. The maximum pressure in the BBT is 66 psia which is the static pressure at the design depth of 35m. With each deployment attempt, the mass flowrate and remaining mass in the LPT change as do the pressure and temperature inside the LPT. In all cases, the flow through the interconnecting pipe is subsonic.

The conditions for each deployment attempt are shown in the following table:

Stage	State Variable	Mass Transfer
Preliminary		
	Air Mass = 4,489 lb _m	
	Pressure = 175 psia	
	Temperature = 60°F	
After Deployment 1		
	Air Mass = 4,035 lb _m	Air Mass = 454 lb _m
	Pressure = 150.5 psia	
	Temperature = 38°F	
After Deployment 2		
	Air Mass = 3,639 lb _m	Air Mass = 396 lb _m
	Pressure = 130.2 psia	
	Temperature = 18°F	
After Deployment 3		
	Air Mass = 3,295 lb _m	Air Mass = 344 lb _m
	Pressure = 113.3 psia	
	Temperature = -1°F	
After Deployment 4		
	Air Mass = 2,999 lb _m	Air Mass = 296 lb _m
	Pressure = 99.4 psia	
	Temperature = -17°F	

The final conditions after each deployment attempt were assumed to be the initial conditions for the following attempt.

3. Rapid Descent System

In case of an emergency, the disengagement of the mooring system involves a rapid submergence of the system back to the sea floor. In order to attain rapid submergence, the LPT purges the air from the BBT by a siphon effect. This is done through a 2 ½ inch pipeline and a 3 inch control valve. The pipeline and valve are sized to maintain a flowrate in the proximity of 70.64 SCFS. The pressure in the BBT is assumed to be atmospheric. In order to size components based on the worst case, the conditions in the LPT prior to the BBT rapid descent are assumed to correspond to the conditions immediately following the fourth deployment attempt, the lowest reserve of compressed air at the lowest pressure. During a rapid descent activation, the valve remains open for a period of 20 seconds.

After the rapid descent, the conditions in the LPT are as follows:

Air Mass = 2,889 lb_m
 Pressure = 94.3 psia
 Temperature = -24°F
 Mass Discharged = 110 lb_m
 Volumetric Flowrate = 72.12 SCFS (Sonic)

The minimum design pressure of the LPT is 80.5 psia. The lowest possible operating pressure of 94.3 psia is greater than the minimum design pressure.

4. Replenishment System

The LPT is replenished by the HPT. After the fourth deployment attempt, the HPT replenishes the LPT to its maximum operating pressure. The HPT is designed for two replenishment cycles before itself needing to be recharged. Recharging takes place at the surface and is performed by the vessel. The maximum and minimum operating pressures of the HPT are 2,987 psia and 2,175 psia, respectively (set by the Scope of Work). The HPT is sized so that the pressure after the second replenishment is slightly above the minimum operating pressure.

The conditions for each recharging of the LPT are as shown in the following table:

Stage	State Variable	Volumetric Flowrate
Preliminary		
	Pressure = 2,987 psia	
	Temperature = 60°F	
After Replenishment 1		
	Pressure = 2,571 psia	Flowrate = 1,299 SCFS
	Temperature = 26°F	(Sonic Flow)
After Replenishment 2		
	Pressure = 2,182 psia	Flowrate = 1,156 SCFS
	Temperature = -8°F	(Sonic Flow)

The valve which opens/closes instantaneously, was calculated to remain open for 15 seconds for the first replenishment and 18 seconds for the second.

The LPT is designed with a pressure relief valve and was sized for the worst case possibility of the replenishment control valve being stuck open. In which case the relief valve needs to vent the mass flowrate from the HPT to the LPT under choked flow. The valve size was calculated to be 8 inch x 10 inch, with a 10% overpressure.

For all systems, the control valves are electronically controlled from the vessel and pneumatically actuated. Instrument air is supplied by the HPT which is filtered and

regulated to the operating pressure for each control valve. The quantities of instrument air employed throughout a full deployment/replenishment/descent cycle are assumed to be negligible.

The air flowrates, the resulting air masses, pressures, and temperatures inside the HPT and LPT were calculated assuming adiabatic expansion. The actual pressures and temperatures of the HPT and LPT in between and after deployment attempts and replenishments are higher due to the warming of the HPT and LPT by the ambient sea water. Any heat transfer from the seawater to the HPT and LPT were neglected.

LEGEND

SUCTION MOORING TECHNOLOGY
COMPRESSED AIR SYSTEM
PROCESS & INSTRUMENTATION DIAGRAM
(P & ID)

Mooring System **(LPT Replenishment)**

Objective:

The purpose is to size the High Pressure Tank (HPT), connecting piping, and control valve between the HPT and the Low Pressure Tank (LPT) in order to replenish the depleted LPT, after four deployment attempts, raising the mass and pressure inside the LPT to its maximum operating pressure. Determine the time required to replenish the LPT.

Given:

- 1) Air mass required to replenish LPT (from Filename: "Deployment-1")
- 2) LPT temperature, pressure, and air mass prior to replenishment (from Filename: "Deployment-1")
- 3) HPT initial temperature and operating pressure range
- 4) Required time to execute one replenishment
- 5) Pipe length

Find:

- 1) Pipe and control valve diameters and flow conditions; subsonic or sonic velocity
- 2) Air flowrate for each replenishment
- 3) Resulting temperature, pressure, and air mass inside HPT after each replenishment (compare to minimum operating pressure for HPT)
- 4) Minimum required control valve C_v (compare to actual manufacturer's C_v)

Methodology:

The resulting pressure, temperature, and air mass inside the LPT after the fourth deployment attempt are known from the previous calculation (Filename: "Deployment-1"). The mass of each replenishment is equal to the sum of the masses discharged from the LPT during the four deployment attempts. The air flowrate between the HPT and LPT was determined based on:

- 1) The difference in pressure between the HPT and LPT
- 2) The pressure drop for an assumed pipe size, length, and number and type of fittings
- 3) An initial guess for the volume of the HPT
- 4) An assumed nominal pipe and valve diameter of 2 inches

The initial conditions of the LPT and HPT prior to the first replenishment, the final condition required for the LPT, and the required mass transfer are given. The flowrate and time required for replenishment were calculated and compared to the specified time for replenishment.

In order to accurately obtain the air flowrate and valve open duration for each replenishment, a correction factor, Y , was determined graphically based on the parameters for each replenishment, and input individually for each attempt. The air flowrate, the resulting air mass, pressure, and temperature inside the HPT were calculated, assuming adiabatic expansion. The resulting conditions inside the HPT after the first replenishment were used as the initial conditions inside the HPT for the second replenishment.

Following the above calculations, the minimum required C_v for the control valve, installed in the line connecting the two tanks, was calculated based on data obtained from Daniel Valve Co. This minimum required C_v was compared to the actual C_v for the valve selected, from the Daniel product line, to determine the adequacy of the valve.

Assumptions:

- 1) Air is an ideal gas
- 2) Process is assumed to be isentropic, reversible adiabatic, closed system
- 3) Due to a rapid open/close time of the control valve, 2 seconds, neglect flow while control valve is opening or closing
- 4) Range of water temperature given as 10 to 20 degree C: assume 15 degrees C for calculations
- 6) Neglect temperature and pressure increase in HPT between replenishments due to HPT warming by the sea water.

References:

- 1) Crane, Flow of Fluids, Technical Paper No. 410, 1982
- 2) Mechanical Engineering Reference Manual for the PE exam, 10th edition, 1998
- 3) Perry's Chemical Engineers' Handbook 6th edition, 1984
- 4) Daniel Valve Co., fax dated 11/24/99, from Jim Wass

Conclusions:

(Refer to Summary on page 12 of this calculation)

The piping connecting the HPT to the LPT is a 2 inch diameter schedule 40 pipe. The control valve is also 2 inch. In both replenishments, the flow is sonic.

Each replenishment delivers the same mass of air to the LPT. The time necessary to replenish the LPT the first time is 15 seconds and the second is 18 seconds. The second replenishment lasts longer due to the depletion of air in the HPT by the first replenishment. The specified replenishment time is 20 minutes, or 1200 seconds. In order to achieve the specified time, the pipe size would have to be approximately 3/8" in diameter or the resistance in the 2 inch line would need to be significantly increased. Possible options may be to insert an orifice with a pinhole near the LPT or to substantially increase the length of the 2 inch piping by spiralling it around the BBT.

The pressure and temperature drops inside the HPT as a result of the two replenishments, assuming adiabatic expansion, are 805psi and 68°F, respectively. Assuming adiabatic expansion is conservative. The actual pressure and temperature are higher due to the warming of the HPT by the ambient sea water during the time intervals between replenishments.

The HPT was sized so that at the completion of the two replenishments, the resulting pressure of the HPT would approach its minimum operating pressure at which point it would need to be recharged. The HPT volume was calculated to be 1200 cu-ft.

The minimum required valve Cv was calculated to be 97 which is well within the actual Cv of 120.

Letter Symbols for Variables:

Piping Parameters

ID	Inside diameter of pipe (in)
f	Pipe friction factor (Crane, page A-26)
L_{pipe}	Length of pipe (ft)
N_{elbow}	Number of 90° elbows
C_v	Valve coefficient of friction (Daniel Valve Co.)
$K_{entrance}$	Resistance coefficient for pipe entrance losses (Crane, page A-29)
K_{exit}	Resistance coefficient for pipe exit losses (Crane, page A-29)
K_{pipe}	Resistance coefficient for pipe (Crane, page 2-8)
K_{valve}	Resistance coefficient control valve (Daniel Valve Co.)
K_{elbow}	Resistance coefficient for elbow (Crane, page A-29)
K_{total}	Sum of above coefficients
N_{ff}	Number of friction factors

Process Parameters

V_{HPT}	HPT volume (cu-ft) (GUESS)
V_{LPT}	LPT volume (cu-ft)
Δt_{actual_1}	Duration of control valve in open position for first replenishment - actual (sec)
Δt_{actual_2}	Duration of control valve in open position for second replenishment - actual (sec)
$\Delta t_{specified}$	Duration of control valve in open position - specified (sec)
T_w	Average water temperature and initial temperature of air in HPT (°F, R)
P_{HPT_min}	Minimum design pressure in HPT (psia)
R_{air}	Individual gas constant for air (ft*lb/lb*R) (Crane, page A-8)
k	Specific heats' ratio for air, taken at max.HPT operating pressure and temperature (200 atm and 60°F) (Crane, page A-8, Perry's, page 3-144)
ρ_{HPT_1a}	Density of air in HPT prior to first replenishment of LPT (lb/cu. ft)
ρ_{HPT_2a}	Density of air in HPT prior to second replenishment of LPT (lb/cu. ft)
ρ_{STP}	Density of air at STP (standard temperature and pressure) (lb/cu. ft) (Crane, page A-10)
K_d	Ratio of densities (ρ_{STP}/ρ_{HPT_1a})
$P_{LPT_4b_a}$	Pressure in LPT after fourth deployment attempt (psia) (from Filename: "Deployment-1")
$P_{LPT_4b_g}$	Pressure in LPT after fourth deployment attempt (psig)
T_{LPT_4b}	Temperature in LPT after fourth deployment attempt (psia) (from Filename: "Deployment-1")
ρ_w	Density of sea water (gr/cu-cm)
P_a	Atmospheric pressure (14.7 psi)

Pressure

$P_{HPT_1a_g}$	HPT pressure prior to first replenishment (psig)
$P_{HPT_1a_a}$	HPT pressure prior to first replenishment (psia)
$P_{LPT_2a_g}$	HPT pressure prior to second replenishment (psig)
$P_{HPT_1b_a}$ and $P_{LPT_2a_a}$	HPT pressure prior to second replenishment (psia)
$P_{HPT_2b_a}$	HPT pressure after second replenishment (psia)

Temperature

T_{HPT_1a} HPT temperature prior to first replenishment ($^{\circ}R$)
 T_{HPT_1b} and T_{HPT_2a} HPT temperature prior to second replenishment ($^{\circ}R$)
 T_{HPT_2b} HPT temperature after second replenishment ($^{\circ}R$)

Mass

m_{LPT_1a} HPT mass prior to first replenishment (lb)
 m_{LPT_1b} and P_{LPT_2a} HPT mass prior to second replenishment (lb)
 m_{LPT_2b} HPT mass after second replenishment (lb)

$m_{replenishment_1}$ Mass of first replenishment (lb)
 $m_{replenishment_2}$ Mass of second replenishment (lb)

Discharge Flowrates

q_1 Replenishment 1 flowrate (Standard cu-ft per sec - SCFS)
 q_2 Replenishment 2 flowrate (Standard cu-ft per sec - SCFS)

Air Density and Specific Volume Parameters

ρ_{1a} Density of air in HPT prior to first replenishment (lb/cu. ft)
 ρ_{1b} and ρ_{2a} Density of air in HPT prior to second replenishment (lb/cu. ft)
 ρ_{2b} Density of air in HPT after second replenishment (lb/cu. ft)

v_{1a} Specific volume of air in HPT prior to first replenishment (cu. ft/lb)
 v_{1b} and v_{2a} Specific volume of air in HPT prior to second replenishment (cu. ft/lb)
 v_{2b} Specific volume of air in HPT after second replenishment (cu. ft/lb)

Graphical Flowrate Correction Factor

Y_1 Correction factor for replenishment 1
 Y_2 Correction factor for replenishment 2

Cv Calculation Parameters

X_i	Critical pressure drop ratio - given - (per Daniel Valve Co.)
q_i	Maximum discharge flowrate (standard cu-ft per second - SCFS) (corresponding to replenishment 1 flowrate)
Q	Maximum discharge flowrate (standard cu-ft per hour - SCFH)
ΔP_{min}	Minimum ΔP across control valve between HPT and LPT
X	Actual pressure drop ratio (per Daniel Valve Co.)
Y	Expansion factor (per Daniel Valve Co.)
$C_{Vrequired_min}$	Minimum required C_v for control valve
$C_{Vactual}$	Design C_v for control valve (per Daniel Valve Co.)

$$gr \approx 1 \cdot \frac{kg}{1000}$$

INPUTS

$$ID := 2.067 \text{ in}$$

$$f := 0.019$$

$$L_{\text{pipe}} := 50 \cdot \text{ft}$$

$$N_{\text{elbow}} := 2$$

$$N_{\text{ff}} := 14$$

$$C_v := 120$$

$$K_{\text{entrance}} := 0.5$$

$$K_{\text{exit}} := 1.0$$

$$V_{\text{HPT}} := 1200 \cdot \text{ft}^3 \quad \textbf{Guess}$$

$$V_{\text{LPT}} := 4945 \cdot \text{ft}^3$$

$$\Delta t_{\text{specified}} := 1200 \cdot \text{s}$$

$$T_w := 60 \cdot \text{R}$$

$$P_{\text{HPT_1a_a}} := 2987 \cdot \text{psi}$$

$$P_{\text{HPT_min}} := 2175 \cdot \text{psi}$$

$$R_{\text{air}} := 53.3 \cdot \frac{\text{ft} \cdot \text{lb}_f}{\text{lb} \cdot \text{R}}$$

$$k := 1.8$$

$$m_{\text{replenishment_1}} := 1490 \cdot \text{lb}$$

$$P_{\text{LPT_4b_a}} := 99.4 \cdot \text{psi}$$

$$T_{\text{LPT_4b}} := 443 \cdot \text{R}$$

$$\rho_{\text{STP}} := 0.0763 \cdot \frac{\text{lb}}{\text{ft}^3}$$

$$\rho_w := 1.03 \cdot \frac{\text{gr}}{\text{cm}^3}$$

$$P_a := 14.7 \cdot \text{psi}$$

ONE-TIME CALCULATIONS

Initial Temperature:

$$T_{HPT_1a} := T_w + 460 \cdot R \quad T_{HPT_1a} = 520 \cdot R$$

Initial pressure in HPT prior to first replenishment of LPT:

$$P_{HPT_1a_a} = 2987 \cdot \text{psi} \quad \text{HPT pressure (psia)}$$

$$P_{HPT_1a_g} := P_{HPT_1a_a} - P_a \quad P_{HPT_1a_g} = 2972 \cdot \text{psi} \quad \text{HPT pressure (psig)}$$

Calculating air density in HPT prior to first replenishment of LPT:

$$\rho_{HPT_1a} := \frac{P_{HPT_1a_a}}{R_{air} \cdot T_{HPT_1a}} \quad \rho_{HPT_1a} = 15.519 \cdot \frac{\text{lb}}{\text{ft}^3} \quad (\text{ME reference manual, page 24-14})$$

Conversion between Standard Cubic Feet (SCF) and Actual Cubic Feet (ACF):

$$\rho_{STP} := 0.0763 \cdot \frac{\text{lb}}{\text{ft}^3}$$

$$K_d := \frac{\rho_{STP}}{\rho_{HPT_1a}} \quad K_d = 0.0049$$

Calculating total Resistance Coefficient (Ktotal) for pipe, fittings, valve, etc.:

$$K_{elbow} := N_{elbow} \cdot N_{ff} \cdot f \quad K_{elbow} = 0.532 \quad K_{entrance} := 0.5$$

$$K_{pipe} := f \cdot \left(\frac{L_{pipe}}{ID} \right) \quad K_{pipe} = 5.515 \quad K_{exit} := 1.0$$

$$K_{valve} := 1443 \cdot \left[\frac{\pi \cdot \left(\frac{ID}{in} \right)^2}{C_v} \right]^2 \quad K_{valve} = 1.128 \quad (\text{Daniel Valve Co., fax 11/24/99})$$

(Equation is valid for SONIC and SUBSONIC flow)

$$K_{total} := K_{entrance} + K_{exit} + K_{elbow} + K_{pipe} + K_{valve} \quad K_{total} = 8.676$$

Calculations for Replenishment 1

$$P_{HPT_1a_a} = 2987 \text{ psi}$$

$$T_{HPT_1a} = 520 \text{ °R}$$

$$m_{\text{replenishment_1}} = 1490 \text{ lb}$$

Calculating Correction Factor Y1 using DeltaP1:

$$P_{LPT_4b_g} := P_{LPT_4b_a} - P_a$$

$$P_{LPT_4b_g} = 84.7 \text{ psi}$$

$$\Delta P_1 := P_{HPT_1a_g} - P_{LPT_4b_g}$$

$$\Delta P_1 = 2888 \text{ psi}$$

$$R_{\text{calculated_1}} := \frac{\Delta P_1}{P_{HPT_1a_a}}$$

$$R_{\text{calculated_1}} = 0.97$$

REFER TO CRANE page A-22

Based on: $K_{\text{total}} = 8.7$

If $R_{\text{calculated_1}} > R_{\text{graphical_max}}$, then flow is SONIC; use $R_{\text{graphical_max}}$ to determine Y_1 & new ΔP_1

If $R_{\text{calculated_1}} < R_{\text{graphical_max}}$, then flow is SUBSONIC; use $R_{\text{calculated_1}}$ to determine Y_1

$$R_{\text{calculated_1}} = 0.97$$

$$R_{\text{graphical_max}} := 0.775 \quad \text{SONIC}$$

INPUT

$$Y_1 := 0.6875$$

$$R_{\text{graphical_max}} := 0.775$$

$$\text{New} \Delta P_1 := R_{\text{graphical_max}} \cdot P_{HPT_1a_a}$$

$$\text{New} \Delta P_1 = 2315 \text{ psi}$$

Calculating First Replenishment Flowrate in (SCFS): (Crane, page 3-4 and 4-14)

$$q_1 := 11.3 \cdot Y_1 \cdot \left(\frac{ID}{in} \right)^2 \cdot \left[\frac{\left(\frac{\text{New} \Delta P_1}{psi} \right) \cdot \left(\frac{P_{HPT_1a_a}}{psi} \right)}{K_{\text{total}} \cdot \left(\frac{T_{HPT_1a}}{R} \right)} \right]^{0.5} \frac{ft^3}{s}$$

$$q_1 = 1299 \frac{ft^3}{s} \quad (\text{SCFS})$$

based on ID = 2.067 in

Calculating time necessary to replenish LPT first time:

(Replenishment 1 con'd)

$$\Delta t_{\text{actual}_1} := \frac{m_{\text{replenishment}_1}}{q_1 \cdot K_d \cdot \rho_{\text{HPT}_1a}}$$

$$\Delta t_{\text{actual}_1} = 15 \text{ s} \quad \text{Actual} \quad \Delta t_{\text{ID}} = 2.067 \text{ in}$$

$$\Delta t_{\text{specified}} = 1200 \text{ s} \quad \text{Specified}$$

Calculating mass of air in HPT prior to first replenishment of LPT (based on guess of HPT volume):

$$m_{\text{HPT}_1a} := \rho_{\text{HPT}_1a} \cdot V_{\text{HPT}}$$

$$m_{\text{HPT}_1a} = 18623 \text{ lb}$$

$$m_{\text{HPT}_1b} := m_{\text{HPT}_1a} - m_{\text{replenishment}_1} \quad m_{\text{HPT}_1b} = 17133 \text{ lb}$$

Calculating specific volume of air in HPT before and after first replenishment of LPT:

$$\rho_{1a} := \rho_{\text{HPT}_1a} \quad \rho_{1a} = 15.519 \frac{\text{lb}}{\text{ft}^3} \quad v_{1a} := \frac{1}{\rho_{1a}} \quad v_{1a} = 0.064 \frac{\text{ft}^3}{\text{lb}}$$

$$\rho_{1b} := \frac{m_{\text{HPT}_1b}}{V_{\text{HPT}}} \quad \rho_{1b} = 14.277 \frac{\text{lb}}{\text{ft}^3} \quad v_{1b} := \frac{1}{\rho_{1b}} \quad v_{1b} = 0.07 \frac{\text{ft}^3}{\text{lb}}$$

Calculating temperature and pressure of air in HPT after first replenishment of LPT:

$$T_{\text{HPT}_1b} := T_{\text{HPT}_1a} \cdot \left(\frac{v_{1a}}{v_{1b}} \right)^{k-1} \quad T_{\text{HPT}_1b} = 486 \text{ °R} \quad (\text{ME reference manual, page 25-8})$$

$$P_{\text{HPT}_1b_a} := P_{\text{HPT}_1a_a} \cdot \left(\frac{v_{1a}}{v_{1b}} \right)^k \quad P_{\text{HPT}_1b_a} = 2571 \text{ psi} \quad (\text{ME reference manual, page 25-8})$$

$$P_{\text{HPT_min}} = 2175 \text{ psi}$$

Calculations for Replenishment 2

$$\begin{aligned}
 P_{\text{HPT_2a_a}} &:= P_{\text{HPT_1b_a}} & P_{\text{HPT_2a_a}} &= 2571 \text{ psi} \\
 T_{\text{HPT_2a}} &:= T_{\text{HPT_1b}} & T_{\text{HPT_2a}} &= 486 \text{ R} \\
 m_{\text{HPT_2a}} &:= m_{\text{HPT_1b}} & m_{\text{HPT_2a}} &= 17133 \text{ lb} \\
 m_{\text{replenishment_2}} &:= m_{\text{replenishment_1}} & m_{\text{replenishment_2}} &= 1490 \text{ lb} \\
 \rho_{\text{HPT_2a}} &:= \rho_{1b} & \rho_{\text{HPT_2a}} &= 14.28 \frac{\text{lb}}{\text{ft}^3}
 \end{aligned}$$

Calculating Correction Factor Y2 using DeltaP2:

$$\begin{aligned}
 P_{\text{HPT_2a_g}} &:= P_{\text{HPT_2a_a}} - P_a & P_{\text{HPT_2a_g}} &= 2556 \text{ psi} \\
 \Delta P_2 &:= P_{\text{HPT_2a_g}} - P_{\text{LPT_4b_g}} & \Delta P_2 &= 2471 \text{ psi} \\
 R_{\text{calculated_2}} &:= \frac{\Delta P_2}{P_{\text{HPT_2a_a}}} & R_{\text{calculated_2}} &= 0.96
 \end{aligned}$$

REFER TO CRANE page A-22

Based on: $K_{\text{total}} = 8.7$

If $R_{\text{calculated_2}} > R_{\text{graphical_max}}$, then flow is SONIC; use $R_{\text{graphical_max}}$ to determine Y_2 & new ΔP_2

If $R_{\text{calculated_2}} < R_{\text{graphical_max}}$, then flow is SUBSONIC; use $R_{\text{calculated_2}}$ to determine Y_2

$$R_{\text{calculated_2}} = 0.96$$

$$R_{\text{graphical_max}} := 0.775 \quad \textbf{SONIC}$$

INPUT

$$Y_2 := 0.6875$$

$$R_{\text{graphical_max}} := 0.775$$

$$\text{New} \Delta P_2 := R_{\text{graphical_max}} \cdot P_{\text{HPT_2a_a}} \quad \text{New} \Delta P_2 = 1992 \text{ psi}$$

Calculating Second Replenishment Flowrate in (SCFS): (Crane, page 3-4 and 4-14)

$$q_2 := 11.3 \cdot Y_2 \cdot \left(\frac{\text{ID}}{\text{in}} \right)^2 \cdot \left[\frac{\left(\frac{\text{New} \Delta P_2}{\text{psi}} \right) \cdot \left(\frac{P_{\text{HPT_2a_a}}}{\text{psi}} \right)}{K_{\text{total}} \cdot \left(\frac{T_{\text{HPT_2a}}}{R} \right)} \right]^{0.5} \cdot \frac{\text{ft}^3}{\text{s}}$$

$$q_2 = 1156 \frac{\text{ft}^3}{\text{s}} \text{ (SCFS) based on ID} = 2.067 \text{ in}$$

Calculating time necessary to replenish LPT second time:

(Replenishment 2 con'd)

$$\Delta t_{\text{actual}_2} := \frac{m_{\text{replenishment}_2}}{Q_2 \cdot K_d \cdot \rho_{\text{HPT}_2a}}$$

$$\Delta t_{\text{actual}_2} = 18 \text{ s} \quad \text{Actual} \quad \Delta t_{\text{ID}} = 2.067 \text{ in}$$

$$\Delta t_{\text{specified}} = 1200 \text{ s} \quad \text{Specified}$$

Calculating mass of air in HPT prior to second replenishment of LPT (based on guess of HPT volume):

$$m_{\text{HPT}_2a} = 17133 \text{ lb}$$

$$m_{\text{HPT}_2b} := m_{\text{HPT}_2a} - m_{\text{replenishment}_2} \quad m_{\text{HPT}_2b} = 15643 \text{ lb}$$

Calculating specific volume of air in HPT before and after second replenishment of LPT:

$$\rho_{2a} := \rho_{\text{HPT}_2a} \quad \rho_{2a} = 14.277 \frac{\text{lb}}{\text{ft}^3} \quad v_{2a} := \frac{1}{\rho_{2a}} \quad v_{2a} = 0.07 \frac{\text{ft}^3}{\text{lb}}$$

$$\rho_{2b} := \frac{m_{\text{HPT}_2b}}{V_{\text{HPT}}} \quad \rho_{2b} = 13.036 \frac{\text{lb}}{\text{ft}^3} \quad v_{2b} := \frac{1}{\rho_{2b}} \quad v_{2b} = 0.077 \frac{\text{ft}^3}{\text{lb}}$$

Calculating temperature and pressure of air in HPT after second replenishment of LPT:

$$T_{\text{HPT}_2b} := T_{\text{HPT}_2a} \cdot \left(\frac{v_{2a}}{v_{2b}} \right)^{k-1} \quad T_{\text{HPT}_2b} = 452 \text{ R} \quad (\text{ME reference manual, page 25-8})$$

$$P_{\text{HPT}_2b_a} := P_{\text{HPT}_2a_a} \cdot \left(\frac{v_{2a}}{v_{2b}} \right)^k \quad P_{\text{HPT}_2b_a} = 2182 \text{ psi} \quad (\text{ME reference manual, page 25-8})$$

$$P_{\text{HPT}_{\text{min}}} := 2175 \text{ psi}$$

Summary

HPT Resultant Temperature

$$T_{\text{HPT}_1\text{a}} = 520^{\circ}\text{R}$$

$$T_{\text{HPT}_2\text{a}} = 486^{\circ}\text{R}$$

$$T_{\text{HPT}_2\text{b}} = 452^{\circ}\text{R}$$

Replenishment Mass

$$m_{\text{replenishment}_1} = 1490^{\circ}\text{lb}$$

$$m_{\text{replenishment}_2} = 1490^{\circ}\text{lb}$$

HPT Resultant Pressure

$$P_{\text{HPT}_1\text{a}_a} = 2987^{\circ}\text{psi}$$

$$P_{\text{HPT}_2\text{a}_a} = 2571^{\circ}\text{psi}$$

$$P_{\text{HPT}_2\text{b}_a} = 2182^{\circ}\text{psi}$$

$$P_{\text{HPT}_{\min}} := 2175^{\circ}\text{psi}$$

Replenishment Flowrate

$$q_1 = 1299^{\circ}\frac{\text{ft}^3}{\text{s}}$$

$$q_2 = 1156^{\circ}\frac{\text{ft}^3}{\text{s}}$$

Cv Requirement (Replenishment)

Reference: (Refer to Daniel Valve Co. fax of 11/24/99)

Inputs: ID = 2.067 in
 $T_{HPT_1a} = 520^{\circ}R$
 $X_t := 0.38$
 $q_1 = 1299 \frac{ft^3}{s}$
 $P_{HPT_2a_a} = 2571 \text{ psi}$
 $P_{LPT_4b_a} = 99.4 \text{ psi}$
 $K_{total} = 8.7$
 $K_{valve} = 1.1$

Calculation:

$$\Delta P_{min} := \frac{(P_{HPT_2a_a} - P_{LPT_4b_a}) \cdot K_{valve}}{K_{total}}$$

$$\Delta P_{min} = 321.4 \text{ psi}$$

$$X := \frac{\Delta P_{min}}{P_{HPT_2a_a}} \quad X = 0.13$$

$$Y := 1 - \frac{X}{3 \cdot X_t} \quad Y = 0.89$$

$$Cv_{required_min} := \frac{\left[\frac{q_1}{\frac{ft^3}{hr}} \right]}{1360 \cdot \left(\frac{P_{HPT_2a_a}}{psi} \right) \cdot Y} \cdot \left[\frac{\left(\frac{T_{HPT_1a}}{R} \right)}{X} \right]^{0.5}$$

$$Cv_{required_min} = 97$$

$$Cv_{actual} = 120$$

Mooring System **(Rapid Descent)**

Objective:

To size the connecting piping and control valve between the Low Pressure Tank (LPT) and the Bottomless Buoyancy Tank (BBT) for the rapid descent system.

Given:

- 1) LPT temperature, pressure, and air mass prior to rapid descent (assuming LPT conditions after fourth deployment attempt) (from Filename: "Deployment-1")
- 2) Pressure inside BBT prior to rapid descent (assuming surface conditions of one atmosphere)
- 3) Specified flow rate for design to achieve.
- 4) Control valve stroke time of 20 seconds
- 5) Pipe length

Find:

- 1) Pipe and control valve diameters and flow conditions; subsonic or sonic velocity
- 2) Air flowrate and mass discharged for rapid descent (compare to specified flowrate)
- 3) Resulting temperature, pressure, and mass inside LPT after rapid descent (compare to minimum operating pressure for LPT)
- 4) Minimum required control valve C_v (compare to actual manufacturer's C_v)

Methodology:

The resulting pressure, temperature, and air mass inside the LPT after the fourth deployment attempt are known from the previous calculation (Filename: "Deployment-1"). The air flowrate between the LPT and BBT was determined based on:

- 1) The difference in pressure between the LPT and BBT
- 2) The pressure drop for an assumed pipe size, length, and number and type of fittings
- 3) An assumed nominal pipe diameter of 2 1/2 inches and valve diameter of 3 inch

The initial conditions of the LPT and BBT prior to rapid descent are known. The flowrate and time required for rapid descent were calculated and compared to the specified flowrate and time. The final conditions of the LPT were calculated. The resulting final LPT pressure was compared to the minimum working pressure for the LPT.

In order to accurately obtain the air flowrate, a correction factor, Y , was determined graphically based on the parameters for the rapid descent. The air flowrate, the resulting air mass, pressure, and temperature inside the LPT were calculated, assuming adiabatic expansion.

Following the above calculations, the minimum required C_v for the control valve, installed in the line connecting the two tanks, was calculated based on data obtained from Daniel Valve Co. This minimum required C_v was compared to the actual C_v for the valve chosen, from the Daniel product line, to determine the adequacy of the valve chosen.

Assumptions:

- 1) Air is an ideal gas
- 2) Process is assumed to be isentropic, reversible adiabatic, closed system
- 3) Due to a rapid open/close time of the control valve, 2 seconds, neglect flow while control valve is opening or closing
- 4) Range of water temperature given as 10 to 20 degree C: assume 15 degrees C for calculations
- 5) Neglect pressure difference between top and bottom of buoyancy tank.
- 6) Neglect temperature and pressure increase in LPT after rapid descent due to LPT warming by the sea water.

References:

- 1) Crane, Flow of Fluids, Technical Paper No. 410, 1982
- 2) Mechanical Engineering Reference Manual for the PE exam, 10th edition, 1998
- 3) Perry's Chemical Engineers' Handbook, 6th edition, 1984
- 4) Daniel Valve Co., fax dated 11/24/99, from Jim Wass

Conclusions:

(Refer to Summary on page 9 of this calculation)

The piping connecting the LPT to the BBT is a 2 1/2 inch diameter schedule 40 pipe. The control valve is a 3 inch valve. The increase in valve size was necessary to accommodate the minimum required valve Cv. The flow is sonic.

The rapid descent discharge flowrate is 72.12 SCFS and deviates approximately 2.1% from the specified flowrate of 70.64 SCFS. The air mass discharged from the LPT was calculated to be 110 lb.

The pressure and temperature drops inside the LPT as a result of the rapid deployment, assuming adiabatic expansion, are 5.1psi and 7°F, respectively. Assuming adiabatic expansion is conservative. The actual pressure and temperature are higher due to the warming of the LPT by the ambient sea water. The lowest calculated pressure of 94.3 psia inside the LPT exceeds the minimum operating pressure of 80.5 psia.

The minimum required valve Cv was calculated to be 161 which is well within the actual Cv of 330.

Letter Symbols for Variables:

Piping Parameters

ID_{pipe}	Inside diameter of pipe (in)
ID_{valve}	Inside diameter of control valve (in)
f	Pipe friction factor (Crane, page A-26)
L_{pipe}	Length of pipe (ft)
N_{elbow}	Number of 90° elbows
C_v	Valve coefficient of friction (Daniel Valve Co.)
$K_{entrance}$	Resistance coefficient for pipe entrance losses (Crane, page A-29)
K_{exit}	Resistance coefficient for pipe exit losses (Crane, page A-29)
K_{pipe}	Resistance coefficient for pipe (Crane, page 2-8)
K_{valve}	Resistance coefficient control valve (Daniel Valve Co.)
K_{elbow}	Resistance coefficient for elbow (Crane, page A-29)
K_{total}	Sum of above coefficients
N_f	Number of friction factors

Process Parameters

V_{LPT}	LPT volume (cu-ft)
$\Delta t_{specified}$	Duration of control valve in open position - specified (sec)
R_{air}	Individual specific gas constant for air (ft*lb/lb*R) (Crane, page A-8)
k	Specific heats' ratio for air, taken at 1 atm and 60°F (Crane, page A-8, Perry's, page 3-144)
ρ_{LPT_1}	Density of air in LPT after fourth deployment attempt (lb/cu. ft) (From Calc: Deployment-1)
ρ_{STP}	Density of air at STP (standard temperature and pressure) (lb/cu. ft) (Crane, page A-10)
K_d	Ratio of densities (ρ_{STP}/ρ_{LPT_1})
$P_{LPT_1_a}$	Pressure in LPT after fourth deployment attempt (psia) (from Calc: Deployment-1)
T_{LPT_1}	Temperature in LPT after fourth deployment attempt (psia) (from Calc: Deployment-1)
P_a	Atmospheric pressure (14.7 psi)

Pressure

P_{BBT_g}	Pressure inside BBT prior to rapid descent (psig)
P_{BBT_a}	Pressure inside BBT prior to rapid descent (psia)
$P_{LPT_1_g}$	LPT pressure prior to rapid descent (psig)
$P_{LPT_1_a}$	LPT pressure prior to rapid descent (psia)
$P_{LPT_2_a}$	LPT pressure after rapid descent (psia)

Temperature

T_{LPT_1}	LPT temperature prior to rapid descent (°R)
T_{LPT_2}	LPT temperature after rapid descent (°R)

Mass

m_{LPT_1}	LPT mass prior to rapid descent (lb)
m_{LPT_2}	LPT mass after rapid descent (lb)
$m_{discharge}$	Mass of discharged air from LPT during rapid descent (lb)
$V_{discharge_STP}$	Volume of discharged air from LPT during rapid descent (Standard cu-ft - SCF)

Discharge Flowrates

q_{actual}	Actual rapid descent flowrate (Standard cu-ft per sec - SCFS)
$q_{specified}$	Specified rapid descent flowrate (Standard cu-ft per sec - SCFS)

Air Density and Specific Volume Parameters

ρ_1	Density of air in LPT prior to rapid descent (lb/cu. ft)
ρ_2	Density of air in LPT after rapid descent (lb/cu. ft)
v_1	Specific volume of air in LPT prior to rapid descent (cu. ft/lb)
v_2	Specific volume of air in LPT after rapid descent (cu. ft/lb)

Graphical Flowrate Correction Factor

Y	Correction factor for rapid descent
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Cv Calculation Parameters

X_i	Critical pressure drop ratio - given - (per Daniel Valve Co.)
T_{LPT_max}	Maximum temperature inside LPT ($^{\circ}R$), ambient water temperature of 60 $^{\circ}F$
q_{actual}	Rapid descent discharge flowrate (standard cu-ft per second - SCFS)
Q	Rapid descent discharge flowrate (standard cu-ft per hour - SCFH)
ΔP_{min}	Minimum ΔP across control valve between LPT and BBT
X	Actual pressure drop ratio (per Daniel Valve Co.)
Y	Expansion factor (per Daniel Valve Co.)
$C_{vrequired_min}$	Minimum required C_v for control valve
$C_{vactual}$	Design C_v for control valve (per Daniel Valve Co.)

INPUTS

$$ID_{\text{pipe}} := 2.469 \text{ in}$$

$$ID_{\text{valve}} := 3.068 \text{ in}$$

$$f := 0.018$$

$$L_{\text{pipe}} := 50 \cdot \text{ft}$$

$$N_{\text{elbow}} := 2$$

$$N_{\text{ff}} := 14$$

$$C_v := 330$$

$$K_{\text{entrance}} := 0.5$$

$$K_{\text{exit}} := 1.0$$

$$V_{\text{LPT}} := 4945 \cdot \text{ft}^3$$

$$\Delta t_{\text{specified}} := 20 \cdot \text{s}$$

$$T_{\text{LPT_max}} := 520 \cdot \text{R}$$

$$P_{\text{BBT_a}} := 14.7 \cdot \text{psi}$$

$$q_{\text{specified}} := 70.64 \cdot \frac{\text{ft}^3}{\text{s}}$$

$$R_{\text{air}} := 53.3 \cdot \frac{\text{ft} \cdot \text{lbf}}{\text{lb} \cdot \text{R}}$$

$$k := 1.4$$

$$P_{\text{LPT_1_a}} := 99.4 \cdot \text{psi}$$

$$T_{\text{LPT_1}} := 443 \cdot \text{R}$$

$$\rho_{\text{LPT_1}} := 0.607 \cdot \frac{\text{lb}}{\text{ft}^3}$$

$$\rho_{\text{STP}} := 0.0763 \cdot \frac{\text{lb}}{\text{ft}^3}$$

$$P_a := 14.7 \cdot \text{psi}$$

ONE-TIME CALCULATIONS

Initial Temperature:

$$T_{LPT_1} = 443 \text{ } ^\circ\text{R}$$

Initial pressure in LPT after fourth deployment attempt and before rapid descent:

$$P_{LPT_1_a} = 99.4 \text{ } ^\circ\text{psi} \quad \text{LPT pressure (psia)}$$

$$P_{LPT_1_g} := P_{LPT_1_a} - P_a \quad P_{LPT_1_g} = 84.7 \text{ } ^\circ\text{psi} \quad \text{LPT pressure (psig)}$$

Conversion between Standard Cubic Feet (SCF) and Actual Cubic Feet (ACF):

$$\rho_{STP} := 0.0763 \cdot \frac{\text{lb}}{\text{ft}^3}$$

$$K_d := \frac{\rho_{STP}}{\rho_{LPT_1}} \quad K_d = 0.1257$$

Calculating total Resistance Coefficient (Ktotal) for pipe, fittings, valve, etc.:

$$K_{\text{entrance}} := 0.5$$

$$K_{\text{exit}} := 1.0$$

$$K_{\text{elbow}} := N_{\text{elbow}} \cdot N_{ff} \cdot f \quad K_{\text{elbow}} = 0.504$$

$$K_{\text{pipe}} := f \cdot \left(\frac{L_{\text{pipe}}}{ID_{\text{pipe}}} \right) \quad K_{\text{pipe}} = 4.374$$

$$K_{\text{valve}} := 1443 \cdot \left[\frac{\frac{\pi}{4} \cdot \left(\frac{ID_{\text{valve}}}{\text{in}} \right)^2}{C_v} \right]^2 \quad K_{\text{valve}} = 0.724$$

(Daniel Valve Co., fax 11/24/99)
 (Equation is valid for SONIC and SUBSONIC flow)

$$K_{\text{total}} := K_{\text{entrance}} + K_{\text{exit}} + K_{\text{elbow}} + K_{\text{pipe}} + K_{\text{valve}} \quad K_{\text{total}} = 7.102$$

Calculations for Rapid Descent

$$P_{LPT_1_a} = 99.4 \text{ psi}$$

$$T_{LPT_1} = 443 \text{ °R}$$

Calculating Correction Factor Y1 using DeltaP1:

$$P_{BBT_g} := P_{BBT_a} - P_a \quad P_{BBT_g} = 0 \text{ psi}$$

$$\Delta P := P_{LPT_1_g} - P_{BBT_g} \quad \Delta P = 84.7 \text{ psi}$$

$$R_{\text{calculated}} := \frac{\Delta P}{P_{LPT_1_a}} \quad R_{\text{calculated}} = 0.85$$

REFER TO CRANE page A-22

Based on: $K_{\text{total}} = 7.1$

If $R_{\text{calculated}} > R_{\text{graphical_max}}$, then flow is SONIC; use $R_{\text{graphical_max}}$ to determine Y & new ΔP

If $R_{\text{calculated}} < R_{\text{graphical_max}}$, then flow is SUBSONIC; use $R_{\text{calculated}}$ to determine Y

$$R_{\text{calculated}} = 0.85$$

$$R_{\text{graphical_max}} := 0.755 \quad \textbf{SONIC}$$

INPUT

$$Y := 0.680$$

$$R_{\text{graphical_max}} := 0.755$$

$$\Delta P_{\text{new}} := R_{\text{graphical_max}} \cdot P_{LPT_1_a} \quad \Delta P_{\text{new}} = 75 \text{ psi}$$

Calculating First Replenishment Flowrate in (SCFS):

$$q_{\text{actual}} := 11.3 \cdot Y \cdot \left(\frac{ID_{\text{pipe}}}{\text{in}} \right)^2 \cdot \left[\frac{\left(\frac{\Delta P_{\text{new}}}{\text{psi}} \right) \cdot \left(\frac{P_{LPT_1_a}}{\text{psi}} \right)}{K_{\text{total}} \cdot \left(\frac{T_{LPT_1}}{R} \right)} \right]^{0.5} \cdot \frac{\text{ft}^3}{\text{s}}$$

(Crane, page 3-4 and 4-14)

based on $ID_{\text{pipe}} = 2.469 \text{ in}$

$$q_{\text{actual}} = 72.12 \frac{\text{ft}^3}{\text{s}} \quad \text{Actual (SCFS)}$$

$$q_{\text{specified}} := 70.64 \frac{\text{ft}^3}{\text{s}} \quad \text{Specified}$$

Calculating mass of discharged air for rapid descent:

$$V_{\text{discharge_STP}} := q_{\text{actual}} \cdot \Delta t_{\text{specified}} \quad V_{\text{discharge_STP}} = 1442 \text{ ft}^3$$

$$\rho_{\text{STP}} := 0.0763 \frac{\text{lb}}{\text{ft}^3}$$

$$m_{\text{discharge}} := \rho_{\text{STP}} \cdot V_{\text{discharge_STP}} \quad m_{\text{discharge}} = 110 \text{ lb}$$

Calculating mass of air in LPT after rapid descent after fourth deployment attempt:

$$m_{\text{LPT_1}} := \rho_{\text{LPT_1}} \cdot V_{\text{LPT}} \quad m_{\text{LPT_1}} = 3002 \text{ lb}$$

$$m_{\text{LPT_2}} := m_{\text{LPT_1}} - m_{\text{discharge}} \quad m_{\text{LPT_2}} = 2892 \text{ lb}$$

Calculating specific volume of air in LPT before and after rapid descent attempt:

$$\rho_1 := \rho_{\text{LPT_1}} \quad \rho_1 = 0.607 \frac{\text{lb}}{\text{ft}^3} \quad v_1 := \frac{1}{\rho_1} \quad v_1 = 1.647 \frac{\text{ft}^3}{\text{lb}}$$

$$\rho_2 := \frac{m_{\text{LPT_2}}}{V_{\text{LPT}}} \quad \rho_2 = 0.585 \frac{\text{lb}}{\text{ft}^3} \quad v_2 := \frac{1}{\rho_2} \quad v_2 = 1.71 \frac{\text{ft}^3}{\text{lb}}$$

Calculating temperature and pressure of air in LPT after rapid descent (after 4th deployment attempt):

$$T_{\text{LPT_2}} := T_{\text{LPT_1}} \cdot \left(\frac{v_1}{v_2} \right)^{k-1} \quad T_{\text{LPT_2}} = 436 \text{ }^\circ\text{R} \quad (\text{ME reference manual, page 25-8})$$

$$P_{\text{LPT_2_a}} := P_{\text{LPT_1_a}} \cdot \left(\frac{v_1}{v_2} \right)^k \quad P_{\text{LPT_2_a}} = 94.3 \text{ psi} \quad (\text{ME reference manual, page 25-8})$$

Summary

LPT Resultant Temperature

$$T_{LPT_1} = 443^{\circ}R$$

$$T_{LPT_2} = 436^{\circ}R$$

Replenishment Mass

$$m_{\text{discharge}} = 110^{\circ}lb$$

LPT Resultant Pressure

$$P_{LPT_1_a} = 99.4^{\circ}psi$$

$$P_{LPT_2_a} = 94.3^{\circ}psi$$

Replenishment Flowrate

$$q_{\text{actual}} = 72.12 \frac{\text{ft}^3}{\text{s}} \quad \text{Actual}$$

$$q_{\text{specified}} := 70.64 \frac{\text{ft}^3}{\text{s}} \quad \text{Specified}$$

Cv Requirement (Rapid Descent)

Reference: (Refer to Daniel Valve Co. fax of 11/24/99)

Inputs: ID_{valve} = 3.068 in

T_{LPT_max} = 520 °R

X_t = 0.38

q_{actual} = 72.12 $\frac{\text{ft}^3}{\text{s}}$

P_{LPT_1_a} = 99.4 psi

P_{BBT_a} = 14.7 psi

K_{total} = 7.102

K_{valve} = 0.724

Calculation:

$$\Delta P_{\min} := \frac{(P_{\text{LPT}_1_a} - P_{\text{BBT}_a}) \cdot K_{\text{valve}}}{K_{\text{total}}}$$

$$\Delta P_{\min} = 8.636 \text{ psi}$$

$$X := \frac{\Delta P_{\min}}{P_{\text{LPT}_1_a}} \quad X = 0.09$$

$$Y := 1 - \frac{X}{3 \cdot X_t} \quad Y = 0.924$$

$$Cv_{\text{required_min}} := \frac{\left[\frac{q_{\text{actual}}}{\frac{\text{ft}^3}{\text{hr}}} \right]}{1360 \cdot \left(\frac{P_{\text{LPT}_1_a}}{\text{psi}} \right) \cdot Y} \cdot \left[\frac{\left(\frac{T_{\text{LPT_max}}}{R} \right)}{X} \right]^{0.5}$$

$$Cv_{\text{required_min}} = 161$$

$$Cv_{\text{actual}} = 330$$

Mooring System **(LPT Relief Valve Sizing)**

Objective:

To size the pressure relief valve located on the Low Pressure Tank (LPT) and to select a model(s).

Given:

- 1) LPT maximum design pressure
- 2) Relief valve overpressure percentage
- 3) Water depth and temperature
- 4) Maximum air mass flowrate into LPT (per Filename: LPT Replenishment)
- 5) Maximum air volume flowrate into LPT (per Filename: LPT Replenishment)

Find:

- 1) Relief valve inlet pressure and back pressure
- 2) Minimum required relief valve inlet diameter based on mass flowrate and volume flowrate
- 3) Model number(s) of relief valves satisfying the minimum requirements

Methodology:

The size of the LPT relief valve was determined using the sizing calculation from Crosby Valves, Catalog No. 318. It was assumed that the greatest overpressurization of the LPT would occur if the control valve between the LPT and the High Pressure Tank (HPT) was accidentally stuck open and the HPT was fully charged. The LPT's and HPT's maximum operating pressures are 175 psia and 2987 psia, respectively. This would result in a tremendous air flowrate from the HPT into the LPT, considerably increasing LPT pressure. Referring to calculation with filename: LPT Replenishment, the maximum air flowrate into the LPT is known. Also known are the LPT interior and exterior ambient conditions. From these conditions, the relief valve inlet and back pressures were calculated. Substituting into Crosby's sizing calculation yielded the minimum valve inlet area from which the minimum diameter was determined. The sizing calculation was performed by two methods as a check. One method was based on the mass flowrate and the other was based on the volume flowrate.

Assumptions:

- 1) Air is an ideal gas
- 2) Range of water temperature given as 10 to 20 degree C: assume 15 degrees C for calculations
- 3) Temperature of air entering the relief valve is the same temperature as the ambient water temperature

References:

- 1) Crosby Valve & Gage Company, "Crosby JPV Series Pilot Operated Pressure Relief Valves Styles JPV and JPVM," Catalog No. 318, December 1986.
- 2) Mechanical Engineering Reference Manual for the PE exam, 10th edition, 1998 (Section 24-19)
- 3) Suction Mooring Technology, Engineering Calculation, (Filename: LPT Replenishment)

Conclusions:

The relief valve inlet pressure was calculated to be the sum of the set pressure plus the overpressure plus atmospheric pressure and equaled 222.6 psia. Based on the static head of the water, the back pressure was calculated to be 66.0 psia. The minimum valve inlet area was calculated using two approaches, the second to check the first. One required the air mass flowrate and yielded an effective area of 19.627 sq. in and the other required the volume flowrate yielding an effective area of 19.595 sq. in. The minimum diameter was determined using the greater of the two areas. The minimum required diameter is 4.999 inches.

In addition to the water temperature, this calculation was also run for temperatures -20°F and 100°F to determine the effect of temperature in the sizing process. The results yielded a minimum diameter of 4.794 inches and 5.092 inches, respectively. With a difference of approximately 6%, temperature is not very significant in sizing the relief valve.

The JPV 8T10 Style 15 or the JPVM 8T10 Style 15, both having ANSI B16.5 Class 150 inlet and outlet flanges, are adequate.

Attachments:

- 1) Crosby Valve & Gage Company, "Crosby JPV Series Pilot Operated Pressure Relief Valves Styles JPV and JPVM," Catalog No. 318, December 1986. (pages 18, 20, 22, 32)

Letter Symbols for Variables:

Input:

CxK	Variable factor multiplied by the coefficient of discharge (page 32)
M	Molecular weight of air
P _{design_max}	LPT maximum design pressure (psig)
P _{atm_a}	Atmospheric pressure (14.7 psia)
Overpressure%	Relief valve overpressure percentage (%)
H _{static}	Depth of water (m)
T	Absolute temperature of air at relief valve inlet (⁰ R)
W	Required relieving capacity in (lbm/hr) (per Filename: LPT Replenishment)
SCFM	Required relieving capacity in (standard cu. ft/min) (per Filename: LPT Replenishment)
Z	Compressibility factor (see: Mechanical Engineering Reference Manual)
ρ _{water}	Density of sea water (lbm/cu. ft)

Calculation:

P _{back_pressure_a}	Back pressure (psia)
P _{set_g}	Relief valve set pressure (psig) (P _{design_max} + Hydrostatic Head)
P _{over_g}	Relief valve overpressure (psig)
P _{inlet_a}	Relieving pressure (set pressure + overpressure + atmospheric pressure) (psia)
Back_Pressure%	Back pressure percentage (%)
K _b	Capacity correction factor due to back pressure for use when superimposed (constant) back pressure exceeds critical pressure (page 32)
A _{mass_rate}	Minimum required effective valve discharge area (sq. in) - using W
A _{SCFM}	Minimum required effective valve discharge area (sq. in) - using SCFM
ID _{min}	Minimum diameter of relief valve discharge (in)

INPUTS:

$$C_x K := 345$$

$$M := 28.97$$

$$P_{\text{design_max}} := 137.75 \cdot \text{psi}$$

$$P_{\text{atm_a}} := 14.7 \cdot \text{psi}$$

$$\text{Overpressure } \% := 10 \cdot \%$$

$$H_{\text{static}} := 35 \cdot \text{m}$$

$$T := 520 \cdot \text{R}$$

$$W := 357600 \cdot \frac{\text{lb}}{\text{hr}}$$

$$\text{SCFM} := 77940 \cdot \frac{\text{ft}^3}{\text{min}}$$

$$Z := 0.99$$

$$\rho_{\text{water}} := 1.03 \cdot \frac{\text{gr}}{\text{cm}^3}$$

$$\text{gr} \equiv 1 \cdot \frac{\text{kg}}{1000}$$

Determining minimum area of relief valve inlet:

Back Pressure:

$$P_{back_pressure_a} := \rho_{water} \cdot g \cdot H_{static} + P_{atm_a} \quad P_{back_pressure_a} = 65.975 \text{ psi}$$

Set Pressure:

$$P_{set_g} := P_{design_max} + \rho_{water} \cdot g \cdot H_{static} \quad P_{set_g} = 189.03 \text{ psi}$$

Overpressure:

$$P_{over_g} := P_{set_g} \cdot \text{Overpressure } \% \quad P_{over_g} = 18.9 \text{ psi}$$

Inlet Pressure:

$$P_{inlet_a} := P_{set_g} + P_{over_g} + P_{atm_a} \quad P_{inlet_a} = 222.6 \text{ psi}$$

Capacity Correction Factor, (Kb):

$$\text{Back_Pressure } \% := \left(\frac{P_{back_pressure_a}}{P_{inlet_a}} \right) \quad \text{Back_Pressure } \% = 29.6 \%$$

$$\text{At Back_Pressure } \% = 29.6 \% \quad K_b := 1.00 \quad (\text{page 32})$$

Calculating minimum valve inlet area based on MASS flowrate in lb/hr:

$$A_{mass_rate} := \frac{\left[\frac{W}{\left(\frac{lb}{hr} \right)} \right] \cdot \left[\left(\frac{T}{R} \right) \cdot Z \right]^{0.5}}{\left(\frac{P_{inlet_a}}{psi} \right) \cdot (C_x K) \cdot K_b \cdot (M)^{0.5}} \cdot in^2 \quad A_{mass_rate} = 19.627 \text{ in}^2$$

Calculating minimum valve inlet area based on VOLUME flowrate in SCFM:

$$A_{SCFM} := \frac{\left[\frac{SCFM}{\left(\frac{ft^3}{min} \right)} \right] \cdot \left[\left(\frac{T}{R} \right) \cdot Z \right]^{0.5}}{1.175 \cdot \left(\frac{P_{inlet_a}}{psi} \right) \cdot (C_x K) \cdot K_b} \cdot in^2 \quad A_{SCFM} = 19.595 \cdot in^2$$

Calculating minimum valve inlet diameter:

$$ID_{min} := \left(\frac{A_{mass_rate}}{\pi} \right)^{0.5} \cdot 2 \quad ID_{min} = 4.999 \cdot in$$

Selecting a relief valve:

(Refer to pages 18 and 22 of the Crosby Valve Catalog)

Referring to page 22 of the attachments, for an effective area of 19.627 sq. in, an air flowrate of 77,940 SCFM, and a set pressure of 189 psig, only the orifice with the letter designation of "T", having an effective area of 26 sq. in., is applicable. One size lower, orifice "R" has an effective area of 16 sq. in which is inadequate. Referring to page 18, the only valve size to accomodate the "T" orifice is 8x10. With a pressure/temperature limit of 285 psig at 100°F, and the actual pressure of 189 psig, the 150 lb flange class is adequate for both the inlet and outlet flanges.

The JPVM 8T10 Style 15, having ANSI B16.5 Class 150 inlet and outlet flanges, is adequate. Style JPVM is a non-flowing modulating pilot operated pressure relief valve. The JPV style valve is a snap-acting pilot operated pressure relief valve which is inadequate for this application.

Gas, Air and Vapor Sizing (English Units) — Styles JPV and JPVM

Gas and Vapor Sizing - LBS/HR - 10% Overpressure

The following is used for sizing valves for gases and vapor when the required flow is expressed as a mass flow rate in pounds per hour. Correction factors are included to account for the effects of backpressure, compressibility and subcritical flow conditions.

$$A = \frac{W\sqrt{TZ}}{P_1 (C \times K) K_b \sqrt{M}}$$

Where:

A = Minimum required effective discharge area, square inches.

C x K = Variable factor, depending upon ratio of specific heats, multiplied by the coefficient of discharge. (See Table on page 32.) Use C x K = 306 if value is unknown.

K_b = Capacity correction factor due to back pressure for use when superimposed (constant) back pressure exceeds critical pressure. (See Table on page 32.)

M = Molecular weight of the gas or vapor obtained from standard tables or Table on page 32.

P₁ = Relieving pressure in pounds per square inch absolute. This is the set pressure + overpressure + atmospheric pressure.

T = Absolute temperature of the fluid at the valve inlet (°F + 460).

W = Required relieving capacity in pounds per hour.

Z = Compressibility factor. Use Z = 1.0 if value is unknown. (See Crosby Engineering Handbook for further information.)

Gas and Vapor Sizing - SCFM - 10% Overpressure

The following formula is used for sizing valves for gases and vapor when the required flow is expressed as a volumetric flow rate in SCFM. Correction factors are included to account for the effects of backpressure, compressibility and subcritical flow.

$$A = \frac{SCFM\sqrt{TGZ}}{1.175 (C \times K) P_1 K_b}$$

Where:

A = Minimum required effective discharge area, square inches.

C x K = Variable factor, depending upon ratio of specific heats, multiplied by the coefficient of discharge. (See Table on page 32.) Use C x K = 306 if value is unknown.

G = Specific gravity of the gas and vapor at flowing conditions.

K_b = Capacity correction factor due to back pressure for use when superimposed (constant) back pressure exceeds critical pressure. (See Table on page 32.)

P₁ = Relieving pressure in pounds per square inch absolute. This is the set pressure + overpressure + atmospheric pressure.

T = Absolute temperature of the fluid at the inlet (°F + 460).

SCFM = Required relieving capacity in standard cubic feet per minute.

Z = Compressibility factor. Use Z = 1.0 if value is unknown. (See Crosby Engineering Handbook for further information.)

Air Capacities (English Units) — Styles JPV and JPVm

Standard cubic feet per minute at 60°F

Overpressure 10% and Above

Meets Requirements of ASME Boiler and Pressure Vessel Code, Section VIII.
Capacities Certified by National Board of Boiler and Pressure Vessel Inspectors.

1 psi incr. 5 psi incr.	2 11	4 19	6 30	10 49	15.5 77	25 126	36 180	56 280	70 352	85 425	125 624	216 1082	313 1566	509 2545
30	44	167	262	429	670	1098	1568	2434	3072	3703	5462	9429	13652	22185
50	137	244	382	626	977	1601	2287	3550	4479	5400	7914	13750	19910	32354
75	190	339	531	871	1358	2226	3180	4935	6229	7509	11039	19118	27682	44985
80	201	358	560	918	1433	2350	3356	5209	6572	7923	11648	20174	29211	47468
100	244	434	681	1115	1740	2853	4074	6324	7980	9621	14143	24495	35468	57636
120	287	511	801	1312	2047	3356	4793	7440	9388	11318	16638	28817	41726	67805
140	330	588	921	1508	2354	3860	5512	8556	10796	13015	19133	33138	47983	77973
160	373	664	1041	1705	2661	4363	6231	9672	12204	14713	21629	37460	54241	88141
180	416	741	1161	1902	2968	4866	6950	10788	13612	16410	24124	41782	60498	98310
200	459	818	1281	2099	3275	5370	7669	11903	15020	18107	26619	46103	66756	108478
220	502	894	1401	2295	3582	5873	8387	13019	16428	19805	29114	50425	73013	118646
240	545	971	1521	2492	3889	6376	9106	14135	17836	21502	31609	54746	79271	128815
260	588	1048	1641	2689	4196	6880	9825	15251	19244	23199	34104	59068	85528	138983
280	631	1124	1761	2886	4503	7383	10544	16367	20652	24897	36599	63389	91786	149151
300	674	1201	1881	3082	4810	7886	11263	17482	22060	26594	39095	67711	98043	159320
320	717	1278	2001	3279	5117	8390	11982	18598	23468	28291	41590	72032	104300	169488
340	760	1354	2121	3476	5424	8893	12700	19714	24876	29989	44085	76354	110558	179657
360	803	1431	2241	3672	5731	9396	13419	20830	26283	31686	46580	80676	116815	189825
380	846	1508	2361	3869	6038	9900	14138	21945	27691	33384	49075	84997	123073	199993
400	889	1584	2482	4066	6345	10403	14857	23061	29099	35081	51570	89319	129330	210162
420	932	1661	2602	4263	6652	10906	15576	24177	30507	36778	54066	93640	135588	220330
440	975	1738	2722	4459	6959	11410	16294	25293	31915	38476	56561	97962	141845	230498
460	1018	1814	2842	4656	7266	11913	17013	26409	33323	40173	59056	102283	148103	240667
480	1061	1891	2962	4853	7573	12416	17732	27524	34731	41870	61551	106605	154360	250835
500	1104	1968	3082	5049	7880	12920	18451	28640	36139	43568	64046	110927	160618	261004
520	1147	2044	3202	5246	8187	13423	19170	29756	37547	45265	66541	115248	166875	271172
540	1190	2121	3322	5443	8494	13926	19889	30872	38955	46962	69037	119570	173132	281340
560	1233	2198	3442	5640	8801	14430	20607	31987	40363	48660	71532	123891	179390	291509
580	1276	2274	3562	5836	9108	14933	21326	33103	41771	50357	74027	128213	185647	301677
600	1319	2351	3682	6033	9415	15436	22045	34219	43179	52054	76522	132534	191905	311845
620	1362	2427	3802	6230	9722	15940	22764	35335	44587	53752	79017	136856	198162	322014
640	1405	2504	3922	6426	10029	16443	23483	36451	45994	55449	81512	141177	204420	332182
660	1448	2581	4042	6623	10336	16946	24202	37566	47402	57146	84008	145499	210677	342351
680	1491	2657	4162	6820	10643	17450	24920	38682	48810	58844	86503	149821	216935	352519
700	1534	2734	4282	7017	10950	17953	25639	39798	50218	60541	88998	154142	223192	362687
720	1577	2811	4403	7213	11257	18456	26358	40914	51626	62238	91493	158464	229450	372856
740	1620	2887	4523	7410	11564	18960	27077	42030	53034	63936	93988	162785	235707	383024
760	1664	2964	4643	7607	11871	19463	27796	43145	54442	65633	96483	167107	241965	393192
780	1707	3041	4763	7803	12178	19966	28515	44261	55850	67330	98979	171428	248222	403361
800	1750	3117	4883	8000	12485	20470	29233	45377	57258	69028	101474	175750	254479	413529
820	1793	3194	5003	8197	12792	20973	29952	46493	58666	70725	103969	180071	260737	423697
840	1836	3271	5123	8394	13099	21476	30671	47608	60074	72422	106464	184393	266994	433866
860	1879	3347	5243	8590	13406	21980	31390	48724	61482	74120	108959	188715	273252	444034
880	1922	3424	5363	8787	13713	22483	32109	49840	62890	75817	111454	193036	279509	454203
900	1965	3501	5483	8984	14020	22986	32827	50956	64298	77514	113949	197358	285767	464371
920	2008	3577	5603	9181	14327	23490	33546	52072	65705	79212	116445	201679	292024	474539
940	2051	3654	5723	9377	14634	23993	34265	53187	67113	80909	118940	206001	298282	484708
960	2094	3731	5843	9574	14941	24496	34984	54303	68521	82606	121435	210322	304539	494876
980	2137	3807	5963	9771	15248	25000	35703	55419	69929	84304	123930	214644	310797	505044
1000	2180	3884	6083	9967	15555	25503	36422	56535	71337	86001	126425	218965	317054	515213
1100	2395	4267	6684	10951	17090	28020	40016	62114	78377	94488	138901	240573	348341	566055
1200	2610	4650	7284	11935	18626	30536	43610	67693	85416	102974	151377	262181	379629	616896
1300	2825	5034	7884	12918	20161	33053	47204	73271	92456	111461	163853	283789	410916	667738
1400	3040	5417	8485	13902	21696	35570	50798	78850	99496	119948	176329	305397	442203	718580
1480	3212	5724	8965	14689	22924	37583	53673	83313	105127	126737	186309	322683	467233	759254

NOTE: See Pages 18 and 19 for Pressure Limits.

Sizing Correction Factors and Multipliers

Flow Factor for Vapors and Gases — K_b for Back Pressures Exceeding Critical

Back pressure generally has no effect on the set pressure or flow capacity of Crosby's Pilot Operated Pressure Relief Valves except when flow is expected to be subcritical (absolute back pressure exceeds 55% of the absolute relieving pressure). In this case the flow correction factor K_b must be applied. If the ratio of absolute back pressure to absolute relieving pressure is less than 55%, no special correction factor is required: $K_b = 1.00$.

Note: Consult the factory for back pressure greater than 70% of set pressure.

$$P_b/P_1 = \text{BACK PRESSURE PERCENTAGE} = \frac{\text{BACK PRESSURE, (PSIA or kPa or bar Absolute)}}{\text{ACCUMULATED INLET PRESSURE (PSIA or kPa or bar Absolute)}} \times 100$$

Back Pressure (PSIA)	K_b
55	1.00
60	0.995
62	0.99
64	0.98
66	0.97
68	0.96
70	0.95

Example for determination of Flow Factor K_b :

Set Pressure = 150 psig

Back Pressure = 100 psig

$$P_b/P_1 = \text{Back Pressure Percentage} = \frac{100 + 14.7}{150 (1.1) + 14.7} \times 100$$

$$= \frac{114.7}{179.7} \times 100 = 64\%$$

Where $P_b/P_1 = 64\%$, $K_b = 0.98$

Typical Properties of Gases

Acetylene	26.04	332	0.899	N-Heptane	100.20	311	3.49
Air	28.97	345	1.00	Hexane	86.17	312	2.975
Ammonia	17.03	338	0.587	Hydrochloric Acid	36.47	346	1.268
Argon	39.94	366	1.377	Hydrogen	2.02	346	.070
Benzene	78.11	319	2.70	Hydrogen Chloride	36.50	346	1.259
N-Butane	58.12	316	2.01	Hydrogen Sulphide	34.07	338	1.19
Iso-Butane	58.12	316	2.01	Methane	16.04	337	0.555
Carbon Dioxide	44.01	336	1.53	Methyl Alcohol	32.04	327	.792
Carbon Disulphide	76.13	328	1.261	Methyl Butane	72.15	315	2.491
Carbon Monoxide	28.00	345	.967	Methyl Chloride	50.49	327	1.785
Chlorine	70.90	341	2.448	Natural Gas (Typical)	19.00	334	0.655
Cyclohexane	84.16	315	2.906	Nitric Oxide	30.00	345	1.037
Ethane	30.07	326	1.038	Nitrogen	28.00	345	0.967
Ethyl Alcohol	46.07	320	1.591	Nitrous Oxide	44.00	336	1.530
Ethyl Chloride	64.52	326	0.903	N-Octane	114.22	311	3.94
Ethylene	28.05	331	0.969	Oxygen	32.00	345	0.967
Freon 11	137.37	321	4.737	N-Pentane	72.15	313	2.49
Freon 12	120.92	321	4.17	Iso-Pentane	72.15	314	2.491
Freon 22	86.48	326	2.982	Propane	44.09	320	1.55
Freon 114	170.93	316	5.894	Sulfur Dioxide	64.06	332	2.26
Helium	4.00	366	0.138	Toluene	92.13	316	3.18

DANIEL

Daniel Valve Company
 PO Box 40421
 Houston, TX 77240
 Telephone: (281) 469-0550
 Facsimile: (281) 894-1332
<http://www.danielind.com>

FAX TRANSMITTAL

Company:	HAN-PADRON ASSOCIATES	Date:	January 10, 2000
To:	MR. ROBERT BURY	From:	Ron Kennedy
Fax Number:	212-629-4406		Danflo Sales Mgr.
Phone Number:	212-736-5466	Total pages, including cover:	(2)
Subject:	DVC QUOTE 00-7768-08-104/YOUR JOB 864-01		
	DVC FAX MESSATE 00-0110-02		

Robert:

Per your request, we offer the following budget quote for the Danflo valves listed on your suction mooring technology compressed air system:

Valve 1

8" ANSI 150#RF 8-411-ALN-50 Solenoid valve operated Danflo valve with one (1) each NO and one N/C solenoid valve, General Purpose Solenoid Valve

Unit Budget Price: \$ 16,550.00 (USD)

Valve 2

2" ANSI 150#RF 2-411-ALN-50 Solenoid valve operated Danflo valve with one (1) each NO and one N/C solenoid valve, General Purpose Solenoid Valve

Unit Budget Price: \$ 10,865.00 (USD)

Valve 3

3" ANSI 150#RF 3-411-ALN-50 Solenoid valve operated Danflo valve with one (1) each NO and one N/C solenoid valve, General Purpose Solenoid Valve

Unit Budget Price: \$ 12,310.00 (USD)

Delivery: 12-14 weeks

1/2

TOTAL P.02

DANIEL

Daniel Valve Company
PO Box 40421
Houston, TX 77240
Telephone: (281) 469-0550
Facsimile: (281) 894-1332
<http://www.danielind.com>

We re quoting our standard Danflo carbon steel valves with soft seats. The leakage rate is classified as Class IV, but for all intensive purposes, it is leak tight.

I would like to point out Mr. Bury that I believe that the application that you have illustrated should use ball valves with either hydraulic or spring return actuators in lieu of what we are offering. You should be able to get the same two (2) second or less full closing/opening cycle. This type of valve is used for ESD valves on pipelines often.

With regards to the drafting symbol for the valve, what you have shown on your drawing is okay and acceptable.

Call me if you need any additional information.

Sincerely yours,

Ron Kennedy
Danflo Sales Manager

Cc: C. Brown
J. Wass

The
DANFLO
family of
CONTROL VALVES

- Axial "straight-path" smooth-flow pattern for high flow capacities (C_v)
- Fast response—rapid open/close, seals tight without slamming shut
- Large annular flow area allows high pressure recovery, low pressure drop
- Low-noise and cavitation trim available

400

For use with pilots or controllers.

DANFLO VALVES
AVAILABLE
IN LARGER SIZES.

NOTE: CAVITATION AND LOW-NOISE TRIM AVAILABLE													
BODY STYLE 41	PILOT OPERATED	SIZE (in)	2	3	4	6	8	10	12	16	20	24	30
		DIN (mm)	50	75	100	150	200	250	300	400	500	600	750
		C _v ⁽¹⁾	120	330	480	1200	1900	3100	4200	7630	11900	17175	38640
		(1)The volume of water in GPM at 60°F that will flow with 1 psi pressure drop across the valve.											
BODY STYLE 42	CONTROLLER OPERATED	Model No. & Pressure Ranges	Control Function		Simplified Schematic		Principal Applications		Ask for Bulletin Number:				
		ANSI 150-1500	Pressure Reducing				Pressure control in process streams and pipelines. Over-pressure protection of meters, manifold systems, etc.		400-10				
		ANSI 150-1500	Back Pressure/Pressure Relief				Hold back pressure for pump, meter, etc. Pressure relief and control of line-pressure surges.		400-20				
		ANSI 150-1500	Over-pressure Protection				Protect process streams and pipelines from overpressure.		400-25				
		ANSI 150-1500	Rate-of-Flow				Controls flow rate in a pipeline by sensing ΔP across a flow element such as an orifice, turbine or P.D. meter.		400-30				
		ANSI 150-1500	Minimum Differential Pressure				Pump ΔP and ΔP by-pass control; also strainers, filters. Vapor-pressure control (LPG and similar products)		400-35				
		ANSI 150-1500	Solenoid Control				Batch operations by preset. Control from level sensing. Line block valve.		400-50				
		ANSI 150-1500	Pneumatic Control				On/Off or modulating pressure, flow, or level control from pneumatic control signals.		400-60				
		ANSI 150-1500	Electronic Control				On/Off or modulating pressure, flow, or level control from electronic control signals.		400-70				
		ANSI 150-1500	Surge Relief (Nitrogen loaded) See page 6				Protect pipelines, pumps, and other devices from transient surge overpressures.		400-40				
BODY STYLE 43	CONTROLLER OPERATED	SIZE (in)	3	4	6								
		DIN (mm)	75	100	150								
		C _v ⁽¹⁾	205	285	675								
		(1)The volume of water in GPM at 60°F that will flow with 1 psi pressure drop across the valve.											
ANSI 150	Truck Loading (Solenoid control)				Rate-of-Flow control. Terminal automation and/or remote control with electronic signals to solenoids.		DA-598						

500

Similar to 400 series but uses a "pressure-balanced" plug with power piston.

BODY STYLE 51	SIZE (in)	6	8	10	12			
	DIN (mm)	150	200	250	300			
	C _v ⁽¹⁾	560	1010	1615	2310			
	⁽¹⁾ The volume of water in GPM at 60°F that will flow with 1 psi pressure drop across the valve.							
E6 Pump Suction Installation	Tank Safety Shut-Off ANSI 150	No solenoid or pneumatic signal required. Self Actuated.				Flow	Prevents withdrawal of any product from a storage tank unless the pump is operating. Requires no external power source. Uses line pressure on power piston for operation.	400-55
BODY STYLE 52	SIZE (in)	12	16	20	24	30		
	DIN (mm)	300	400	500	600	750		
	C _v ⁽¹⁾	4390	7630	11900	17175	38640		
	⁽¹⁾ The volume of water in GPM at 60°F that will flow with 1 psi pressure drop across the valve.							
ANSI 150-600	Servo Control with external hydraulic source.				Servo 4-20 ma Hydraulic Supply	Flow	Flow, pressure, or back-pressure control.	400-90

400 SERIES

A 400 Series DANFLO valve, in its simplest form, consists of a dynamically balanced-plug assembly that slides back and forth easily and rapidly to open, close, and throttle.

- Pressure in the plug cavity closes the valve.
- With no pressure in the cavity, the valve opens.

Pressures are applied through three ports: upstream, downstream, and to the plug cavity "behind the plug."

Downstream port provides for venting plug-cavity pressures rapidly to speed up valve response. The port leads to the point of lowest internal pressure in the valve.

For convenience, the ports (and related pressures) are identified:

P_u = Upstream
 P_d = Downstream
 P_c = Cavity

TYPICAL VALVE ACTION

P_c is connected to P_u . This equalizes pressures on upstream and downstream faces of the plug. The internal-spring force closes the valve.

By connecting P_c to P_d , the plug cavity is vented. Upstream line pressure overcomes the spring force, and the plug is forced open.

Ports P_u and P_c connected
 Upstream pressure is equalized across the valve
 Spring pressure forces plug to seat
 VALVE CLOSED

Ports P_u and P_c connected
 A differential pressure exists across the plug
 Upstream pressure greater than mechanical spring pressure moves the plug downstream — away from the seat — VALVE OPEN

PILOT OPERATION

400 SERIES—BODY STYLE 41

The pilot connects P_c to either P_u or P_d to close or open the valve. The connection is made in the pilot by an internal poppet that shuttles back and forth depending on whether force from the pressure provided by a "sense line" is larger or smaller than the pilot spring force. (Differential-pressure pilots are also available.)

An easy way to remember how the pilot works is that the valve, after the initial start-up sequence, will normally be closed if the spring "points" upstream (back-pressure or relief operation), normally open if "pointed" downstream (pressure-reducing service).

Use of the pilot is therefore:

- "Point" the spring so the valve is normally open or closed, as desired.
- Connect the "sense line" upstream or downstream to "sense" the pressure you want to actuate the pilot.

Poppet right
 Pressure is equalized across the plug.
 Plug moves left —
 VALVE IS CLOSED.

Poppet left
 Pressure differential is created
 Plug moves right
 VALVE IS OPEN.

500 SERIES

500 Series valves also use axial flow for high flow capacity and are very similar to the 400 Series valves. However, a pressure-balanced plug design has ports to equalize effects of line pressure on each side of the plug—and the plug is connected to a power piston which forces it open or closed.

Principal applications for 500 Series are Tank Safety Shut-Off and Electrohydraulic Servo Control.

TANK SAFETY SHUT-OFF

500 SERIES—BODY STYLE 51

- Automatic operation.
- When pump is running, valve is open.
- If pump stops or pressure equalizes across pump, pressure in sense line is no longer sufficient to hold valve open. Valve closes to prevent lost product and spills.

MODEL 80, LOCATE IN PUM'
 MODEL 85, LOCATE IN PUM'

Operation:

- Line pressure applied to both faces of power piston.
- Spring forces plug CLOSED.
- Pump starts; discharge pressure on power piston forces plug OPEN.
- Pump stops; pressure again equal across power piston.
- Spring forces plug CLOSED.

Pressure drop in pilot chamber
Mechanical spring pressure is greater
Poppet moves right
Valve plug left
VALVE IS CLOSED.

Pressure rise
Pressure in the sensing unit is greater than the mechanical spring force.
Poppet moves left
Valve plug moves right
VALVE IS OPEN.

Velocity is higher and pressure is lower at point Cv than it is at point Cs.
In regulating service, plug chamber is exhausted to point Cs for faster response to changing pressure.

IMPORTANT NOTE: Reversing the direction of the DAN-FLO pilot sensing unit reverses the direction of valve plug response.

In pressure reducing/regulating conditions operational characteristics are reversed.
A drop in pressure downstream
Poppet moves left,
Valve plug moves right.
Valve is OPEN.

THROTTLING-CONTROLLER OPERATION

400 SERIES—BODY STYLE 41

By connecting P_c to P_u through a small orifice (to "smooth out" control action) and also connecting P_c to P_d via a single-seat globe valve with a pneumatic (3-15# or 6-30#) or electronic (4-20 Ma) control signal, the valve will throttle in response to the pneumatic or electronic signal from the controller.

PNEUMATIC CONTROL

MODEL 60

ELECTRONIC CONTROL

MODEL 70

E IN PUMP SUCTION
E IN PUMP DISCHARGE

Model 80

ELECTROHYDRAULIC SERVO CONTROL

500 SERIES—BODY STYLE 52—MODEL 90 SIZES 12" THRU 30"

The DANFLO Model 90 valve is designed for use with an external hydraulic supply with suitable piping to apply hydraulic force on each side of the valve's power piston. Control over the two hydraulic lines comes from a servo control board in response to standard low-milliamper or low-voltage signals.

The major use of this efficient valve is for flow, back-pressure, or pressure control. An indicator to show plug position is standard on Model 90 valves.

The versatile, efficient, cost-effective DANFLO Control Valve

Two basic designs with balanced, guided plug assemblies

400 SERIES (Illustrated above)
For use with pilots and controllers
MODELS 10, 20, 25, 30, 35,
40, 50, 55, 60 and 70

500 SERIES
With internal power piston
MODELS 80, 85 and 90

THE DANFLO DESIGN

The 400 and 500 series DANFLO valves (with body styles 41, 42, 43, 51, and 52) all share two important characteristics:

- Flow through the valve when open is via a large, venturi-type flow path that provides a high flow coefficient (C_v) and low pressure drop across the valve.
- Flow is controlled with a guided-plug assembly that moves in response to upstream or downstream line pressure according to the valve application.

TYPICAL DANFLO VALVE

(Model 20 in Back Pressure/Pressure Relief Service)

(TYPICAL BACK PRESSURE CONFIGURATION)

Note: Details of valve body and piping configuration depend on the specific application.

PRESET TRUCK-LOADING/BATCH-OPERATION

400 SERIES—BODY STYLE 43—MODEL 55

An interesting form of flow control can be achieved with DANFLO valves by using a pair of solenoid valves as shown in the accompanying sketch. They operate in synchronism, alternately tending to open/close the valve but pulsed at such a rapid rate that the plug dynamically "floats" in the correct position to maintain a desired flow rate.

Daniel makes use of this unique digital control in its truck-loading systems by coupling DANFLO valves with Daniel LR turbine meters (made specifically for high repeatability measurement in light-hydrocarbon service).

ORDERING GUIDE

Because of the many variations available in DANFLO valves, it is important that the factory know as much as possible about the intended installation, including:

- Line size and pipe schedule
- Pressure rating (ANSI)
- Maximum line pressures (Inlet and outlet)
- Max/min differential pressures
- Max/min line-media temperatures
- Max/min line flow rates
- Composition of line media
- Specific Gravity of media
- Vapor pressure of media
- Batch or continuous operation
- Operational mode and type control device to be used (pilot, controller, servo, etc.)
- Low-noise or cavitation trim needed
- Special considerations.

SURGE RELIEF

(Nitrogen pressure loaded)

400 SERIES—BODY STYLE 42—MODEL 40

One of the major uses of DANFLO valves in recent years has been for surge relief in liquid pipelines. Only the P_c connection is used, and through it a "set" pressure (from a nitrogen charging system) is applied to the plug cavity.

When a transient surge occurs, line pressure exceeds the "set" pressure and forces the valve plug open instantaneously. The pressure surge volume is dumped to a collection tank or bypassed to downstream. When line pressure drops below the "set" pressure, the valve quickly but smoothly closes. The valve "tracks" all subsequent transient surges until line-pressure equilibrium returns.

Operation is fast, automatic, and requires no attention from operating personnel. There is nothing to reset or replace after surge-relief action. The DANFLO Surge valve is always ready for immediate action to prevent damage to equipment and/or harm to personnel.

Cavity behind plug filled with nitrogen gas. Valve closed until pressure surge in line exceeds "set" pressure. Valve immediately opens to abate surge, closes when line pressure drops below "set" pressure.

DANIEL

Valve Company

DANIEL VALVE COMPANY
19191 Hempstead Highway
P.O. Box 40421
Houston TX 77240
Phone: (713) 469-0550
Outside Texas: 1-800-231-3690
Telex: 762-400
Fax: (713) 894-1332

DANIEL VALVE COMPANY
Library House
The Green
Datchet, Slough
Berkshire, England
SL3 9AU
Phone: (011-44) 753-548173
Fax: (011-44) 753-582765

DANIEL INDUSTRIES CANADA
#114-4215-72 Avenue, S.E.
Calgary, Alberta, Canada
T2C 2G5
Phone: (403) 279-1879
Telex: 03-827701
Fax: (403) 236-1337

4. Risk Analysis

In this chapter a failure tree analysis is presented examining the risks inherent in the use of the mooring as described in the previous sections. The risks are evaluated by examining a primary failure and then subsequent failure of each of the systems used following the primary failure and a listing of the consequence of each successive failure.

4.1 Operational Mooring Risks

This section examines the risks that are inherent in the mooring operation:

In a successful mooring attempt the following systems are used in sequence aboard the ship:

- The navigation system (differential GPS and back-up (e.g. Miniranger))
- The bow thruster on the vessel
- The autopilot
- The main propulsion machinery
- The underwater video equipment
- The acoustic communication system
- The optical communication system
- The releasable hatch in the bottom of the ship
- The pressure maintenance pumps

The following equipment is used aboard the mooring buoy:

- The buoy wake-up system (acoustic)
- The low pressure tank charging system (A and B system)
- The optical communication system
- The Rapid Ascent system (A or B system)

In the event of failure to capture the buoy the following system will be used:

- Emergency descent system.

The failure tree for the failure of shipborne equipment is shown in figure 4-1. The most serious consequence of the worst scenario sequence of events is the damaging of the hull of the vessel and of the buoy due to lateral impacts as the buoy surfaces next to the ship. In extreme cases the damage to the hull of the ship may consist of holing through of the side plating in the vicinity of the mooring equipment. It then depends on what is behind the plating whether this represents pollution incident or not. The damage so caused is not likely to cause serious problems concerning stability or seaworthiness to the vessel.

Damage to the buoy would cause it to lose buoyancy and descend to the seabed. If severely damaged salvage equipment may be required to effect repairs because the buoy's ability to surface may no longer exist.

Legend

Figure 4-1

Figure 4-1

Figure 4-1

4.2 Buoy Equipment Failure

The failure tree of equipment aboard the buoy is shown on figure 4-2. The most serious consequence of a series of failures is the over pressurization of a low-pressure tank used for the rapid ascent system. This may lead to an explosion of the subject tank or rupture of it. This will lead to the buoy sinking to the seabed and making mooring attempts impossible.

Figure 4-2

Figure 4-2

4.3 Stay Moored and Unmooring.

While the buoy is moored to the vessel all systems are inactive with the exception of the high pressure tank re-charge and the charging of the batteries in the electrical system.

The emergency descent system is used following each successful mooring to bring the buoy to a condition that it will descend following release from the vessel. Because the rapid ascent buoyancy volume is not airtight it will fill with water in any event even if the emergency descent system fails to actuate. Therefore no later than 15 minutes after a successful mooring the buoy is always poised to descend when released.

Unmooring is provoked by the simple action of reversing the pressure maintenance pumps. These will pump in approximately 0.3 m³/sec. 300 seconds later 90 m³ has been added to the volume above the buoy. At this point the exterior seal will be broken and the buoy will fall away.

A failure tree analysis of the stay-moored condition is shown in figure 4-3.

A special note is required concerning the unmooring process following the breakage of one of the mooring chains. In the case of a 6 or 9 point spread mooring the buoy may or may not be strongly buoyant. In the case, however, of general arrangement number one where the mooring is secured by lifting weights the buoy will be strongly buoyant following a mooring chain failure. The safe unmooring procedure in this case is to release the buoy with the vessel hovering above the buoy's neutral position. Following release of the buoy the vessel is accelerated astern such that momentum is gained before the buoy surfaces next to the vessel.

Figure 4-3

Figure 4-3

Figure 4-3

4.4 Fluid Connection System.

The fluid connection system is comprised of a number of fluid conductors each individually connected by a quick connector with a double seal charged with nitrogen between the two seals. The nitrogen pressure is maintained above the fluid pressure in the conductor, thereby positively preventing leaks in normal operations.

Each individual conductor is shown in concept below in Figure 4-4. The all valves shown are auto-return valves that automatically shut when the stay open signal is lost.

Figure 4-4. Fluid connector system.

The valves labeled ESD and C are electrically controlled valves. These are opened when the fluid connection is desired. The seal pressure in the connector operates the valves S. Thus the normal operating sequence is that the connector is made up and the seals are pressurized. If the seals leak at a rate below some established value the valves S open. Following the opening of the valves S the valves C and ESD are opened by electrical command. The electrical connection is established through a separate electrical connector.

At disconnect the fluid conductor is flushed by a separate system that is not illustrated. Thus at normal disconnect no hydrocarbons are released.

Figure 4-5

Figure 4-5

Appendix F

CORRESPONDENCE WITH THE AMERICAN BUREAU OF SHIPPING

From: MLee@eagle.org <MLee@eagle.org>
To: edbo@ix.netcom.com <edbo@ix.netcom.com>
Cc: rdeschamps@eagle.org <rdeschamps@eagle.org>; hpatel@eagle.org
 <hpatel@eagle.org>; wma@eagle.org <wma@eagle.org>
Date: Thursday, August 03, 2000 3:17 PM
Subject: Re: Hydrostatic Mooring: Approval in Principle

We acknowledged your reply, and are awaiting your additional calculations. As to your inquiries regarding corrosion allowance and bearing safety factor, we offer:

Corrosion Allowance

Section 3/3.3.3 of the ABS SPM Rules provides some specific requirements on corrosion control. Alternatively, we'll accept a corrosion allowance in the weight considerations and member calculations. However, the minimum member size after corrosion consideration should be the size used in the structural calculations while the original member size (before corrosion) should be used in the buoyancy calculations.,

Bearing S.F.

Section 4/1.7.3 a) of the ABS SPM Rules specifies a safety factor of not less than 2 without yielding. We'll be happy to consider your design modification and/or further studies to increase the system reliability.

Regards,

Ming-Yao Lee
 Offshore Engineering Department
 ABS Americas (281) 877-6735

edbo@ix.netcom.com

To: <MLee@eagle.org>

31-07-00 11:13 PM

cc:

Subject: Re: Hydrostatic Mooring: Approval in Principle

Sorry for being a little tardy in responding.

1. The existing model tests already in your possession had a force deflection curve very close to both the mooring systems, which we will demonstrate shortly.
2. Stability calculations will be done and submitted on the actual buoy. We have stability calcs on two prior versions and do not expect any problems in this area.
3. Would it be ok to simply include a corrosion thickness allowance in all weight and buoyancy calculations?

4. Pile interaction calcs will be furnished.

5. We use a proprietary riser that may be designed to not contact the seabed. We will furnish documentation. It will be clear from this documentation that any amount and size of riser may be accommodated.

Concerning risk assessment. The only element that is non redundant is the main bearing. There is possibly enough space too include structural elements that take over in the event of a bearing element failure. We will check this. Another possibility is to increase the factor of safety on the structural elements in the bearing (25% ?? 50%??). Can I have guidance here?

You could take the position that the fluid seal is non redundant. Failure of this is however gradual, such that there would be warnings and enough time to disconnect in the usual fashion.

Best regards
Jens Korsgaard

-----Original Message-----

From: MLee@eagle.org <MLee@eagle.org>

To: edbo@ix.netcom.com <edbo@ix.netcom.com>

Cc: wma@eagle.org <wma@eagle.org>; rdeschamps@eagle.org <rdeschamps@eagle.org>;

lsamuelsson@eagle.org <lsamuelsson@eagle.org>; hpatel@eagle.org <hpatel@eagle.org>

Date: Thursday, July 27, 2000 5:50 PM

Subject: Hydrostatic Mooring: Approval in Principle

Dear Jens,

Per your request, we have the following comments based on a cursory review completed so far:

Mooring and Buoy Design:

1. Mooring design loads of anchor legs and mooring elements between the buoy and the vessel should be established through proper physical model testing and/or analyses taken into account design safety factors.
2. Stability calculations should be carried out to demonstrate that the system is installable, repairable, and that the buoy is inspectable on the surface.
3. Corrosion protection and/or provisions should be included in the scantling calculations.
4. Calculations verifying the piles and its interactions with mooring legs, both structurally and geotechnically, need to be included.
5. The mechanical wear from the risers in contact with the sea floor, the mooring chains or the buoy body should be investigated. The risers should also be verified for the riser minimum bending radius requirements.

Piping/Mechanical:

(Yet to be furnished by our machinery group)

Risk Assessment:

Where parts of the system are identified as non-redundant and where redundancy is not possible, we

suggest that quantitative rather than qualitative analyses be performed to ensure that the risks are minimized.

Please consider the above comments as preliminary at this time. We'll provide a more detailed list of comments and/or suggest areas for further engineering once we complete our review work.

Regards,

Ming-Yao Lee
Offshore Engineering Department
ABS Americas (281) 877-6735

From: edbo@ix.netcom.com <edbo@ix.netcom.com>
To: MLee@eagle.org <MLee@eagle.org>
Date: Tuesday, August 01, 2000 12:13 AM
Subject: Re: Hydrostatic Mooring: Approval in Principle

Sorry for being a little tardy in responding.

1. The existing model tests already in your possession had a force deflection curve very close to both the mooring systems, which we will demonstrate shortly.
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3. Would it be ok to simply include a corrosion thickness allowance in all weight and buoyancy calculations?
4. Pile interaction calcs will be furnished.
5. We use a proprietary riser that may be designed to not contact the seabed. We will furnish documentation. It will be clear from this documentation that any amount and size of riser may be accommodated.

Concerning risk assessment. The only element that is non redundant is the main bearing. There is possibly enough space too include structural elements that take over in the event of a bearing element failure. We will check this. Another possibility is to increase the factor of safety on the structural elements in the bearing (25% ?? 50%??). Can I have guidance here?

You could take the position that the fluid seal is non redundant. Failure of this is however gradual, such that there would be warnings and enough time to disconnect in the usual fashion.

Best regards
Jens Korsgaard

-----Original Message-----

From: MLee@eagle.org <MLee@eagle.org>
To: edbo@ix.netcom.com <edbo@ix.netcom.com>
Cc: wma@eagle.org <wma@eagle.org>; rdeschamps@eagle.org <rdeschamps@eagle.org>; lsamuelsson@eagle.org <lsamuelsson@eagle.org>; hpatel@eagle.org <hpatel@eagle.org>
Date: Thursday, July 27, 2000 5:50 PM
Subject: Hydrostatic Mooring: Approval in Principle

Dear Jens,

Per your request, we have the following comments based on a cursory review completed so far:

Mooring and Buoy Design:

1. Mooring design loads of anchor legs and mooring elements between the buoy and the vessel should be established through proper physical model testing and/or analyses taken into account design safety factors.

2. Stability calculations should be carried out to demonstrate that the system is installable, repairable, and that the buoy is inspectable on the surface.
3. Corrosion protection and/or provisions should be included in the scantling calculations.
4. Calculations verifying the piles and its interactions with mooring legs, both structurally and geotechnically, need to be included.
5. The mechanical wear from the risers in contact with the sea floor, the mooring chains or the buoy body should be investigated. The risers should also be verified for the riser minimum bending radius requirements.

Piping/Mechanical:

(Yet to be furnished by our machinery group)

Risk Assessment:

Where parts of the system are identified as non-redundant and where redundancy is not possible, we suggest that quantitative rather than qualitative analyses be performed to ensure that the risks are minimized.

Please consider the above comments as preliminary at this time. We'll provide a more detailed list of comments and/or suggest areas for further engineering once we complete our review work.

Regards,

Ming-Yao Lee
Offshore Engineering Department
ABS Americas (281) 877-6735

From: MLee@eagle.org <MLee@eagle.org>
To: edbo@ix.netcom.com <edbo@ix.netcom.com>
Cc: wma@eagle.org <wma@eagle.org>; rdeschamps@eagle.org
<rdeschamps@eagle.org>; lsamuelsson@eagle.org <lsamuelsson@eagle.org>;
hpatel@eagle.org <hpatel@eagle.org>
Date: Thursday, July 27, 2000 5:50 PM
Subject: Hydrostatic Mooring: Approval in Principle

Dear Jens,

Per your request, we have the following comments based on a cursory review completed so far:

Mooring and Buoy Design:

1. Mooring design loads of anchor legs and mooring elements between the buoy and the vessel should be established through proper physical model testing and/or analyses taken into account design safety factors.] ok
2. Stability calculations should be carried out to demonstrate that the system is installable, repairable, and that the buoy is inspectable on the surface.] ok
3. Corrosion protection and/or provisions should be included in the scantling calculations.] ok
4. Calculations verifying the piles and its interactions with mooring legs, both structurally and geotechnically, need to be included.] ok
5. The mechanical wear from the risers in contact with the sea floor, the mooring chains or the buoy body should be investigated. The risers should also be verified for the riser minimum bending radius requirements.] ok

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Please consider the above comments as preliminary at this time. We'll provide a more detailed list of comments and/or suggest areas for further engineering once we complete our review work.

Regards,

Ming-Yao Lee
Offshore Engineering Department
ABS Americas (281) 877-6735

Jens Korsgaard
318 North Post Road
Princeton Junction NJ 08550
Phone: 609-936-8543
Fax: 609-936-9373

07/17/00

Mr. Ming-Yao Lee
ABS Americas
16856 Northchase Drive
Houston TX 77060-6796

File Ref: 1014/DBL/RQ

Dear Ming-Yao:

This refers to our submittal for approval in principle for the Hydrostatic Mooring

Here are the details of Section 3 Electrical/Mechanical design to be inserted following the summary report by Han Padron Associates.

Section 5 is still pending.

Best regards

Jens Korsgaard

Jens Korsgaard
318 North Post Road
Princeton Junction NJ 08550
Phone: 609-936-8543
Fax: 609-936-9373

07/07/00

Mr. Ming-Yao Lee
ABS Americas
16856 Northchase Drive
Houston TX 77060-6796

File Ref: 1014/DBL/RQ

Dear Ming-Yao:

Here is our submittal for approval in principle for the hydrostatic mooring. I have completed this on a trip.

The submittal lacks section 5, Applicable Standards. This will be sent to you on or about July 16 after my return to USA.

Section 3 Electrical/Mechanical design contains only the summary report by Han Padron Associates. The detailed calculations will be submitted with Section 5.

Please make a fast review in order to identify potential items that are missing. We will furnish these as fast as possible following identification. We are of course available with respect to any clarifications required. If needed we are also available to meet with you and your staff in Houston

Best regards

Jens Korsgaard

A DIVISION OF THE AMERICAN BUREAU OF SHIPPING

16855 NORTHCHASE DR, HOUSTON, TEXAS 77060-6008

TEL: 281-877-8000

FAX: 281-877-8796

TELEFAX MESSAGE

Page 1 of 1

To:	SUCTION MOORING TECHNOLOGY	Date:	25 August 1999
Attn:	Jens Korsgaard	Fax No:	609 936 9373
		Fax No:	
From:	David Lorenz	Branch code:	86203
File Ref:	1014/DBL/RQ	PID	#

Subject: Concept Evaluation

Mr. Korsgaard,

We hereby accept your conditions for the Approval in Principle of the Hydrostatic Mooring, as detailed in your letter of 28 July 1999.

An invoice will be sent to you for the first payment next week.

You may begin by submitting drawings and calculations as described in our proposal at your earliest convenience.

Please forward all submittals through me.

Thank you for your business.

Best regards,

A handwritten signature in black ink, appearing to read "DL", followed by a long horizontal line.

David B Lorenz
Principal Engineer
Project Manager
Offshore Engineering Department

Suction Mooring Technology

Offshore Mooring Systems

318 North Post Road
Princeton Jct. NJ 08550
Phone: (609) 936-9568
Fax: (609) 936-9373

July 13, 1999

Mr. David A. Crouch, EE-24
US Dept. Of Energy
Mailstop 5E-052
Washington DC 20585

By fax to 202-586-3180 (12 pages total)

Reference: Invention 703

Dear Mr. Crouch:

Attached is the proposal from American Bureau of Shipping.

I have clarified the proposal over the phone with ABS, see handwritten notes in the margin of the proposal.

The words "Concept Evaluation" are the same as "Approval in Principle" thus the proposal covers what I desire.

The cost is higher than the basis for my budget. One reason for this is the "Risk Assessment Evaluation". This item was not present in prior proposals from ABS. ABS claims that this item is required and that it was mistake not to include it in prior proposals.

I intend to accept the proposal as modified. I believe that I need your blessing before formal acceptance.

I have a problem with the timeframe. Before we actually have an executed contract and start work it is the end of the month. The ABS budget has increased and the work required from me is increased by virtue of the "Risk Assessment Evaluation". I may need an extension of time, say 3 months, with respect to overall completion.

Because of the increased ABS budget and the increased requirements I may want to move monies from the HPA budget to the ABS budget. I presume that I can do that because this is within the same work item.

Please review the attached for acceptability.

Sincerely yours

Jens Korsgaard

1. Mooring System

The present mooring system is a single point mooring attached to the keel of the moored vessel. The mooring buoy is held firmly to the bottom of the vessel by differential hydrostatic pressure. A structural swivel is built into the mooring buoy that permits the moored ship to weathervane in relation to the mooring chains.

Pressure maintenance pumps aboard the vessel maintain the differential pressure. These pumps take suction within the volume isolated by the top of the buoy and the hull of the vessel.

1.1 General Arrangement

The function and basic general arrangement is explained in the previous section. Single point moorings are typically moored to the seabed through a series of radially deployed catenary mooring lines terminating in drag anchors or stake piles in the sea bed. This standard arrangement is illustrated on Figure 1-2 (Hydrostatic Mooring General Arrangement - 2).

A special mooring system has been developed that take advantage of the unique properties inherent in the present mooring system as shown on figure 1-1 (Hydrostatic Mooring General Arrangement - 1). This system is comprised of a series of heavy weights that are lifted by the excursions of the mooring buoy. When the buoy deflects horizontally the connecting chain is bent over a fairlead in the top of the stake pile. In the proposed system that is specifically designed for the water transport system at Askelon Israel six stake piles are provided. This system maintains a higher fraction of its initial capabilities than the traditional system shown in Figure 1-2 when one mooring line fails.

use in concept 1
Because of the small amount of chain it is not a significant economic penalty to oversize the mooring chains to compensate for the wear that will occur at the fairlead. It is the intent to frequently inspect the system and to replace chain and fairleads when significant wear has occurred.

This is the preferred system partly because of significant cost reductions and partly due to its much superior force deflection characteristics as illustrated in figures 1-4 and 1-5.

The graph in Figure 1-3 depicts the chain force as a function of the horizontal excursion of the vessel. Because the chain force is supplied by a hanging weight it is nearly constant. It is, however, modified above the fairlead by the friction in the fairlead. The present calculation is based on a friction coefficient of 10% as being the steel on steel friction coefficient. Figure 1-4 shows the resulting component of the chain force for a single chain. There are six chains, therefore the actual mooring force is six times the force shown on Figure 1-4.

The principal buoyancy is provided in an exterior near toroidal shaped ring beam. This ring beam serves three main purposes:

1. It protects the mooring surface of the buoy against vessel impact
2. It serves as the main buoyancy and trim volume in the buoy
3. It provides low-pressure air storage tanks for the rapid ascent system used in the mooring process.

This is shown in more detail in figure 1-5. The ring beam is in the shape of a 12-sided polygon. Each side of the polygon is protected against ship impact by a 2 meter long standard cylindrical ship fender 1400 mm by 700 mm as shown in more detail on Figure 1-6. Later in this section an analysis is presented showing that this level of fendering is sufficient to protect both the ship and the buoy against damaging impact during the mooring and the unmooring processes.

kinetic energy

1.2 Compression Elements

Figure 1-5 also shows the main compression elements between the buoy surface and the vessel hull. These are comprised of a series of Trellex Morse Fender bar units deployed in a radial pattern as shown. Because of the density of fender bars they may for computational purposes be treated as a continuous surface. The force capacity of the fender bars is 54 tonnes or 530 kN per meter. There are a total of 360 meters of fender bars on the buoy surface. The total theoretical capacity of these units are to resist a total compressive force of 191,000 kN (19,500 tonnes). The maximum possible compression is obtained when absolute vacuum exists above the buoy while submerged to its deepest submergence. The area within the outer seal ring is 346 m².

In the case that the pressure above the buoy is 0 absolute the differential load is 35 tonnes/m² resulting in a total load of 12,100 tonnes. The mooring load is at most applied 8 meters below the fender surface. Assume 600 tonnes; then the resulting moment is 4800 tonnes meters. The fendering circle ring has an OD of 18.5 m and an ID of 10.5 m. The section modulus of this ring is $\pi/32 \cdot (18.5^3 - 10.5^3) = 508 \text{ m}^3$. The resulting pressure differential is $4800/508 = 9.45 \text{ tonnes/m}^2$. The allowable is the difference between the stress resulting from 12,100 tonnes and 19,500 tonnes or 21.4 tonnes per m².

This margin is required to cope with the ship's bottom being out plane. The total allowable stress is $19,500/346 = 56.4 \text{ tonnes/m}^2$. The allowable margin is $21.4 - 9.45 = 11.9 \text{ tonnes/m}^2$ or 21 % of the fully allowed deflection. Since the allowable deflection is 150 mm the system can cope with $2 \cdot 0.21 \cdot 150 = 63 \text{ mm}$ out plane deviation within the mooring area. Note, however, that from a practical point of view significantly higher out of plane deviation would at most cause some minor damage to the fender bars, and this only in the event that full vacuum, maximum submergence and full horizontal mooring force all occur simultaneously.

horizontal mooring load

1.3 Sealing Units

The sealing units contact the keel plating in the ship and impede the flow of water from the sea to the volume in which the low pressure is maintained. There are two annular seals an inner and an outer as for example illustrated in Figure 2 in the Brief Overview.

Because ^{the pumps} the pressure is maintained low above the buoy through continuous removal of water the seals need not be perfect. Rather, their function is to impede the water flow sufficiently that the pumps may reliably maintain the ^{low} pressure above the buoy.

Figure 1-6 shows an outer sealing element. This sealing elements must be capable of the following:

- To maintain contact with the hull for all pressure differential ranging from a low 50 kPa to a high of 350 kPa.
- To maintain sealing pressure in the presence of unevenness of the hull.
- To be able to deflect without damage when a maximum impact between the buoy and the vessel deflects the exterior fenders fully.
- To be able to slide on the bottom plating of the vessel without damage.
- To resist safely all possible levels of differential pressure
- To provide the highest practical level of sealing.

A range of materials were investigated and the result was that the steel unit shown on figures 1-6, 1-7, and 1-8 was the only unit that was able to fulfill all criteria. Figure 1-7 shows in more detail how the unit pivots. Figure 1-8 shows the structural make-up of an exterior unit.

^{The structural design is presented in another section of this document}
The sealing units are seated in "boxes" at the edge of the buoy. Each "box" holds one sealing unit. The sealing unit fits loosely in its "box" and is prevented from sliding out by a tab on the underside. The curved surface shown on the top of the unit is bolted on after the unit is placed in the "box". The units are spaced some 25 mm apart along the perimeter. A special Trellex Morse extruded fender is placed in a continuous ring above the units and is bolted onto the unit and is held securely by bolted on angle irons. On the exterior and below the sealing element there is a continuous rubber sheet made from conveyor belting. This rubber sheet seals the gaps between the sealing elements.

The conveyor belting would typically be capable of resisting differential pressures in excess of 1000 kPa in this application. Thus there is no issue with the structural strength of the rubber sheet. Both the rubber sheet and the extruded fender will be stretched when the sealing ring is depressed. However the stretch is less than 5% well within the capabilities of these elements.

The sealing elements are cantilevered. The purpose of the cantilever is to make it possible for the sealing element to deflect vertically and also to have the hydrostatic pressure differential increase the sealing pressure as the pressure differential increases.

each (and the gap between the hull of the buoy and the sealing element)

26
Figure 1-8 shows the exterior sealing element. The interior sealing element is similar, however, the taper is in the opposite direction. In consequence the "box" design is with parallel sides and the unit also has parallel sides for the part that is placed within the "box"

in prior sec.

A DIVISION OF THE AMERICAN BUREAU OF SHIPPING

16855 NORTHCHASE DR, HOUSTON, TEXAS 77060-6008
TEL: 281-877-6000 FAX: 281-877-6796**TELEFAX MESSAGE**

Page 1 of 11

To:	SUCTION MOORING TECHNOLOGY	Date:	9 July 1999
Attn:	Jens Korsgaard	Fax No:	212 629 4406
		Fax No:	609 936 9373
From:	David Lorenz	Branch code:	86203
File Ref:	1014/DBL/RQ	PID	#
<hr/>			
Subject:	Panama Approval		

Mr. Korsgaard,

Please find attached our proposal for concept evaluation of the hydrostatic mooring.
Also please find attached our terms and conditions.

If you have any questions, please call. I look forward to hearing from you.

Best regards,

David B Lorenz
Principal Engineer
Project Manager
Offshore Engineering Department

*approval in principle/
concept evaluation
what is difference*

specific force 4

fit with

*concept evaluation =
approval in principle
is the same thing.*

PROPOSAL FOR CONCEPT EVALUATION

07/09/99

PROPOSAL FOR CONCEPT EVALUATION OF HYDROSTATIC MOORING FOR SUCTION MOORING TECHNOLOGY

GENERAL

The American Bureau of Shipping (ABS) proposes to conduct a Concept Evaluation for Suction Mooring Technology for their Hydrostatic Mooring System. This evaluation will consist of a Mooring review, buoy structural review, standards review, risk analysis review, and applicable mechanical systems review. A final report will be issued at the completion of the study.

DISCUSSION

The Hydrostatic Mooring system proposed by Suction Mooring Technology is basically an underwater buoy that is raised to a position underneath a ship or barge and is attached and maintained by hydrostatic pressure to the bottom of the hull.

This system can be used to connect a tanker to an underwater pipeline or PLEM in order to transfer water, oil or gas to either the tanker or from the tanker to the shore.

Therefore, in order to evaluate this concept, the following must be reviewed:

1. Mooring System
2. Buoy mechanical and structural components
3. Shipboard mechanical and piping components
4. Control systems
5. Risk review due to potential pollution hazards.

In addition, a list of proposed design standards, such as ASME, ANSI, or others must be listed and evaluated.

SCOPE OF WORK

Mooring Evaluation

The mooring will be evaluated by reviewing the mooring design calculations and two sets of model tests. This review will consist of examining the methodology presented in the calculations, the calculations

*select force
calculate
approx environmental
conditions is OK*

PROPOSAL FOR CONCEPT EVALUATION

07/09/99

themselves for completeness and accuracy, a review of the design loads, and a review of the mooring system for one specific sea-state and vessel.

A report will be written for this work and incorporated into the final report.

Buoy Structural Evaluation

The buoy structural elements will be examined for adequacy against the proposed loads imposed both by the mooring system and by the vessel. The loads will be taken from the mooring analysis and hydrostatic suction loads in both symmetric and non-symmetric loading cases.

This review will be for one specified sea state and one specific vessel (the same that is proposed for the mooring study).

A report will be written for this work and incorporated into the final report.

Mechanical and Control Evaluation

The piping, mechanical and control systems will be reviewed to insure that the capacities and machinery are suitable for their intended use. They will also be reviewed to ensure that they have the capacity to perform adequately in the chosen environmental conditions.

The control system will be reviewed with respect to its logic and components.

A report will be written for this work and incorporated into the final report.

Risk Assessment Evaluation

A risk assessment provided by Suction Mooring Technology will be reviewed to determine the risks associated with the operation of the system. This analysis will be examined to ensure that the risks to personnel, the vessel and buoy and the environment are minimized.

A report will be written for this work and incorporated into the final report.

Page 2 of 5

PROPOSAL FOR CONCEPT EVALUATION

07/09/99

Standards Evaluation

The various standards for the components and the design criteria will be examined to ensure that they are suitable for marine use and are suitable for this application.

A report will be written for this work and incorporated into the final report.

Project Management.

Since the review of this concept cuts across many disciplines and departments within ABS, the project will be assigned a project manager to coordinate these efforts and to make sure that the project is delivered on schedule.

The project manager will also act as liaison with the customer.

SUBMITTAL REQUIREMENTS

The following drawings, drawings and calculations must be submitted to ABS for the work to be completed.

Mooring Evaluation

- Mooring Calculations
- Model Test Reports
- Design Assumptions
- Environmental conditions
- Derivation of loads

Buoy Structural Evaluation

- Structural Drawings and Plans
- Structural calculations, including derivation of loads

Mechanical and Control Evaluation

- Piping Diagrams
- List of Equipment
- Control Logic description or diagram

PROPOSAL FOR CONCEPT EVALUATION

07/09/99

Risk Assessment Evaluation

Failure Mode and Effect Analysis or other suitable risk assessment technique.

Standards Evaluation

A list of standards (ANSI, ASME, AISC, etc.) to be used in the design and the selection of equipment.

SCHEDULE

The Evaluation will be completed 6 weeks after the delivery of the final documents by Suction Mooring Technology.

COSTS

The following hours will be necessary to complete this project:

TASK	Hours
Mooring Evaluation	60
Buoy Structural Evaluation	40
Mechanical and Control Evaluation	40
Risk Assessment Evaluation	24
Standards Evaluation	Included above
Project Management	10
Final Report	<u>16</u>
TOTAL	190

ABS Fees for these hours will be at a rate of \$105.00 per hour, making the total for the project \$19,950.00.

TERMS

Payment for these services is to be made in two (2) installments. The first payment of 50% of the fee (\$9,975.00) is due upon acceptance of this proposal and prior to the commencement of work. The remainder of the fee must be paid prior to the issuance of the final report.

PROPOSAL FOR CONCEPT EVALUATION

07/09/99

The work described and priced in this proposal includes one submittal only. In the event that re-submittals are required, this work will be additional and billed at the rate of \$105.00 per hour.

The standard ABS Terms and conditions are attached.

TERMS AND CONDITIONS

1. ABS SERVICES

- a) The work shall be performed solely under the terms and conditions of this Agreement, and any printed terms or conditions found in other documents used to implement this Agreement shall be void and shall not affect or extend any rights or obligations under this Agreement nor create any new rights or obligations.
- b) In performance of this Agreement, ABS shall be and remain, at all times, an independent contractor and neither ABS nor any of its officers, employees, servants, agents or subcontractors shall be or act as the employee, servant or agent of any other party hereto in its performance of any of the terms and conditions of this Agreement.
- c) All work performed on behalf of flag administrations shall be governed by the terms and conditions of this Agreement unless the flag administration specifies otherwise.
- d) Client shall verify to ABS that the materials and components intended for classification or certification meet the requirements of the Rules by producing certificates for such materials and components.
- e) If any part of the vessel's construction is subcontracted Client shall provide ABS with the names of the subcontractor(s), and address of the subcontractor's site(s), and shall provide the subcontractors with correct and adequate information regarding ABS requirements and any statutory requirements. ABS shall be entitled to rely on certificates provided by such subcontractors as it would rely on Client's certificates. Client stands surety for the acts and debts of its subcontractors. The cost of services at a subcontractor are in addition to those stated in section 3a), and will be billed directly to the subcontractor.

2. PAYMENT CONDITIONS

- a) Fees are to be paid in two installments as described in the proposal, unless alternate arrangements have been agreed upon by both the Client and ABS.
- b) Unless otherwise directed by American Bureau of Shipping, all fees are to be remitted upon receipt of invoice in U. S. Dollars to American Bureau of Shipping, P.O. Box 201614, Houston, Texas 77216-1614 U.S.A. by check and shall refer to the ABS issued invoice number. Wire transfers may be made through Texas Commerce Bank, Houston, Texas 77252-8025 U.S.A., account number 0010-088-8180.
- c) Unless otherwise provided by Agreement or prohibited or restricted by law, interest will be charged at a rate of 1 1/2% per month on any amounts not paid within 30 days from invoice date.
- d) The Client shall be liable to ABS for the payment of all charges including but not limited to court costs, expenses and reasonable attorney's fees incurred in collecting sums due ABS, and ABS may take judgment for the entire amount due. Payment to anyone other than ABS or its authorized agent shall not be deemed payment and shall be made at payor's sole risk.

TERMS AND CONDITIONS

3. DEFAULT

In the event of a default in the payment of any fees assessed in accordance with this Agreement, ABS shall have the right to terminate this Agreement and cease work, as well as all plans, drawings, specifications, information and reports in possession of ABS, shall be subject to a lien for the payment of all fees and expenses due and owing by virtue of this Agreement and the termination or default hereof.

4. ASSIGNMENT & SALE

Any attempt to subcontract, assign, delegate, sublet or transfer this Agreement without prior written notice to ABS shall at ABS's option render this Agreement void. ABS may deem the classification of any vessel canceled upon the vessel's sale or transfer without prior written notice to ABS.

If Client shall breach any provision hereof or shall become insolvent, enter voluntary or involuntary bankruptcy or receivership proceedings, or make an assignment for the benefit of creditors, or should the vessel be arrested or sold at auction or at a Marshall's sale ABS shall have the right (without limiting any other rights or remedies which it may have hereunder or by operation of law) to terminate this Agreement, whereupon ABS shall be relieved of any and all further obligation hereunder and Client shall be liable to ABS for all resulting damages. ABS's right to require strict performance of any obligation hereunder shall not be affected by any previous waiver, forbearance or course of dealing.

5. CONFIDENTIALITY

Subject to sections 3 and 4 hereof, all plans, drawings, specifications and information given to and reports prepared by ABS in connection with performance under this Agreement shall be treated as confidential by ABS and shall not be used for any other purposes than those for which furnished without prior written consent, except as required by judicial order, governmental order or regulation, by subpoena or by direction of a governmental agency with subpoena power.

By signing this Agreement Client authorizes ABS to disclose to future owners, if any, the design assumptions on which classification was based and, in accordance with the IACS Transfer of Class Agreement, to provide future classification societies, if any, with any information, plans or calculations reasonably requested in connection with their classification duties.

5. ACCESS

ABS, its officers, employees, servants, agents or subcontractors shall have access to all drawings, plans, records, other items necessary to complete the requested services

Client shall provide ABS with the following documentation before issuance of a full-term classification certificate:

- a) Plans and calculations required by the Proposal

TERMS AND CONDITIONS

7. NON-WAIVER AND SEVERABILITY

No waiver by either party of any breach of any of the terms of this Agreement shall be construed as a waiver of any subsequent breach, whether of the same or of any other term hereof. If a provision of this Agreement is held invalid all valid provisions that are severable from the invalid provision remain in effect.

8. FORCE MAJEURE

Upon prompt notification of the other party by fax, telex or letter communication, neither party hereto shall be liable to the other for default or delay in performing its obligations hereunder if such default or delay is caused by fire, strike, riot, war, act of God, delay of carriers, governmental order or regulations and/or any other similar or different occurrence beyond the reasonable control of the party so defaulting or delaying, except that cancellation for such causes may not be made without reimbursement to ABS for expenditures actually incurred for labor and materials upon the authority of this Agreement prior to receipt of such notice.

9. TERM

This Agreement shall remain in force until terminated pursuant to the terms of this Agreement or by either Client or ABS upon thirty days' prior written notice.

10. RESPONSIBILITY AND LIABILITY

It is understood and agreed that any report, statement, notation of plan review or certificate (hereafter referred to collectively as "certificate") issued as part of the services rendered under this Agreement is a representation solely to the signatory to this Agreement and only that at the time of survey the vessel, structure, item of material, equipment or machinery or any other item covered by a certificate has met one or more of the Rules or standards of American Bureau of Shipping and is issued solely for the use of ABS, its committees, clients or other authorized entities. ABS is not an insurer or guarantor of the integrity or safety of a vessel or of any of its equipment or machinery. The validity, applicability and interpretation of a certificate issued under the terms of or in contemplation of this Agreement is governed by the Rules and standards of American Bureau of Shipping who shall remain the sole judge thereof. Nothing contained herein or in such a certificate or in any report issued in contemplation of such a certificate shall be deemed to relieve any designer, builder, owner, manufacturer, seller, supplier, repairer, operator, insurer or other entity of any duty to inspect or any other duty or warranty express or implied. Except for such entity, nothing in this Agreement or in any certificate or report issued under this Agreement shall be deemed to create any interest, right, claim or benefit in any insurer or other third party. It is understood and agreed that nothing expressed herein is intended or shall be construed to give any person, firm or corporation, other than the signatories hereto and any identified "Owner", any right, remedy or claim hereunder or under any provisions herein contained; all provisions hereof are for the sole and exclusive benefit of the parties hereto.

11. LIMITATION

ABS MAKES NO REPRESENTATIONS BEYOND THOSE CONTAINED IN SECTIONS 1 AND 11 HEREOF REGARDING ITS REPORTS, STATEMENTS, PLAN REVIEW, SURVEYS, CERTIFICATES OR OTHER SERVICES.

TERMS AND CONDITIONS

12. HOLD HARMLESS

The party requesting services hereunder, or his assignee or successor in interest, agrees to release ABS and to indemnify and hold harmless ABS from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, to persons and/or property, tangible, intangible or otherwise which may be brought against ABS incidental to, arising out of or in connection with this Agreement, the work to be done, services to be performed or material to be furnished hereunder, except for those claims caused solely and completely by the negligence of ABS, its agents, employees, officers, directors or subcontractors. The parties agree that for the purposes of the Convention on Limitation of Liability for Maritime Claims, 1976, ABS is a person for whose acts the shipowner is responsible.

Any other individual, corporation, partnership or other entity who is a party hereto or who in any way participates in, is engaged in connection with or is a beneficiary of, any portion of the services described herein shall also release ABS and shall indemnify and hold ABS harmless from and against all claims, demands, lawsuits or actions for damages, including legal fees, to persons and/or property, tangible, intangible or otherwise, which may be brought against ABS by any person or entity as a result of the services performed pursuant to this Agreement, except for those claims caused solely and completely by the negligence of ABS, its agents, employees, officers, directors or subcontractors. Said individual or party shall assert no claims, directly or indirectly, against ABS.

13. ARBITRATION

Any and all differences and disputes of whatsoever nature arising out of this Agreement shall be put to arbitration in the City of New York pursuant to the laws relating to arbitration there in force, before a board of three persons, consisting of one arbitrator to be appointed by ABS, one by Client, and one by the two so chosen. The decision of any two of the three on any point or points shall be final. Until such time as the arbitrators finally close the hearings either party shall have the right by written notice served on the arbitrators and on an officer of the other party to specify further disputes or differences under this Agreement for hearing and determination. The arbitration is to be conducted in accordance with the rules of the Society of Maritime Arbitrators, Inc. The arbitrators may grant any relief other than punitive damages which they, or a majority of them, deem just and equitable and within the scope of the Agreement of the parties, including, but not limited to, specific performance. Awards made in pursuance to this clause may include costs including a reasonable allowance for attorney's fees and judgment may be entered upon any award made hereunder in any court having jurisdiction. ABS and Client hereby mutually waive any and all claims to punitive damages in any forum.

Client shall be required to notify ABS within thirty (30) days of the commencement of any arbitration between it and third parties which may concern ABS's work in connection with this Agreement and shall afford ABS an opportunity, at ABS's sole option, to participate in the arbitration.

14. TIME BAR TO LEGAL ACTION

Any statutes of limitation notwithstanding, Client expressly agrees that its right to bring or to assert against ABS any and all claims, demands or proceedings whether in arbitration or otherwise shall be waived unless (a) notice is received by ABS within ninety (90) days after Client had notice of or should reasonably have been expected to have had notice of the basis for such claims; and (b) arbitration or legal proceedings, if any, based on such claims or demands of whatever nature are commenced within one (1) year of the date of such notice to ABS.

TERMS AND CONDITIONS

15. LIMITATION OF LIABILITY

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Appendix G

EVALUATION OF THE MOORING BY THE NAVIGATOR, CAPTAIN JAMES ATKINSON

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12 February 1999

Mr. Jens Korsgaard
President
Suction Mooring Technology
318 North Post Road
Princeton Junction, NJ 08550

Dear Mr. Korsgaard:

The week I just spent running simulated mooring approaches to your suction mooring system in the ship maneuvering simulator at Nichols Advanced Marine was challenging, stimulating, and a very satisfying learning experience. I am impressed with your concept and with how you have attacked its various aspects, and I could not help becoming excited by the potential that it offers for liquid or gas transfer in exposed marine locations, even under harsh conditions.

The past week of simulations convinced me that a tanker can be positioned very closely over the submerged buoy under any combination of winds up to about 50 knots, waves up to 8 meters of significant height, and currents up to two knots. Indeed, I found little difference between 40 and 50 knots of wind, and see no reason why currents higher than two knots cannot be coped with without much difficulty.

The concept that I used most of last week is one I developed specifically for your moorings; I call it the balance-of-forces concept. It depends upon having an omnidirectional thruster of sufficient thrust at the bow, which your selection of the Elliott White Gill thruster fulfills, and the fact that your mooring does not restrain the ship to any particular orientation, during the mating process, or once moored.

The balance-of-forces concept includes achieving a balance of forces between currents, on one hand, and wind and waves, on the other, when they are not from the same direction; between propeller thrust and bow thruster; between propeller thrust and a combination of bow thruster and the axial components of environmental forces; and between propeller-and-rudder and bow thruster vectors. Once an equilibrium heading is established, where the lateral components of current on one side are about equal to the lateral components of winds and waves on the other, with the ship at or near zero groundspeed, but with bow thruster at or near 180°, balanced against propeller thrust, permitting sufficient propeller thrust for effective steering, very small imbalances in lateral forces are used to move the ship to port or starboard, achieved by

very small heading changes; while very small imbalances in axial force, achieved mostly by small changes in thruster force, are used to move the ship very slowly ahead or astern. When all the environmental forces are from the same direction, propeller thrust is balanced against the environmental forces, plus added thruster force, applied to permit greater propeller thrust for improved steering, and to permit very slow fore-and-aft movement, mostly by varying the thruster force. When there are little or no environmental forces, thruster vectors are worked against propeller and rudder for all movements until stopped, with the moon pool very close to the buoy; thence one can either continue that scheme until mated, or simply stop and use the bow thruster to pull the moon pool over the buoy, with no regard for orientation.

This is the concept. To apply it requires a little practice in several specific tactics, and that is how I spent most of last week. To apply the tactics, I found it useful, first, to work out in my mind the precepts of shiphandling fundamentals that seemed applicable, in one way or another, to this maneuvering concept. Because it is virtually impossible to perform calculations while shiphandling—a high-stress occupation by any measure—I also found it helpful to have at hand a few simple reference tables, to help me in positioning the moon pool and in determining the precise moment to press the buoy-release button.

Since my involvement began, I have been developing a sort of manual for shiphandlers, including the concept, the relevant precepts, and the reference materials that seem to be useful. Initially, this document is for my own reference and review; it will be expanded to include diagrams that can be used to indoctrinate others into the use of this maneuvering concept, and the mating process. I will add a few approach plans, to assist in the deceleration process for straightforward approaches, or in approaches where there may be geographical or navigational restrictions of one sort or another. This document could constitute the basis for site-specific or ship-specific maneuvering manuals, should the need arise for such manuals.

In the course of last week, I managed to experiment with most of the tactics that I had in mind for the balance-of-forces concept, but not all. On the final day, Friday, I did begin to shorten up the approaches, by starting a bit closer in and decelerating more rapidly. I also took one opportunity to try moving the ship more quickly sideways, by using thruster vectors angled aft and to port, opposed to ahead propeller thrust and a hard-right rudder. It worked very well, but I need more practice with it, not only for moving the ship sideways while holding a heading, but for stopping that movement by reversing those angles of force.

Early on, we found that a 15-tonne thruster is not strong enough for the candidate 150,000-dwt ship, as ballasted, but that a 20-tonne thruster is sufficient. I also found that the minimal rudder rate of the candidate tanker, 2.4° per second (the least allowed by the classification society), and the standard rudder, do not provide the steering response or rudder authority that is needed, and their lack costs considerable time in the final positioning. To double the rudder rate is not usually a very costly provision. For more rudder force, a high-lift rudder is needed. A flap-rudder, such as the Becker system, or a Schilling rudder would seem to be a good choice.

available for all but the first two runs on Friday, and I believe they helped me significantly. That day, I missed the mark on the first run; the remaining seven fell inside the 2.5 meter radius, but not all on the first try. I believe a couple took three releases.

The experience of the four days of meaningful simulation convinced me that it is extremely difficult to make a proper mating when the larger waves of the wave spectrum are at play. It is much better to wait for the smaller waves, which require that the moon pool be in the proper place when they occur. Sometimes that takes a few minutes. And this is what is wrong with simply steering to pass over the buoy while the ship is moving ahead; you just have to be lucky and miss the larger waves as you move across, if fairly large waves are in effect. Otherwise, the approach is missed. But that tactic can be used in smooth seas.

On Friday, I also experimented with the use of thruster vectors in various directions while moving the moon pool over the buoy for the mating. I found that, with the autopilot set for a heading that would keep the rudder hard-over in one direction, and with a propeller thrust that was very nearly in balance with the external forces, I could use thruster vectors both for fore-and-aft and lateral movement, keeping the axial speed at or near zero by using thruster angles a little ahead or aft of abeam. But I also found that as the wave heights and their energies vary over the wave spectrum, the ship accelerates both ahead and astern, sometimes too much to control by the thruster alone, so it is sometimes necessary to use propeller changes. In large waves, I found considerable power changes useful, even necessary, if time is to be saved.

In waves of any appreciable size, because of the accelerations, both negative and positive, I found that equilibrium is not possible, so one has to settle for near-equilibrium balances, which also work. But that is reality.

Another thing I experimented with on the last day or two was to initiate the approach up-wind/up-wave, rather than up-current. What led me to do this was, first, the thought that this would require less turning during the final phase of the approach, and, second, that this approach would hold the wind and waves at a smaller angle to the bow, which would reduce the tendency for the wind and waves to take over the steering, providing better steering at slower speeds in high winds and large waves. It had become clear that in currents of no more than two knots, the ship, at or near an equilibrium heading in high wind and waves, would be pointing considerably closer to the wind and waves than to the current.

I found out very quickly that I could not steer adequately and at the same time take care of conning the ship and all that that entails. Not having a human helmsman, I had to rely upon the autopilot, and that worked out reasonably well. It might have worked a little better had I been able to apply response tuning to the autopilot, as one normally can do with most autopilots.

The simulator operators were understandably reluctant to tweak the autopilot, as they had no knobs on the console for that purpose.

I learned a good deal in a week. But I do not feel I have exhausted the learning experience. Nevertheless, we did quite enough to convince me that the candidate ship, with a 20-tonne omnidirectional bow thruster, can be mated with the suction mooring under all the conditions we simulated. With improved steering, it could be done more efficiently. Smaller ships might be more problematical, as they tend to be more lively in movement in a seaway. Mass may be a problem for shiphandling, and it is, but it also has some advantages too.

Each site and choice of shuttle tanker needs to be simulated, to determine the design features related to navigation, maneuvering and mating with the buoy. Once the shuttle tanker has been simulated and its maneuvering characteristics determined, the first masters should be indoctrinated into the maneuvering concept and mating process, utilizing a simulator. This should involve discussions, aided by diagrams, and simulations. To save on simulator time, a day or two of discussion should precede the simulator exercises. Then the simulator exercises should be coached, with debriefings after each run. If I am to do the training, I would work up discussion guidelines and talking points. It might be a good idea to allow an extra day for the first such session, to provide some extra time as the instruction scheme is refined for future use. Eventually, I now believe, about five days will suffice, the first day being committed to discussion of precepts and tactics, and possibly an introduction to the simulator, followed by four days of simulation exercises, with a debriefing after each run.

In summary, the approaches and mating are clearly feasible. The concept uses fundamental shiphandling principles, but in a different way than one usually uses them in port, or than is dealt with in the texts. But it all is learnable, and the Nichols simulator is an excellent device for the requisite training.

Again, I enjoyed the challenge of this project. For your suction mooring system concept, I believe its time has come.

Sincerely,

James A. Atkinson

Appendix H

OFFSHORE TECHNOLOGY CONFERENCE
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THE SUCTION MOORING, A NEW TYPE OF OFFSHORE SINGLE POINT MOORING

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ABSTRACT

Existing systems for mooring offshore oil production vessels of the ship type only permit the mooring or tying up of the vessel in quite low wave conditions. Virtually all existing systems do not permit the vessel to moor in wave conditions exceeding $H_s = 4.5$ m. Most systems require wave heights smaller yet to moor. This is a problem in cases where frequent mooring operations are required such as for shuttle tankers and for disconnectable oil production or storage vessels moored in areas with a high incidence of tropical storms. The wait for the waves to subside following the storm causes additional production losses due to the oil field being shut in.

A newly developed mooring system, the suction mooring, promises to overcome this problem by permitting the mooring of the vessels in wave heights to at least $H_s = 8$ m. The principle of the mooring consists of using the hydrostatic pressure available at the keel of the vessel to press a mooring buoy onto the bottom and holding the vessel by the resulting friction. The action of the mooring buoy is similar to that of a suction cup.

The pressure above the buoy is lowered and maintained low by means of pumps aboard the vessel.

This paper reports on model tests carried out to prove the feasibility of conducting the mooring operations in high waves. Three different configurations of the mooring buoy were tested. For two of the configurations it was found that the mooring process could be carried out safely in all wave heights tested i.e. up to $H_s = 7.7$ m.

The impact upon offshore operations of this capability was investigated by performing Monte Carlo simulations on a hypothetical oil field in the center North Sea and in the northern North Sea. An actual center North Sea wave record was used in the simulations.

The suction mooring system was compared to two other high performance mooring systems. The results show that weather related oil field shut-ins are reduced an order of magnitude by application of the suction mooring compared to the other systems simulated.

References, nomenclature, and figures at end of paper.

MOORING PRINCIPLE

The suction mooring principle involves mooring a submersible buoy to the bottom of a vessel utilizing differential hydrostatic pressure, in a manner similar to a suction cup.

A mooring buoy is brought into contact with the flat portion of the bottom of the ship either by means of a retrieval line such as commonly used for the Buoyant Turret Mooring (BTM) and Submerged Turret Loading (STL) type mooring or by means of reduced buoyancy utilizing a system aboard the buoy to control the buoyancy.

The reduction in hydrostatic pressure above the buoy is provided by pumps aboard the ship. A bowthruster pump of the Omni-thruster or the Elliott Turbo Machinery type having its intake at the keel in the mooring area is used to achieve the initial pressure reductions. This type of pump has a capacity from 4 to 11 m³/sec. When the buoy comes into contact with the keel of the vessel, it blocks the thruster pump intake. This lowers the pressure above the buoy and is causing the buoy to be pressed against the bottom of the vessel.

As illustrated on Figure 1, the top surface of the buoy is equipped with fenders and seals which prevent damaging impacts between the buoy and the vessel. After contact has been achieved, the seals limit the leakage of water to the top of the buoy to acceptably low values. The leakage rate following the mooring is two orders of magnitude less than the flow rate required to make the initial contact between the buoy and the vessel. This allows the bow thruster pump to be stopped after the mooring has been achieved and the leakage is removed using only pressure maintenance pumps.

A typical buoy has a circular upper surface with a diameter of approximately 20 m. Differential pressures of 100 to 200 kPa are normally achievable, resulting in a vertical attractive force between the buoy and the vessel of 30,000 to 60,000 kN.

The horizontal mooring forces between the buoy and the vessel are then resisted by the friction between the buoy and the bottom of the ship. Horizontal forces in excess of 10,000 kN may be resisted by this system.

APPLICATIONS OF THE MOORING SYSTEM

The mooring system is applicable to ship type vessels engaged in offshore petroleum production such as floating production, storage, and offloading vessels (FPSO), floating storage and offloading vessels (FSO), and shuttle tankers engaged in transporting the crude oil ashore.

It is also expected that the system will be applicable to the ordinary maritime transportation of crude oil and refined products employing single point moorings.

MODEL TESTS

The new mooring system is presently under development and has in the development period being considered for several offshore fields. Specific designs were developed for an FSO for the conditions offshore Liverpool in Liverpool Bay in the UK. As part of this design process, model tests were carried out at the Danish Maritime Institute in Lyngby, Denmark to assess the feasibility of mooring the FSO to a buoy based on the suction mooring principle.

The FSO was a 125,000 dwt vessel which had not been selected. The model tests were carried out for a generic 125,000 dwt tanker with the properties listed in Table 1.

TABLE 1
VESSEL PARTICULARS

		Loading Condition	
		<u>Loaded</u>	<u>Ballasted</u>
Displacement	(m ³)	149,000	59,600
L _{pp}	(m)	258.3	
B	(m)	40.6	
Depth	(m)	21.9	
Draft fore	(m)	16.5	5.95
Draft aft	(m)	16.5	7.95

The tests were carried out for two loading conditions. Namely, a fully loaded vessel and a ballasted vessel with a displacement of 0.4 times the fully loaded displacement.

The tests had two objectives:

- To test the feasibility of mooring operations in extreme wave conditions using the suction mooring principle.
- To test a mooring in which the mooring legs were partially made up from synthetic rope instead of wire rope or chain.

The latter was necessary because of the shallow depth of 30 m which did not permit the application of chain and wire rope catenaries. If the mooring system had been comprised entirely of wire rope and chain, sufficient resiliency was not obtainable without the application of buoys and sinkers in each mooring leg to enhance the elasticity of the mooring leg. The application of buoys and sinkers would cause navigational problems in the area due to the danger of the submerged buoys coming into contact with the ship's hull.

Only the tests performed for the first objective, determining the feasibility of the mooring operations, are reported in this paper.

TEST SET UP

The tests were conducted in the towing tank at the Danish Maritime Institute as shown in Figure 2.

The tests involved the testing of vessels subjected to combined wave, current, and wind. Due to limitations in the test set up, only co-linear actions of these forces were considered. Wind and waves always acted in the same direction whereas currents acted either opposite to or in the same direction as the wind. The site has very high tidal currents and therefore the vessel would frequently be subjected to the winds and waves going in one direction and the currents going in the opposite direction.

In the test set up, this was emulated by having the carriage travel through the towing tank at the appropriate speed either toward or away from the wave maker.

The tests were conducted in a scale of 1:50. The towing tank has a water depth of 5.3 m. This would correspond to a prototype water depth of 265 m. Therefore, in order to conduct the tests at the shallow water depth at the test site of 30 m, a false floor was erected underneath the towing carriage as shown on Figure 2.

The leading and trailing edges of the false floor represent abrupt depth change in the model. This caused problems in modeling the waves because the waves hitting the leading edge of the false floor was partially reflected from the edge. The same also took place at the trailing edge. It was, therefore, necessary to experiment with the setting of wave generator in order to obtain the appropriate spectrum in the test area.

The wave conditions used are shown below in Table 2.

TABLE 2
TEST WAVE CONDITIONS

ID	H _s (m)	T _z (sec)	T _p (sec)
A	6.6	10.1	12.1
B	7.7	13.1	13.6
C	5.6	9.3	8.7*
D	5.0	8.9	9.1
E	4.7	8.0	8.8
F	4.1	7.7	8.6

*Secondary peak at 12.0 sec.

The wave maker was initially programmed to make a Jonswap spectrum with a γ factor of 3.3. However, due to the distortions taking place at the leading and trailing edges of the false floor, the wave maker was ultimately programmed to generate waves which caused the best obtainable wave spectrum at the vessel.

The model tests were documented through four video cameras as indicated on Figure 3. In addition, the mooring ropes and the retrieval line were instrumented with strain gages. The wave action was recorded by four wave gages, one at the wave maker, one placed ahead of the test area on the false bottom, and two wave gages placed laterally to the test area on the false bottom. The measurements from all these gages were recorded on a computer with a frequency of 30 hertz and they were synchronized with the video recordings.

Three different buoy configuration were tested. Buoy configuration 1 is shown on Figure 4. This buoy has an upward protruding 1/4 toroidal "cone" to mate with a corresponding female toroidal recess in the vessel. The buoy's toroidal surfaces were protected by ordinary cylindrical dock fenders with a diameter of 1 m mounted vertically. The exterior fender seal element on the buoy serves as a seal after mooring and protects against impact during the mooring process. This was also a circular cylindrical fender with a diameter of 1 m. The elasticity of the fendering elements as not represented in the model. Rather the exterior fender was represented by a rubber hose having a diameter equal to that of a compressed fender/seal element. The upward protruding "cone" was not equipped with any fender elements in the model. This buoy configuration was equipped with a retrieval line. The buoy was mated with the vessel by pulling on the retrieval line from the deck of the vessel with a constant force of 981 kN.

The dock fenders used were Bridgestone cylindrical fenders 1,000 mm diam using rubber type R1. The resulting maximum allowable horizontal impact velocity between the cone and the recess was 0.81 m/sec. The maximum allowable vertical impact velocity between the buoy and the vessel depends on the tilt of the buoy at impact. The higher the tilt the smaller a portion of the fender would be engaged and consequently the allowable impact velocity reduced. The allowable values are stated in Table 3.

TABLE 3
ALLOWABLE IMPACT VELOCITIES

Tilt of Buoy	Allowable Vertical Impact Velocity m/sec
0.05	2.4
0.10	1.95
0.15	1.55
0.20	1.30
0.25	1.18

The second configuration of the buoy was a flat top buoy equipped with an exterior fender/seal element at a radius of 10 m from the axis of symmetry similar to buoy configuration 1. This buoy is illustrated on Figure 5. This buoy was also brought into contact with the vessel by means of a retrieval line pulled in by a constant tension winch on the deck of the vessel. The retrieval force in this case was also 981 kN.

The third configuration of the buoy, shown on Figure 6, was equal to the second configuration with the exception that the buoy was not fitted with any retrieval line. Rather the buoy contained an internal buoyancy tank which during the mooring process was filled with air thereby increasing the buoyancy of the buoy causing it to rise in the water to contact the bottom of the vessel. This retrieval system requires that the vessel be navigated in such a manner that the buoy is properly positioned relative to the vessel during the mating. The positioning system was emulated in the model by two elastic ropes which were controlled by a technician during the test. In this manner, the navigation of the vessel was emulated, however, no attempts were made to make the emulation conform to any particular bow thruster/propulsion system performance.

The configuration 3 buoy is equipped with internal buoyancy chambers. The chambers were made with a larger than specified diameter during the manufacture of the model buoy. Therefore, the buoy had a lower than intended metacentric height. It was intended that the metacentric height for the buoys with configurations 2 and 3 would be approximately equal. The actual

metacentric height of the configuration 3 buoy was very close to zero. Therefore, during the tests, the buoy exhibited somewhat unstable behavior. Nevertheless, as can be seen from the results mooring and unmooring of the configuration 3 buoy never resulted in impacts between the buoy and the vessel exceeding the capacity of the exterior fender.

The means of creating the suction on the vessels was in the model two positive displacement pumps pumping from a moon pool at a rate of $4.5 \text{ m}^3/\text{sec}$. A cross section of the moon pool located 40 m aft of the forward perpendicular and the emulation of the constant tension retrieval winch is shown on Figure 7. Note that the pump intake is located nearly flush with the bottom of the vessel, therefore, when the pumps start sucking air, the space between the buoy and the vessel is still water filled. Atmospheric air has free access to the mooring area. Therefore, in the model, the lowest possible differential hydrostatic pressure on the buoy is equal to the head from the draft of the vessel. In the prototype the mooring recess area will be closed to the access of atmospheric air. Therefore, in the prototype higher differential pressures can be obtained than in the model.

MODEL TEST RESULTS

The model tests were made for two purposes.

- Assess the forces in the elastomeric mooring arrangement.
- Assess the feasibility of the mooring and unmooring process in high waves.

Only the second part is reported in this paper. A total of 83 mooring and unmoorings were performed with the ballasted vessel in the model. These were distributed among the three different buoy configurations and the various wave heights tested in the model as indicated below in Table 4.

TABLE 4
IMPACTS DURING
MOORING AND UNMOORING

Buoy Type	H_s m	No. of Tests	Max. Impact % of Allowable
1	6.6	5	258
1	5.0	6	<20
1	4.7	6	195
1	4.7	4	75
1	4.1	7	123
2	6.6	8	24
2	5.0	7	11
2	4.7	7	6
3	7.7	4	58
3	6.6	4	<10
3	6.6	4	20
3	5.0	5	10
3	5.0	5	65
3	4.7	4	<10
3	4.7	3	38
3	4.1	4	5

The impacts between the buoy and the vessel were analyzed by studying the underwater video recordings frame by frame and determining the tilt and position of the buoy in each frame. The vessel model was equipped with a characteristic mark on the side of the vessel enabling the continuous determination of the relative position between the vessel and the buoy.

By analyzing the frames on the video recording, it is possible to determine the relative velocity between the buoy and the vessel with a tolerance of approximately 20 percent. This tolerance translates into a tolerance of 40 percent on the recorded energies. The most important results from these tests is that the buoy with the upward protruding toroidal mating cone suffered damaging impacts for most wave heights tested, i.e., $H_s = 4.1 \text{ m}$ to $H_s = 6.6 \text{ m}$. The model buoy with a flat top surface retrieved by a retrieval line in no instance had impacts above 25 percent of the allowable impacts for the selected fender. The configuration 3 buoy was raised with compressed air. This buoy had despite the low metacentric height in all cases smaller than allowable impact between the buoy and the vessel. In the extreme case of $H_s = 7.7 \text{ m}$, an impact of up to 58 percent of the allowable impact

was experienced. Also at a lower wave height of $H_s = 5.0$ m an impact of 65% of the allowable was recorded.

Regardless of the method of retrieval the flattop buoy can safely mate with the vessel for all wave heights tested, i.e., from $H_s = 4.1$ m to $H_s = 7.7$ m. $H_s = 7.7$ m was the highest obtainable wave height in the test set up. It is likely that mooring and unmooring can be performed in substantially higher wave heights than those tested.

The navigation of the vessel to the buoy and the maintenance of the position of the vessel relative to the buoy during the mooring process was not tested in this series of tests. These tests only show that the physical process of bringing the buoy into contact with the vessel and of releasing the buoy upon departure of the vessel can be safely done in the wave heights tested. Whether or not the vessel can maneuver into the proper position in high wave heights depends on the configuration of the vessel propulsion and thruster systems. These systems were not tested in this series of tests.

The conclusion from the tests is that mooring and unmooring of the flat top type suction mooring buoy may safely take place in all wave heights up to at least $H_s = 8$ m.

OPERATIONS ANALYSES

The fact that the suction mooring buoys can moor and unmoor in very high wave heights has implications for the type of operations which may be conducted offshore when planning for FPSO, FSO, and shuttle tanker operations. To examine the implications of this capability a series of Monte Carlo simulations were performed for two hypothetical oil production systems located either in the middle North Sea or in the northern North Sea in more severe environmental conditions. The two hypothetical systems are illustrated on Figures 8 and 9. The first system consists of two buoys connected to an oil field with no storage aboard the production vessel or platform. Two shuttle tankers bring the oil to a port 500 nautical

miles distant. This system is compared with an alternative system with a small storage and one mooring buoy. The operation of the first system is that whenever a shuttle ship arrives it ties up to the idle buoy. At an appropriate moment when the shuttle ship that was receiving the oil is full, the production is switched to the second vessel and the loaded vessel leaves for port.

The suction mooring (SM) system was compared to two other shuttle mooring systems. System 1 (S1), capable of mooring at $H_s = 4.5$ m and of remaining on the mooring up to $H_s = 8$ m. These values have been derived from Reference 1. Reference 1 claims a higher disconnect limit than 8 m. However, the highest wave height at which the vessel can remain moored is also a function of the cost of the mooring system. Therefore, for purposes of this paper a maximum disconnect wave height of 8 m has been selected for all mooring systems that are capable of maintaining the ship moored at that wave height or beyond.

Another shuttle mooring system System 2 (S2) has connect limits of $H_s = 4.5$ m and disconnect limits of $H_s = 6$ m. These values were derived from Reference 2.

The corresponding values for the suction mooring buoy are a connect limit of $H_s = 8$ m and disconnect limit of $H_s = 8$ m. A common feature of all three systems is that petroleum transfer can take place at all wave heights in which the ship can remain moored.

A record of the winds and waves from the central North Sea was obtained for the purpose of making a detailed operations analysis. The record spans a continuous three year period. The record consists of hourly measurements from two different types of wave gages, a waverider type wave gage and a radar wave gage. The measurements from each of the two wave gages were in general agreement. However, at any specific time they might disagree by as much as 25 percent. For purposes of the Monte Carlo simulations, the two records were unified by taking the average value of the two wave

recordings in each hour. At certain times the record from only one of the two wave gages was available. In these instances, the available record was used for the value of the wave height. Small gaps exist in the wave record where both gages did not record any data. For purposes of continuity in the simulation, these gaps were filled in by a straight line interpolation between the last recorded wave height prior to the gap and the first recorded wave height following the gap.

Although the weather record also contains information about the velocity and direction of the wind, this data was not taken into account in order to simplify the simulations. It is, however, recognized that for certain combinations of winds and waves, the wave height limits may be lower than those utilized in the simulation.

The simulations simulated a hypothetical shuttle tanker round trip of 500 nautical miles each way to an oil receiving port some place in the North Sea area. The speed with which the shuttle tanker can transit to and from the receiving port also depends on the weather. During high waves, the speed of the vessel must be either be involuntarily or voluntarily reduced. For the purposes of this paper, it has been assumed that the oil tanker will have speed reduction characteristics similar to the bulk carrier Mineral Sering. The Mineral Sering was a 65,000 dwt bulk carrier for which extensive speed reduction studies were made in the late 1960s. The data reported in reference 3 is the basis for the speed reduction function utilized in the simulations. The speed reduction function is given in Figure 10.

For purposes of the simulation, it was assumed that the vessel was subject to the speed reduction whenever it was within 300 nautical miles of the oil field. The characteristics of the round trip for the vessel is given below in Table 5.

TABLE 5
VESSEL ROUND TRIP

	<u>Time</u>	<u>Speed</u>
Mooring	1.5 H	
Loading	variable*	
Unmooring	0.75 H	
Sail First 300 NM		reduced speed
Next 200 NM		15 knots
Enter port	12 H	
Discharge	variable**	
Leave port	4 H	
First 200 NM		15 knots
Last 300 NM		reduced speed

* Maximum Loading Rate 150,000 bpd.

** Unloading Rate 40,000 bph.

It was assumed that the suction mooring system and Systems 1 and 2 had similar times for hook up and disconnect. While it is believed that the suction mooring system is somewhat faster than the other systems, the same times were assumed for the purpose of having uniform conditions among each of the tested systems in the Monte Carlo simulations.

System 1, System 2, and the suction mooring vessels were treated equally. They were all assumed to have the same rate of transfer between production equipment and the vessel while moored in the oil field and having the same characteristics when delivering the cargo in port.

The actual central North Sea weather record was used in the simulations. No random events were simulated in these simulations. It was assumed that the hypothetical oil field was in production at the beginning of the weather record and had a constant production of 100,000 bpd throughout the three years that the weather record lasted. The results of the simulation were the measurements of the lost production for each of the scenarios simulated. An initial set of simulations was made with the case of having two buoys with no storage at the production facilities, as shown on Figure 8. For this scenario, vessels with a capacity from 350,000 barrels to 500,000 barrels were considered in 25,000 barrel increments.

A second production scenario, shown on Figure 9, was also simulated. This scenario has only one mooring buoy and a small in-line storage between the production equipment and the single point mooring buoy. The storage assumed for these simulations was 15,000 barrels. The range of vessel sizes was the same as for the two-buoy case.

The storage basically permits continuation of the production during the time it takes for the vessel to unmoor and the following vessel to moor and get ready receive the cargo.

Following the initial simulations, a series of simulations was made for the one buoy case using a constant size shuttle vessel of 450,000 barrels but, varying the amount of storage available at the production facilities between 0 and 120,000 barrels in 30,000 barrels increments.

In addition to the actual mid North Sea weather record, a transformed record was made by multiplying all the wave heights by 1.2 and adding .25 m. In this manner, the wave record was transformed in such a way that it acquired the characteristics of a northern North Sea wave record as reported in Reference 4. It is not certain that the transformed record has the proper persistence characteristics. However, for the purposes of the simulations, comparing the performance of the three types of mooring systems, the northern North Sea weather is adequately represented by the artificial wave records so generated.

The wave conditions actually used are stated below in Table 6.

TABLE 6
MID NORTH SEA WAVE STATISTICS

<u>H_s (m)</u>	<u>Frequency</u>
0 - 1	24.06%
1 - 2	36.13%
2 - 3	20.58%
3 - 4	10.97%
4 - 5	4.91%
5 - 6	2.16%
6 - 7	0.73%
7 - 8	0.27%
8 - 9	0.08%
9 - 10	0.06%
10 - 11	0.03%

The northern North Sea waves used are shown in Table 7. Table 7 also shows the wave statistics reported in Reference 4 for the northern North Sea.

TABLE 7
NORTHERN NORTH SEA WAVE STATISTICS

<u>H_s (m)</u>	<u>Frequency Used</u>	<u>Frequency Ref 4</u>
0 - 1	8.29%	8.64%
1 - 2	33.91%	32.16%
2 - 3	25.55%	25.92%
3 - 4	14.93%	15.44%
4 - 5	8.71%	9.12%
5 - 6	4.51%	4.83%
6 - 7	2.35%	2.33%
7 - 8	1.04%	1.03%
8 - 9	0.35%	0.42%
9 - 10	0.22%	0.16%
10 - 11	0.05%	0.06%
11 - 12	0.05%	0.02%
12 - 13	0.02%	0.01%
13 - 14	0.02%	0

SIMULATION MODEL

The simulation model was written in the GPSSH language. A simplified logic diagram of the simulation model is shown on Figure 11.

In contrast to the usual Monte Carlo simulation models, this model had no random variations in it at all. It was based on assuming that the process simulated took place during the period at which the actual weather record utilized was recorded. In consequence, the results are simply the results which would have been obtained had the specific production scenario taken place during the period of record. The results, therefore, do not represent a statistical average but rather the actual outcome of an assumed production scenario taking place over the three years covered by the weather record. The result which was recorded in the model was the lost production due to weather.

Other causes for lost production such as downtime due to maintenance or malfunctioning of the mooring, production difficulties, and downtime or malfunction of shipboard equipment, were not simulated. The results reported in this paper are caused solely by the different mooring limits that each of three mooring systems modeled have.

OPERATIONS ANALYSES RESULTS

The operations analyses were in all cases made on a hypothetical field producing a constant 100,000 bpd oil throughout a three year period.

Figures 12 and 13 show the results from simulation of the case of two mooring buoys, no storage and two shuttle tankers. The only storage, in the system is the shuttle tanker moored to a buoy. The size of the shuttle tankers were varied in 25,000 barrel increments between 350,000 barrels and 500,000 barrels. The results of the center North Sea simulation are shown on Figure 12 and the results from the northern North Sea simulation are shown on Figure 13. In both cases, the lost production when utilizing the suction mooring systems is 20 to 25% of the nearest competing system.

For the case with only one buoy and two shuttle tankers, but with a storage of 15,000 barrels at the oil production facilities, the performance was

somewhat better than for the two buoy case. Figure 14 shows the center North Sea results and Figure 15 shows the northern North Sea results. In this case, the suction mooring has production losses 10 to 20% of the nearest competing system.

The effect of varying the size of the storage was examined for the case of having one buoy and two 450,000 barrel shuttle tankers. The results from center North Sea for as little as 30,000 barrels storage at the oil production facilities, shown on Figure 16, show that the lost production for the suction mooring case is negligible whereas the S1 and S2 systems show losses in the order of 300,000 to 800,000 barrels per year. For the northern North Sea case, shown on Figure 17, a storage at the oil field facilities of 30,000 barrels resulted in the suction mooring system causing losses of approximately 150,000 barrels per year whereas systems 1 and 2 experienced well in excess of 1 million barrels per year losses.

These simulations indicate that in general the lost production due to weather outages could be reduced by approximately one order of magnitude by application of the suction mooring compared to the competing mooring systems simulated.

NOMENCLATURE

bpd	=	Barrels per day
bph	=	Barrels per hour
L_{pp}	=	Length between perpendiculars
B	=	Breadth
H_s	=	Significant wave height
T_z	=	Zero crossing period
T_p	=	Peak period
NM	=	Nautical miles

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Fig. 1 Section of Mooring System

Fig. 2 Test Basin

FIG. 3 Test Set-Up

FIG. 4 Mooring Buoy Configuration 1

Fig. 5 Mooring Buoy Configuration 2

Fig. 6 Mooring Buoy Configuration 3

Fig. 7 Moonpool

FIG. 8 Oil Production Scenario 1

FIG. 9 Oil Production Scenario 2

FIG. 11 Simplified Simulation Model Diagram

Fig 12 Center North Sea -2 Buoys -2 Shuttles -No Storage
Production Loss vs. Shuttle Size

Fig 13 Northern North Sea -2 Buoys -2 Shuttles -No Storage
Production Loss vs. Shuttle Size

Fig 14 Center North Sea -1 Buoy -2 Shuttles -15,000 bbl Storage
Production Loss vs. Shuttle Size

Fig 15 Northern North Sea -1 Buoy -2 Shuttles -15,000 bbl Storage
Production Loss vs. Shuttle Size

Fig 16 Center North Sea -1 Buoy -2 Shuttles (450,000 bbl each)
Production Loss vs. Storage

Fig 17 Northern North Sea -1 Buoy -2 Shuttles (450,000 bbl each)
Production Loss vs. Storage

Appendix I

HYDROSTATIC MOORING BROCHURE

— LVL HORIZONTAL FENDER 1400X700X2000 (TYP.)

— SA 1000Hx2500 (TYP.)

— SA 800Hx1500 (TYP.)

— INNER SEAL LIP

— OUTER SEAL LIP

THE HYDROSTATIC MOORING SYSTEM

A new era in mooring.

R=3000

2700

R=15000

*Suction Mooring Technology
Offshore Mooring Systems*

The Hydrostatic Mooring System

A New Era in Mooring

Maybe once in a lifetime you are

presented with an opportunity that

undeniably and positively impacts

every aspect of your mooring

operations. The Hydrostatic

Mooring System is your passport

to success. Relying on outmoded,

inadequate, limited, dangerous and

expensive mooring systems is

ancient history. And here's why...

What Other Mooring Systems Offer You

- Costly downtime due to weather conditions.
- Retrieval lines and hawsers between the tanker and the mooring device that snag and break.
- Weather-related downtime costing millions of dollars per year.
- Mechanical connectors that fail and delay successful mooring and tanker departure.
- Personnel and vessel hazards such as line handling, tugboats, hawsers, winches and other equipment — elements that are always required to operate current mooring systems.
- The need for special vessel maneuvers during routine and emergency departures.
- The potential for explosions.
- Unproductive, lengthy and dangerous mooring and release time.
- Expensive maintenance vessels.
- The potential for pollution.
- Expensive vessel retrofit and fit-out.

What Will the Hydrostatic Mooring System Offer You

No Matter the Weather

- When the tanker can operate it can moor to the Hydrostatic Mooring System. And operations will not be limited, curtailed or abandoned when sea states reach Hs above 8 meters. Only the Hydrostatic Mooring System is capable of safely and effectively handling tanker mooring in these extremes.
- There is no weather-related downtime typical among competing systems. This unique ability may allow you to recoup the mooring costs within months.

Safety First

- All mooring operations are remotely controlled from the bridge of the tanker.
- The Hydrostatic Mooring System can be safely released under maximum weather stresses.
- Unlike other mooring devices, the Hydrostatic Mooring System presents no risk to passing vessels. Even the deepest draft vessels pass safely over the Hydrostatic Mooring System's resting position.

**Suction Mooring Technology
Offshore Mooring Systems**

- The fluid transfer equipment in a Hydrostatic Mooring System is continually immersed in water mitigating any chance of explosion.
- The Hydrostatic Mooring System is virtually risk free and eliminates hazardous elements.

Lightning Fast Speed

- The speed of the Hydrostatic Mooring System is extraordinary. The entire mooring operation lasts only nine seconds — a key requirement for mooring in extreme wave heights!
- Unmooring lasts only three minutes!
- Obviously, tanker productivity — particularly on short shuttle runs with less than 24 hour sailing time — is unparalleled, due to the Hydrostatic Mooring System's extreme efficiency of operation.

Classification Society Rule Compliance

- The Hydrostatic Mooring System complies with all current Classification Society rules including:
 - The American Bureau of Shipping "Rules for Single Point Moorings," 1996
 - The American Bureau of Shipping "Rules for Underwater Vehicles, Systems, Hyperbaric Facilities," 1990

Unprecedented Performance and Performance Monitoring

- The Hydrostatic Mooring System resides below the surface, below the keel of the deepest draft vessels. Its strategic placement reduces survival condition loads. Yet, the Hydrostatic Mooring System easily surfaces upon command. (See Figure 1)
- All maintenance is done on the surface with light duty vessels.
- Any storm a tanker can weather, the Hydrostatic Mooring System can weather too. Unlike other mooring systems, the Hydrostatic Mooring System continues to operate in the most severe conditions.
- The cost to modify a tanker to accept the Hydrostatic Mooring System is 5 to 10 times less than the modification costs associated with other high performance mooring systems.

Step 1

Step 2

Step 3

Figure 1

Unprecedented Performance and Performance Monitoring Cont'd

- The Hydrostatic Mooring System reduces time on station because it offers the lowest possible hydraulic power consumption in the piping system.
- The Hydrostatic Mooring System has a greater capacity to carry risers than other submerged mooring systems, increasing the range of water depths and riser diameters.
- Monitoring by Differential Geopositional Satellite System (GPS) — automatically warns you of design limit violations as well as immediately revealing any anchoring component failures, allowing you to take action before damage occurs.

Environmental Responsibility

- The Hydrostatic Mooring System isolates fluid couplings from the ocean.
- The Hydrostatic Mooring System maintains a low pressure in the mooring-tanker interface, allowing ocean water to flow toward the mooring preventing leaking fluids from escaping.
- The fluid swivel is located on the tanker further reducing the potential for fluid to escape.

Standard Construction

- The Hydrostatic Mooring System is comprised entirely of proven standard components, readily available from a number of different oil industry suppliers.
- The installation of the Hydrostatic Mooring System is the same as an ordinary single point mooring. The required construction spread depends somewhat on local conditions, but typically involves crane vessels, anchor handling vessels and diving support vessels.

***Suction Mooring Technology
Offshore Mooring Systems***

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