SPE 11173

SPE

Society of Petroleum Engineers of AIME

Installation of the Fulmar SALM and Storage Tanker

by R.H. Gunderson, *Exxon Production Research Co.*; J.G.B. Coombe, *Shell U.K. Exploration & Production*; and P.A. Lunde and C.O. Etheridge, *Ocean Resources Engineering, Inc.*

This paper was presented at the 57th Annual Fall Technical Conference and Exhibition of the Society of Petroleum Engineers of AIME, held in New Orleans, LA, Sept. 26-29, 1982. The material is subject to correction by the author. Permission to copy is restricted to an abstract of not more than 300 words. Write: 6200 N. Central Expressway, P.O. Drawer 64706, Dallas, Texas 75206.

ABSTRACT

The Fulmar Single Anchor Leg Mooring (SALM) permanently moors a converted tanker serving as a Floating Storage Unit (FSU) in the North Sea at Shell/Esso's Fulmar Field. The Fulmar storage and offloading system is the first such system installed in a rough weather area.

The installation of the SALM was unique, not by choice, but because of the requirements imposed by the nature of the system and by the environmental effects on the structure during installation. The SALM is comprised of very large, heavy structural components joined by mechanical articulations and connections. The size and weight necessitated that the connection of the FSU to the buoy be made offshore. The installation of the structure was weather sensitive, requiring the design of numerous "hold points" into the procedure; for instance, the SALM buoy acted temporarily as a gravity structure, being transformed finally into a pile founded structure.

The loadout and installation strained the capacity of both dockside and floating equipment and produced several new world weight records. Novel applications of conventional equipment were used for loadout and transport of the components, for rigging used to make the major offshore lifts and connection between moving assemblies and for the rapid slurry installation of the permanent ballast.

This paper describes the installation procedures along with the corresponding field experience. Data on rigging, lift weights, seastate limitations and schedule are presented for use by those who may be faced with a similar opportunity.

INTRODUCTION

The Fulmar Field development plan emphasized early production. A seafloor template was set on location and several wells drilled that were tied back to a wellhead jacket set over the drilling template. A main jacket supporting the quarters, production and drilling facilities was set alongside and connected to the wellhead jacket by a bridge. The production from these first wells will generate revenue while the remaining wells are being drilled from the main platform and bring the production up to full capacity earlier in the life of the field. Production flows through a 16 inch pipeline from the platform to the storage tanker (FSU) moored to the SALM[1] located 2.3 km (1.4 mi.) away (Figure 1). The produced oil is stored on board until it is offloaded to shuttle tankers which moor in tandem astern the FSU. The total development cost of the Fulmar Field will be approximately £580 M. The total installed cost of the SALM and FSU are £27 M and £42 M, respectively.

The installation of the Fulmar SALM buoy and base was accomplished using a large semisubmersible crane barge fitted with two revolving cranes - the "HERMOD" owned by Heerema Offshore Contractors. At one time during the design phase an alternate method of a self-floating vertical tow of the buoy and base was considered. This entailed some risk if a summer storm developed when the buoy was towed in less than the Fulmar site depth of 80 m (280 ft.). Also, because the "HERMOD" (or its sister ship, the "BALDER") was to be used on the Fulmar platform installation and a heavy lift crane was required for the attachment of the tanker to the buoy, the HERMOD was selected for the SALM installation as well.

The "HERMOD" is equipped with one 3000 short ton (2700 tonnes) revolving crane and one 2000 short ton (1800 tonnes) revolving crane both mounted on the stern of the vessel. Both cranes were utilized in lifting the 3100 tonne (3400 short ton) SALM off the transport barge. This is the heaviest offshore lift that has been done. Only the 3000 short ton crane was used for the 1090 tonne (1200 short ton) lift to connect the rigid arm to the buoy.

This paper describes the installation of the Fulmar SALM and FSU. Dates of key events are indicated in Table 1. A general description of the configuration and operation of the SALM and FSU is also given.

SALM DESCRIPTION

The SALM was designed by Exxon Production Research Company and Ocean Resources Engineering, Inc. and constructed by Rhine-Schelde-Verolme at The Rotterdam Dockyard Company (RDM Yard). The primary components of the Fulmar SALM (Figure 2) are the buoy, rigid arm, base, and the mechanical articulations that connect them. The buoy provides the restoring force to moor the FSU, supports the rigid arm, and contains the pipeline riser. The rigid arm connects the bow of the FSU to the buoy, thus providing mooring force and also preventing the FSU from overrunning the buoy. The rigid arm is connected to the FSU by a hinged mechanical joint in order to allow relative pitch between the FSU and the arm. At the buoy end of the rigid arm, mechanical joints are provided to allow relative pitch, roll, and weathervaning with respect to the buoy. The buoy is a large, varying diameter, compartmented cylinder connected to a combination pile/gravity type base on the ocean floor. A cross pin u-joint assembly allows the buoy to articulate with respect to the base. Hydraulically driven routing valves are mounted on the base to select the flow path of the product line from the platform and through the SALM to the FSU.

Outside diameters of the buoy range from 8 m (26 ft.) at the lower end to 15.9 m (52 ft.) at the maximum diameter and down to 5.5 m (18 ft.) at the top. The structure of the buoy is conventional stiffened plate and weighs 1830 tonnes (2012 short tons). To provide damage stability and capability for controlled flooding during upending, the buoy is subdivided into 18 compartments. A 3 m (10 ft.) diameter central column provides access to the various compartments for inspection and maintenance. The central column also houses the two production lines as well as the auxiliary piping and other mechanical and electrical equipment. Entrance to the central column is gained through either of two watertight doors atop the mooring swivel. All buoy compartments, except the ballast compartment, are dry and under atmospheric pressure during normal operating conditions.

The buoy compartment immediately above the universal joint was filled with a mixture of water and high-density hematite particles during installation. This ballast mixture weighing approximately 2580 tonnes (2838 short tons) reduces the net buoyancy force applied to the universal joint and base assembly.

The rigid arm truss structure weighs 800 tonnes (880 short tons.) The arm measures 61 m (200 ft.) in length and is 30.5 m (100 ft.) wide at the hinge connecting the FSU. In addition to providing the structural connection of the FSU to the mooring swivel, the arm supports the two production lines, all auxiliary piping and electrical conduits, and a walkway designed to transport equipment from the FSU to the buoy.

The FSU weathervanes about the buoy spindle shaft which is also used to join the FSU/rigid arm assembly to the buoy during installation offshore (Figure 8). This shaft is tapered toward the top to facilitate roller bearing installation, and tapered at the bottom to allow connection to the buoy offshore. For final connection, wedges are hydraulically inserted at the lower end of the buoy spindle to react radial loads in all directions. Large-diameter stud bolts are installed and pretensioned to transfer axial loads from the spindle to the buoy.

The 360 tonne (396 short ton) universal joint (Figure 2) connects lugs on the bottom of the buoy to those on the base structure by two 1560 mm (5.1 ft.) diameter by 7.9 m (25.9 ft.) long tubular pins and a coupler sleeve assembly. The universal joint is designed to transmit buoy loads to the base structure at angles up to 30 degrees relative rotation between the buoy and the base in all compass directions.

The combination gravity/pile base of the Fulmar SALM is of conventional stiffener and plate fabrication. It is hexagonally shaped and is fitted with a pile sleeve at each of the six corners. Sixteen compartments of the base were filled with a hematite slurry during installation offshore. Total ballast of the buoy and base will provide a positive reaction on the soil during calm sea conditions. To complete the anchoring of the SALM, six piles were driven to a depth of 29 m (95 ft.) and then grouted to the pile sleeves to resist the environmentally imposed loads.

The SALM production piping consists of two 16 in. pipelines from the base to the FSU in order to have full redundancy. Each pipeline has a maximum capacity of 300,000 BOPD and a maximum operating pressure of 1,900 KN/m^2 (275 psig).

Five surface-operated subsea valves are located on the top of the base to allow selection of the primary or secondary SALM piping and to provide multiple flow paths through the base manifold.

The fluid swivel stack atop the mooring swivel accommodates weathervaning. It consists of an in-line elastomeric swivel in the primary production line, a concentric swivel in the secondary production line, and an electrical/instrument air slip ring swivel for power and instrumentation and control signal transmittal.

FLOATING STORAGE UNIT (FSU)

THE FSU selected for the Fulmar Field was the Shell tanker "MEDORA" built in 1968 by Mitsubishi. The "MEDORA" was a 210,000-DWT tanker with an overall length of 325 m (1066-ft.). The usable cargo volumes total 180,000 tonnes (1,300,000-bbl.), which gives more than 7 days of storage even at maximum field production rates of 180,000 BOPD.

The conversion of the tanker to FSU was completed at Chantiers Navals de la Ciotat (CNC). The conversion involved the fulfillment of three main requirements:

(A) Modification and upgrading of the existing structure to conform with present-day regulations for offshore structures in the North Sea.

(B) Modification and upgrading of the vessel to cope with an additional 20-year infield operational life.

(C) Modifications to the hull to accommodate connection to the rigid arm.

To satisfy requirement (A), the accommodation spaces were completely stripped and the area was upgraded to conform with all the latest fire and safety requirements. Totally enclosed survival craft, helicopter landing deck and offshore stores-handling facilities were also added.

The work under (B) involved renovating any painted area in tanks that showed signs of deterioration; fill-in welding and grinding smooth all pits on tank bottoms; cleaning and painting all ballast tanks; cleaning, blasting, and painting underwater exterior portions of the hull; repainting the entire deck and superstructure; and cosmetic painting most other innerspaces. In addition, most of the cargo lines were renewed and stripping lines were replaced with fiberglass-reinforced pipe. Cathodic protection systems were renewed and improved to provide additional protection to hull exterior.

The work under (C) involved correcting any weakness in the design of the existing steel structure by additional stiffeners and brackets. The forward bulkhead was strengthened to withstand the rigorous pounding that it will receive on station. The bow has also been structurally modified to accept a large beam, which serves as the physical connection of the rigid arm hinges to the ship hinges.

CRUDE OIL AND BALLAST HANDLING

The FSU has segregated ballast tanks. Three independent pumping systems, for crude oil, ballast, and stripping, are provided. Each system is fitted with a control and monitoring system and can be operated from the central control room.

Loading procedures allow unrestricted flow of crude from the Fulmar platform to the center reception tank via a drop inlet. The tanker piping system distributes the crude from the reception tank to the storage tanks. A remotely operated system has been installed to measure liquid levels in all tanks coupled with an automated hull load monitoring system.

The water is separated from the crude on the Fulmar platform; however, any water that settles out in the reception tanks can be stripped back to the slop tanks. The reception tank has been designed to minimize the possibility that water contained in the crude will reach the storage tanks and induce bottom pitting corrosion.

The inert gas system has been modified so that the auxiliary boiler provides an alternate supply, and an additional scrubber has been added to give 100% redundancy. The purpose of the inert gas system is to keep the atmosphere in the cargo tanks in a nonflammable condition.

The principal method of offloading the FSU is via tandem mooring with the hoses suspended between the stern of the FSU and the bow of the shuttle tanker by a specially built offtake loading boom. As an alternative, it is possible to moor a tanker alongside, weather permitting. Approximately 15 hours are required to load a 110,000 DWT shuttle tanker (550,000 bbl. of crude).

SALM INSTALLATION

The SALM and the FSU were installed during the late Spring and Summer of 1981 by Heerema Offshore Contractors using the semisubmersible crane vessel "HERMOD". The vessel has the capacity to lift 5000 short tons (4500 tonnes) by the simultaneous use of its 3000 short ton (2700 tonnes) and 2000 short ton (1800 tonnes) revolving cranes.

In preparation for the tow and installation, the buoy and base were loaded onto a cargo barge and sea fastened with the buoy in a horizontal position. Tidal conditions were selected to minimize the amount of ballast transfer necessary during load-out to maintain the proper cargo barge/dock relationship.

Great care was exercised in the design and installation of the sea fastenings to insure that the cargo was properly supported, but could still be easily and quickly removed at the installation site.

Falsework used during assembly of the buoy sections was designed to be incorporated into the support structure used on the cargo barge. It was further designed to provide a two area support during load-out and sea transport. The weight of the buoy at load-out was 2209 tonnes (2430 short tons) and the combined buoy and support structure moved was some 2730 tonnes (3000 short tons). It was carried on two groups of rubber-tired wheeled wagons. A total of 1536 wheels were involved, mounted in 384 steerable assemblies with axle loads supported by vertically mounted hydraulic cylinders. All cylinders in each group of wagons were hydraulically linked together, so that the load "floated". As wheels traversed the articulated ramp between shore and barge, each assembly of four wheels could move vertically relative to their bogies to maintain a constant supporting load and keep the buoy horizontal. This load-out is thought to have set a new weight record for rubber-tired transport on land.

The base had been constructed in a horizontal attitude, but required rotation to a vertical plane for its attachment to the buoy. Three floating cranes carried the 800 tonne (880 short ton) base and rotated it into a vertical plane before landing it on skid beams prepared on the cargo barge. After landing on the cargo barge, the base was jacked forward on the skid beams until the lower u-joint pin could be moved in horizontally to join the base to the buoy. Until offshore up-righting of the buoy and base was completed, significant rotation of the base around the u-joint was unacceptable, and was prevented by means of four tie-back slings (Figure 4).

Next, hydraulic cylinders were used to rotate the base around this lower u-joint pin, and the upper tie-back wires were shackled to buoy and base. Relief of the cylinder pressure permitted counter rotation of the base until the wires were tensioned leaving the base entirely supported from the buoy. No support of the base from the barge was required, but the space was filled in with plate and beams to provide lateral restraint (seafastening) and to avoid dynamic cyclic loading of the upper tie wires during sea transport.

Before lifting offshore, this seafastening steel was cut away to ensure that the structure would unquestionably be on only two areas of support. This permitted the inevitable slight relative rotation of the barge and buoy when the unevenly distributed cargo load was removed, without risking contact of the base with the barge deck. Had such contact been possible, it could have caused loss of pre-tension in the upper wires or overload of the lower tie-back slings, and in either case a sequential risk of damage to areas about to be submerged. A need to repair such structures would have had disastrous effects on the programme at a very critical moment.

The cargo barge with the buoy/base assembly was towed from Rotterdam to Fulmar Field by the Heerema tug "HUSKY". When the tow arrived at the installation site, the "HERMOD" was already anchored in position for the lift. The SALM lift operation was delayed for five days while waiting for the seas to subside. The primary concern was the large roll motions of the cargo barge caused by the swell. When the sea conditions and weather forecast were favorable, the cargo barge was maneuvered into position and secured at the stern of the "HERMOD". Each of the cranes was then connected to pre-rigged slings on the buoy (Figure 4). When the sea fastenings had been removed and it was ascertained that the base was fully supported by the buoy u-joint and tie wires, the assembly was lifted free of the cargo barge by the cranes. The aft ballast tanks of the "HERMOD" were simultaneously de-ballasted by 4000 tonnes (4400 short tons) to keep the "HERMOD" at a constant draft as the load was transferred from the cargo barge to the "HERMOD" and also to increase the speed of separation of the buoy from the seafastenings.

Immediately following the lift, the cargo barge was moved away and the buoy/base assembly was lowered into the water, causing flooding of the base through a number of prepared holes in the "lower" side. The 3000 short ton crane continued lowering until the base was completely flooded and the lower end of the buoy floated, with the slings of the 3000 short ton crane slack, in an equilibrium attitude about 40° from horizontal. The lower lifting slings were then removed, releasing the 3000 short ton crane. The buoy was now supported at the upper lift points by the 2000 short ton crane. The buoy was brought to a vertical position by lifting with the crane and sea water flood valves to the buoy compartments were then opened. During the continued flooding of the buoy compartments the lift load was allowed to build to 730 tonnes (800 short tons) which was maintained until the base was about 2 m above bottom. The upending and lowering operations took about 12 hours.

Flooding was halted for 4 hours while proper positioning and orientation was confirmed by use of survey equipment linked to the production platform. During this time, the tie back slings between the buoy and base were cut and removed with the aid of divers. Prior to final lowering, the pipeline flange on the base was brought to within 1 m of the end of a pipeline spool piece measuring fixture. This fixture previously connected to the pipeline was used as a reference for positioning of the base. Up to this point, the operations could have been stopped and the buoy taken off location; once the buoy was set on bottom, reversal of the operations would be extremely difficult due to the long time required to pump ballast water from the buoy. The buoy/base was then lowered to the bottom, causing the shear skirts under the base to penetrate the soil under the weight of the buoy.

Once the buoy was on bottom, the installation of permanent ballast in the base and lower compartment of the buoy proceeded. This was done using an ore carrying ship equipped with automatic weight measuring conveyors, slurry pumps and hoses. All the ballast lines had been pre-installed with connections at the top of the buoy. During the ballasting of the base, shear skirts penetrated the soil as the base remained level within very satisfactory limits of $\pm \frac{1}{2}$ degree. The installation of 3700 tonnes (4070 short tons) of ballast took 44 hours. At this point the buoy was able to withstand a 10 year Summer storm with the base acting as a gravity foundation.

As soon as the ballasting was complete, pile installation commenced. Piles were maneuvered into the guide cones at each sleeve by control of the lifting crane. Pile stabbing was monitored by an RCV and confirmed by divers. Each pile was driven to 29 m (95 ft.) by use of a MRBU 6000 underwater hammer. The actual driving time for each pile was less than 30 minutes.

Preparation to grout the piles began immediately. Grout was mixed and tested. Pile packers at the lower end of each sleeve were energized and grout was pumped into the annulus through temporary piping installed along the outside of the buoy. Density of the grout was monitored by measuring arriving from a known radioactive source across a sampling standpipe adjacent to the annulus being filled. The nuclear densitometers were provided and operated by staff of the Atomic Energy Research Authority, Harwell.

Some difficulty was experienced in mixing grout to the required pre-placement density without the setting time being unacceptably short. Based on the Contractor's previous experience with the particular cement supplied, a lower density was judged acceptable and work proceeded. Densities were measured in-situ and cube tests made after 1, 7 and 28 days were entirely satisfactory.

Twenty-nine hours of delay were attributed to grout mix problems with some further delays caused by leaks in air lines at the inflatable sleeve packers, however, actual grouting time averaged only 30 minutes for each of 6 piles, somewhat less than originally foreseen.

Following the setting of the grout, the buoy and base were then secure against any storm conditions which might have developed.

To meet Contractor commitments, a planned interruption of the installation occurred at this stage, during which the mooring arm was attached to the FSU at Rotterdam. Before leaving the SALM, the HERMOD crew closed all valves on the base and the buoy, removed external installation piping, washed some internal buoy compartments with fresh water, installed shock absorbers for the arm connection, and performed an internal and external inspection.

FSU INSTALLATION

After the FSU modifications were completed at La Ciotat, France the next phase for installation of the FSU was a 2100 mile tow to the Verolme Shipyard in Rotterdam. The arm was then towed on a cargo barge down the river from The Rotterdam Dockyard Company to the Verolme Shipyard where mating to the FSU occurred. The connection of the rigid arm took one week total, with the actual structural connection taking three hours.

Immediately prior to the planned departure date from the Verolme Yard, the buoy end of the arm was lifted by the Heerema-owned crane vessel "THOR". The temporary support barge was removed and the arm was lowered into the water.

With good weather in Rotterdam and a favorable weather forecast at Fulmar Field for the next several days, departure from Rotterdam was authorized. Harbor tugs were utilized for maneuvering until the FSU was clear of the Nieuwe Waterweg and past the Hoek van Holland. The tug "HUSKY" was then connected to the stern of the FSU and the tow proceeded. With the FSU towed stern first and the arm with temporary buoyancy tanks behind, a speed of approximately 6 knots was easily maintained during the 2½ day tow.

Prior to the arrival of the FSU at Fulmar Field, the "HERMOD" had returned, moored in location at the SALM buoy and completed the fabrication and installation of the pipeline spool piece between the SALM base and the end of the pipeline.

When the FSU arrived in the area, weather and sea conditions were very good. This allowed all efforts for this most critical and delicate phase of the installation to proceed. While the "HERMOD" anchors were moved to allow proper orientation, three additional tugs were connected to the FSU as it was slowly maneuvered to within about 100 m of the buoy. At this point, the additional lines from the "HERMOD" were connected as shown in Figure 7. Three tugs were stern anchored from their towing winches to high holding power Delta anchors, and secured by the bow to the FSU. Two tugs provided opposing transverse pulls at the front of the FSU, to give lateral control at the bow of the FSU. The towing tug "HUSKY" remained attached to the stern of the FSU, and assisted in controlling the vessel's heading throughout the installation. Two lines from the FSU bow were attached to winches on the "HERMOD", opposed to the pull of the stern tug to give fore and aft control of the vessel.

It was now time for possibly the most delicate offshore lift yet attempted to begin! The FSU was moved to within about 20 m of the buoy where the crane hook was lowered to connect the pre-installed slings at the end of the arm. The line to manipulate the buoy spindle from a deck winch on the FSU was rigged and slack taken up while hydraulic power was connected to the spindle securing clamp. All equipment was then ready for the lift. The arm was raised to allow adequate clearance above the top of the buoy and the FSU was moved in to position the spindle above the top of the buoy. Confirmation was made that the relative motions between the arm and buoy would allow a successful stabbing and connection. At this point the spindle securing clamp was opened and the spindle raised into a vertical position to align with the buoy. The shock absorber assemblies had now been energized and the actual stabbing operation began. Approximately two hours elapsed while proper positioning was made and knowledge of motion patterns was improved. Until this point, the operations could be reversed and the FSU towed back to shelter if necessary.

Actual lowering of the spindle into the buoy was quite smooth and without incident except that one small rubber bumper was dislodged and happened to wedge into a position that prevented the spindle from seating onto its previously fitted position.

After the problem was identified, slight lifting and cleaning allowed reseating of the arm. Approximately 18 hours elapsed between the time when the maneuvering of the FSU began to completion of the stabbing operation. Six temporary hydraulic latches were then engaged while permanent connection work continued. Permanent connection was realized by activating twenty hydraulically driven wedges with lock nuts. Twenty stud bolts thru a rotating flange were installed to transfer the tensile loads.

Hook-up work to bring the SALM to an operational state began thereafter. All of the installation aids were removed; this included the auxiliary buoyancy tanks, spindle clamp, rigging platform, shock absorbers, and temporary latches. Spool pieces for production lines were placed inside the buoy spindle. The swivel support house with the two fluid swivels and electric swivel was joined to the top of the buoy spindle. Pipelines, utility air and water lines, instrument air lines, power and instrumentation lines were connected and tested to complete the installation. These hook-up operations took approximately 10 days after the stabbing was completed.

In order to confirm and document the condition of the SALM, an RCV survey with video tape was performed during the final phases of hook-up and testing. This survey revealed that only small pieces of debris or hardware had been dropped during the FSU connection to the buoy. No damage of significance to any SALM component was found.

After the completion of the hook-up work on the SALM, commissioning activities continued on the FSU and production platform during the remainder of 1981.

First oil flowed to the FSU on February 11, 1982. The final major milestone was reached on April 3, 1982 with the offloading of oil onto the tanker "ESSO ABERDEEN".

ACKNOWLEDGEMENTS

The authors wish to thank Shell U. K. Exploration and Production, Esso Exploration and Production, U. K. and Exxon Production Research Company for permission to publish this paper. We also wish to thank W. Van Dam and K. Bosma of Heerema Engineering Services for their assistance during the construction and installation of the Fulmar SALM.

REFERENCES

1. Mack, R. C., Wolfram, W. R., Gunderson, R. H., Lunde, P. A., "Fulmar, The First North Sea SALM/VLCC Storage System." OTC Paper 4014, Houston, Texas, May 4-7, 1981.

TABLE 1

KEY CALENDAR DATES
FOR FULMAR SALM PROJECT

	ACTIVITY	DATE
1.	Preliminary Design & Model Test	Fall, 1977
2.	Final Design Complete	December, 1978
3.	Request for Tender	December, 1978
4.	Fabrication Contract Signed	April 4, 1979
5.	Contract for Tanker Conversion to FSU	September 9, 1979
6.	16-Inch Pipeline from Platform to SALM Site	June, 1979
7.	Load-Out of Buoy	October, 1980
8.	Load-Out of Base	October, 1980
9.	Load-Out of Rigid Arm	January, 1981
10.	Completion of Buoy/Base Assembly	April, 1981
11.	Installation of Buoy/Base	May 16, 1981
12.	FSU Completed at CNC	May, 1981
13.	Rigid Arm Joined to FSU Verolme Rotterdam	June, 1981
14.	FSU/Rigid Arm Tow from Verolme Rotterdam	July 1, 1981
15.	FSU/Rigid Arm Mated to SALM Buoy	July 5, 1981
16.	Hook Up Complete	July 22, 1981

TABLE 2

SUMMARY OF TIME REQUIREMENTS AND SEA CONDITIONS
FOR CRITICAL PHASES OF LOAD-OUT AND INSTALLATION

		TIME REQUIRED		SEA CONDITIONS (H_s)	
	ACTIVITY	PLANNED	ACTUAL	LIMITING	ACTUAL
1.	Buoy Loaded Onto Cargo Barge	1 Day	1 Day	——	Protected Waters
2.	Base Mated to Buoy	1 Day	1 Day	——	Protected Waters
3.	Tow Buoy & Base to Fulmar	4 Days	3 Days	Summer Storm	3 M
4.	Buoy Lift & Uprighting	1 Day	1 Day	1.4 M	1.2 M
5.	Ballast Base & Buoy	3 Days	2 Days	2.4 M	1.2 M
6.	Install & Drive Piles	4 Days	2½ Days	1.8 M	1 M
7.	Grout Piles	1 Day	½ Day	2.4 M	1 M
8.	Install Pipeline Spool Piece	6 Days	4 Days	1.8 M	1 M
9.	Tow FSU, La Ciotat-Rotterdam	15 Days	12 Days	Summer Storm	Good
10.	Connect Arm to FSU	9 Days	7 Days	——	Protected Waters
11.	Tow FSU, Rotterdam-Fulmar	2½ Days	2½ Days	Summer Storm	2 M
12.	Position FSU & Connect Assist Tugs	½ Day	½ Day	1.6 M	1 M
13.	Lift Arm & Stab Spindle	½ Day	½ Day	1.6 M	1 M
14.	Secure Spindle to Buoy	1 Day	1 Day	1.6 M	1.2 M
15.	Complete Hook-Up & Testing	2½ Days	7 Days	——	——

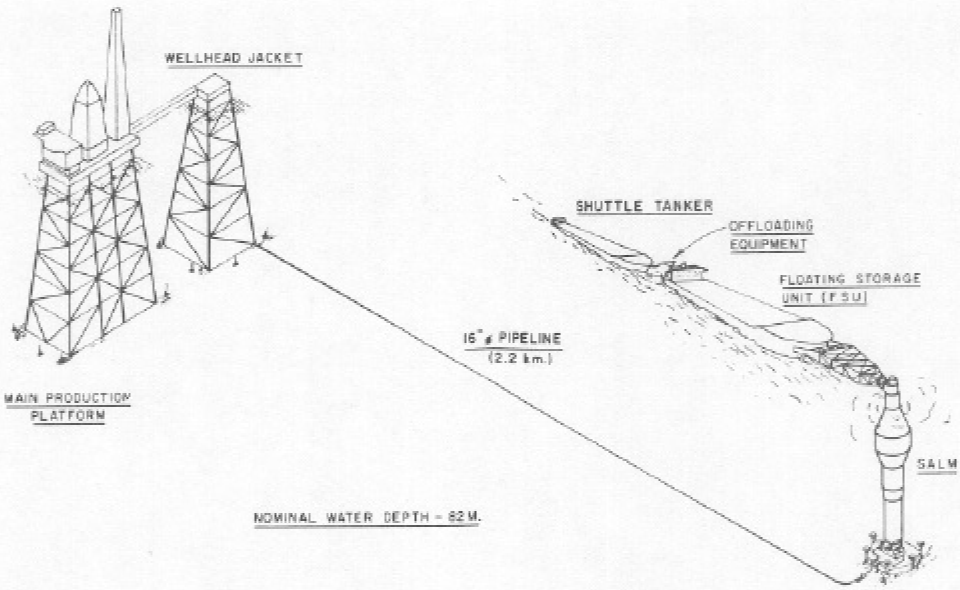

Fig. 1—Fulmar field development plan.

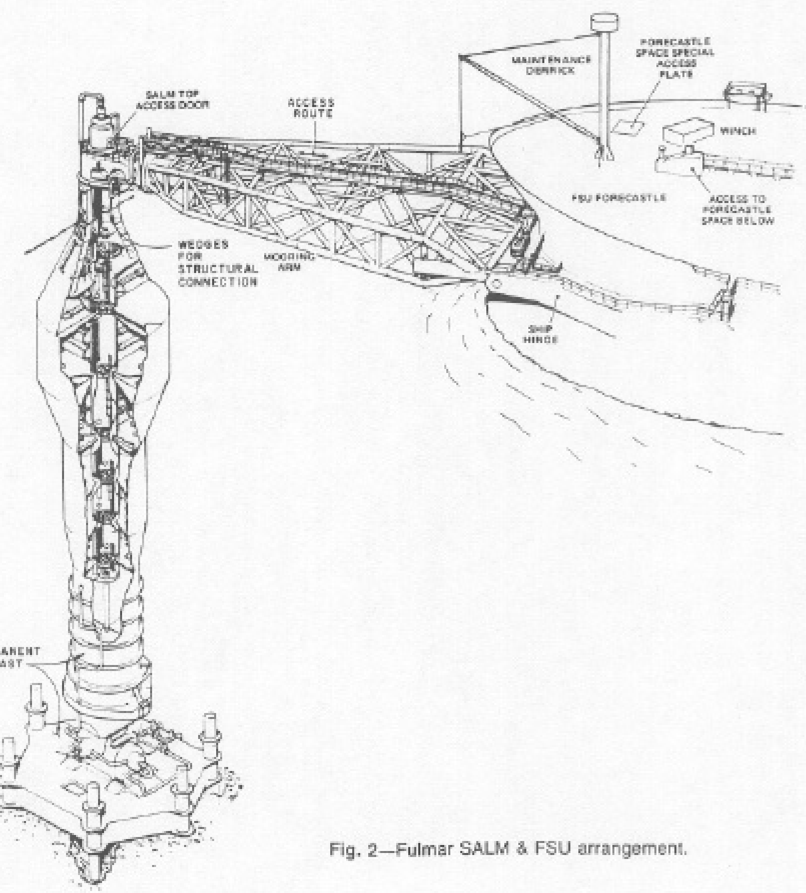

Fig. 2—Fulmar SALM & FSU arrangement.

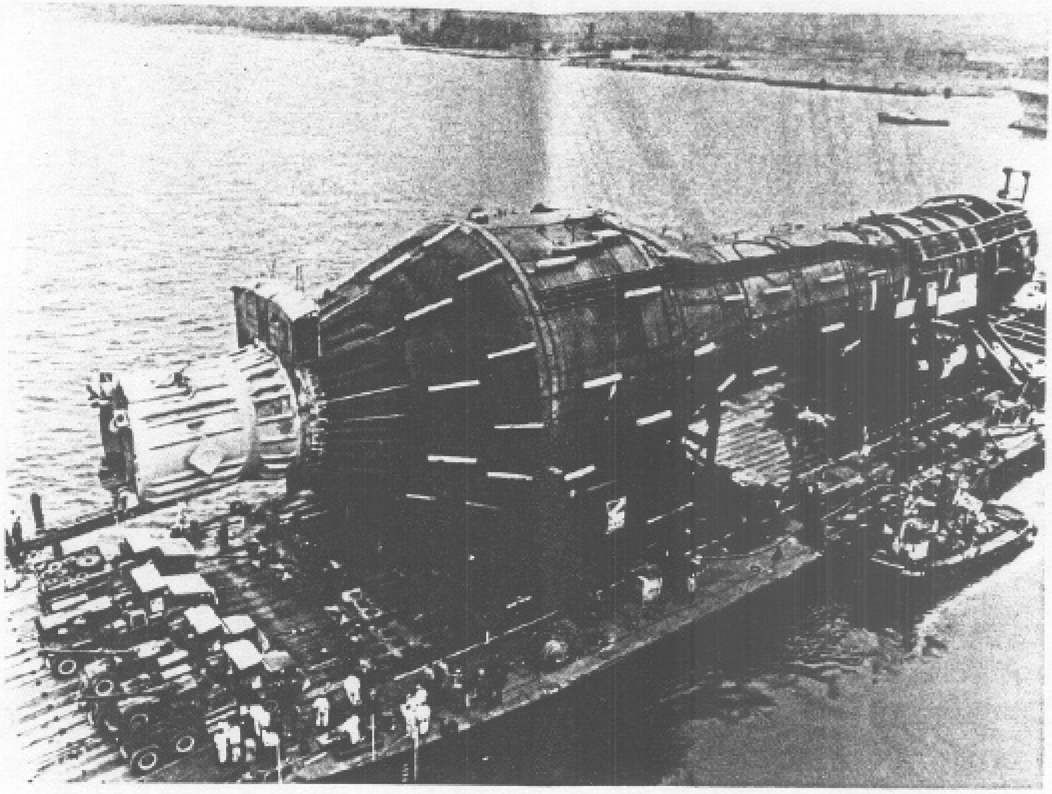

Fig. 3—SALM buoy load-out.

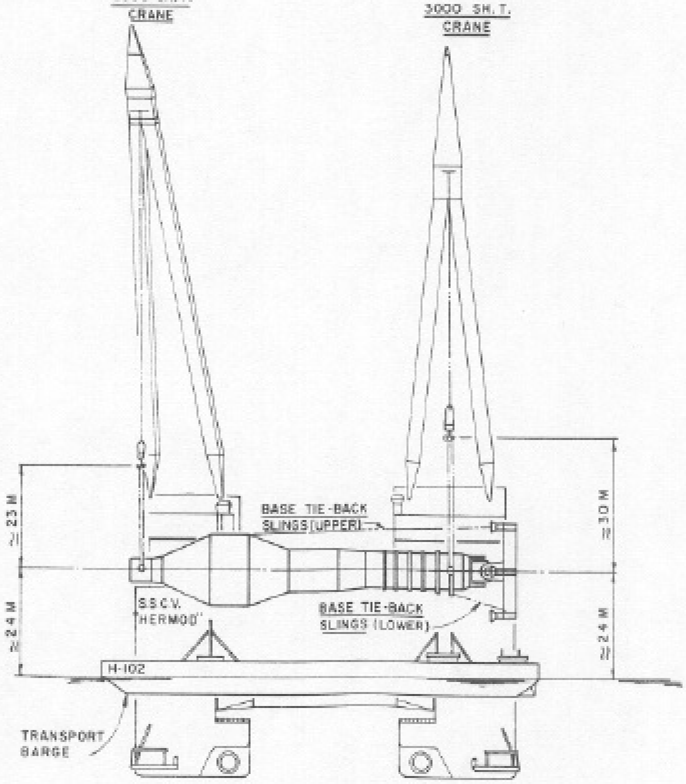

Fig. 4—SALM lift sling arrangement.

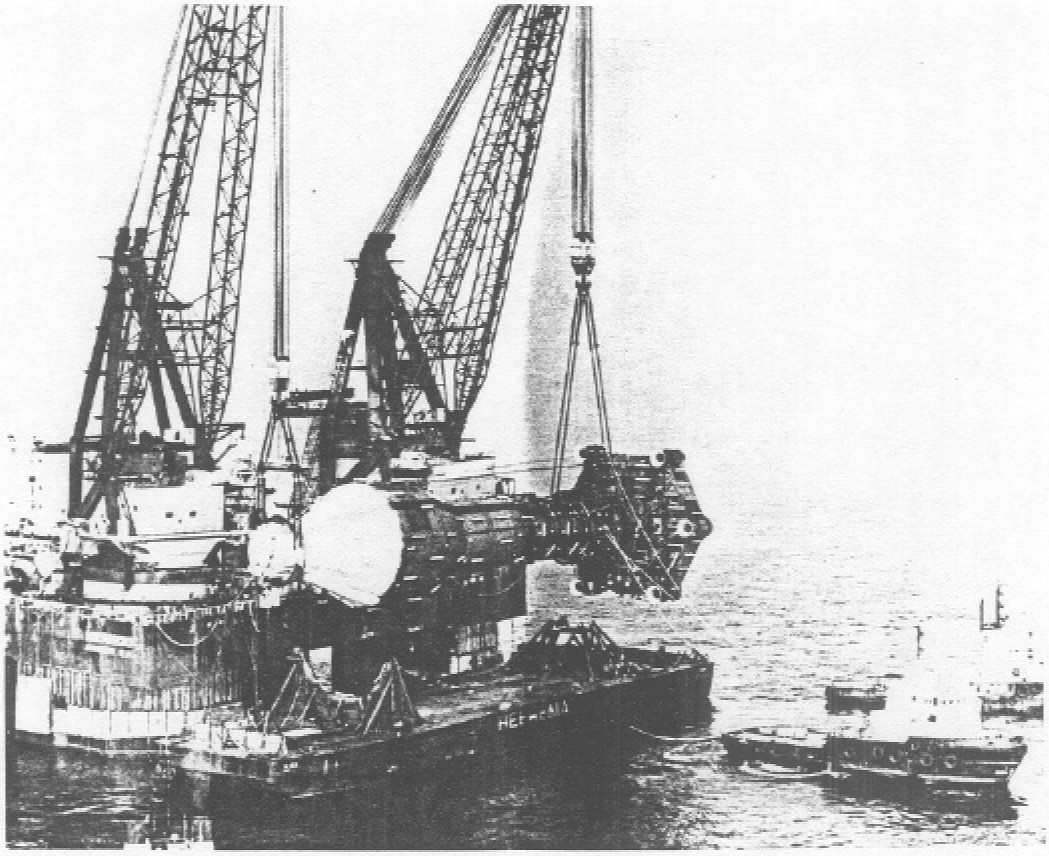

Fig. 5—SALM buoy lift.

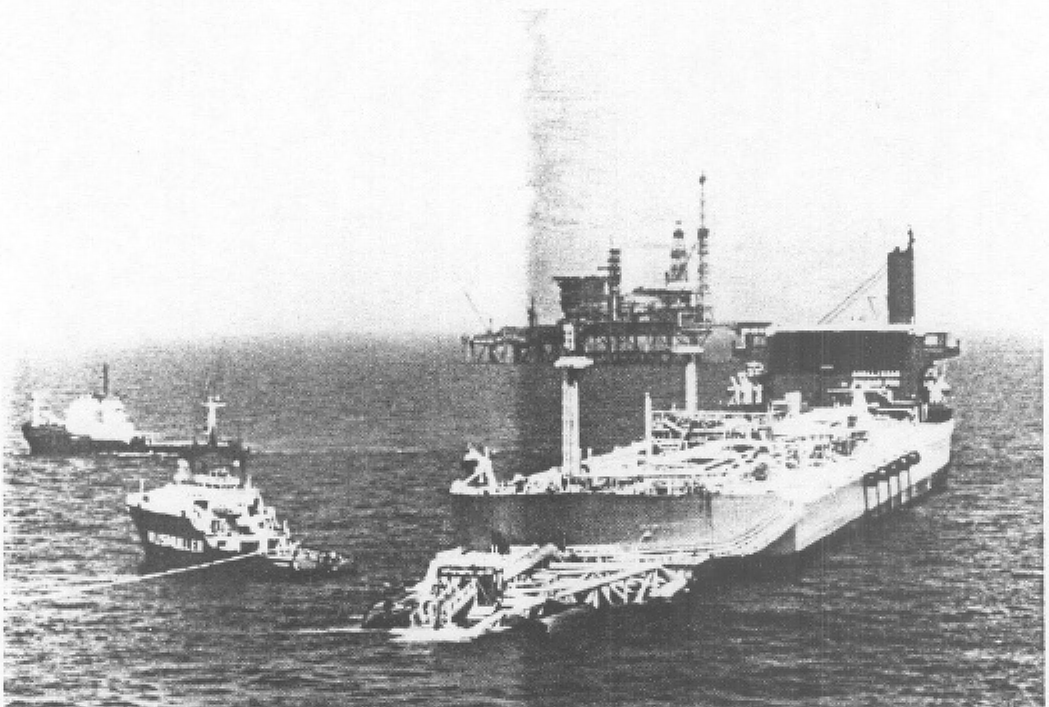

Fig. 6—FSU/rigid arm tow.

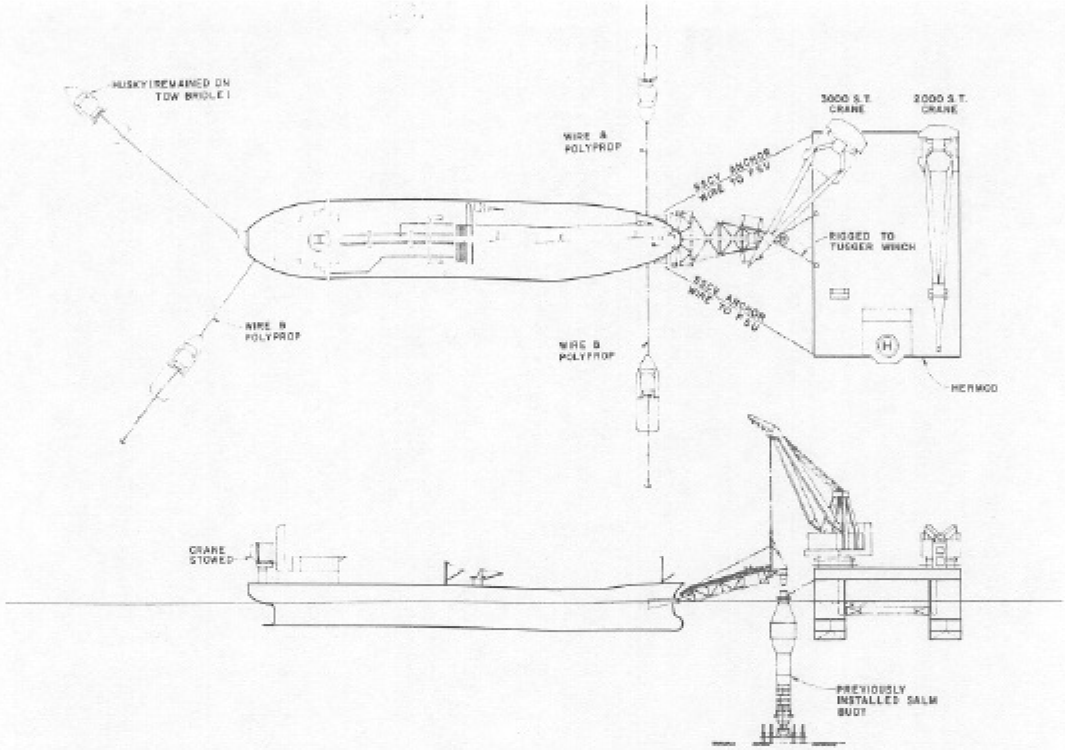

Fig. 7—Mooring and rigging arrangement for FSU positioning for arm lift and spindle stab.

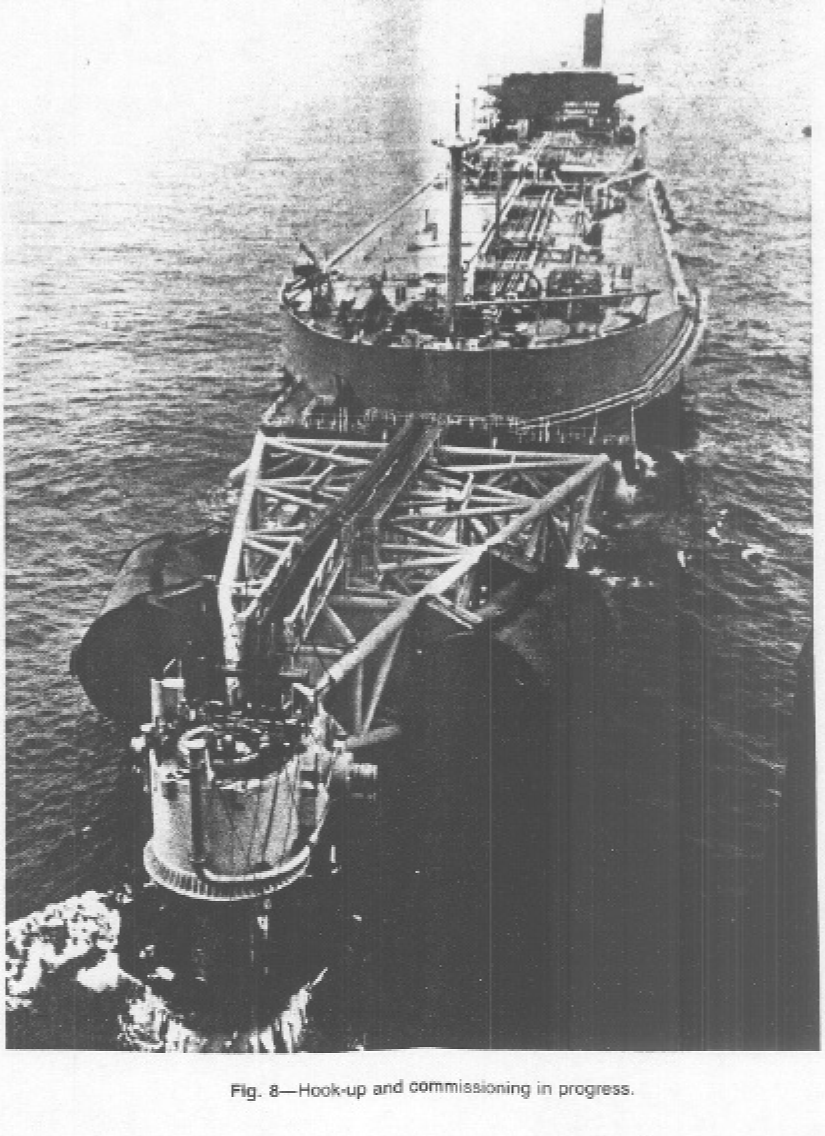

Fig. 8—Hook-up and commissioning in progress.

Fig. 9—Completed SALM/FSU.