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Disconnectable Turret Moored Floating Storage And Offloading Unit at Lufeng 13-1 Field

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ABSTRACT

This paper describes the design and construction of a tanker converted disconnectable turret moored Floating Storage and Offloading Unit (FSOU), the NANHAI SHENGKAI for Lufeng 13-1 oil field was developed by JHN Oil Operating Co. and China Offshore Oil Nanhai East Corporation.

In order to accommodate harsh environmental condition in South China Sea where typhoons pass every year, the disconnectable turret mooring system was chosen to moor the FSOU.
Smooth reliable and safe operation of the FSOU with a disconnectable mooring system was verified through one year operation at the field.

INTRODUCTION

In June of 1991, JHN Oil Operating Co. called for a tanker based Floating, Production. Storage and Offloading System to be installed at the Lufeng 13-1 field in the South China Sea offshore the People's Republic of China, located approx. 110 sea miles SE of Hong Kong. as shown in Figure 1. Water depth at the site is 142 meters.

After, the bid JHN decided to procure and modify the unused existing platform "Julius" with its top side production facilities instead of fabricating new platform. "Julius" was owned by Shell. Therefore the field development plan was changed to "Production Platform and Floating Storage and Offloading Unit (FSOU)" from "Wellhead Platform and FPSO".

At the end of 1991 JHN acquired 124,000 DWT tanker "Sea Queen" built in 1975 to be converted to on FSOU.

In February 1992, MODEC, Inc. as a main Contractor was awarded lump sum contract for design / conversion of the "Sea Queen " to an FSOU and design / supply of a Flowline between the Platform and the FSOU.

The disconnectable mooring system equipped on the FSOU was designed and built by SOFEC, Inc. in Houston, TX and Japan.
All components were transported to Singapore where MODEC managed the tanker conversion and turret installation.

The tanker conversion work was started at the end of 1992 at Sembawang Shipyard in Singapore and the FSOU was hooked up to pre-installed mooring system in August 1993.

After commissioning including connection and disconnection test of the mooring system, the FSOU has been under full operation without any problem.

The FSOU has already been safely and smoothly disconnected and connected 4 times including trials.

SYSTEM DESCRIPTION

(1) Field Characteristics

For the development of the FSOU basic design, the following major field characteristics were into consideration:

(a) Harsh environment

The field is located in the typhoon corridor. Every year several typhoons are anticipated to be encountered. The disconnectable turret mooring system was selected which allows the FSOU to evacuate in case of typhoon approach.

(b) High pour point crude oil

The pour point of the crude oil is 38 deg C. The flowline/riser, the tanker tank/piping and the offshore system shall be designed to accommodate high pour point crude oil to avoid crude oil solidification especially in the

subsea flowline. The whole subsea flowline/riser and tanker piping are insulated and electric or steam heating system is provided for tanker piping and cargo storage tanks. Flushing system using diesel oil is provided for non heat traced flowline/piping.

(2) Field Layout

The FSOU is installed approx. 1 mile apart from the platform. Processed crude oil is transferred from the platform to the FSOU via the subsea flowline and stored in the FSOU as shown in Figure 2 and 3. One 6" insulated flowline is adopted for the subsea pipeline.

The FSOU has 880,000 BBL storage capacity. The storaged crude oil is offloaded to an offtake tanker of which size is less than 100,000 DWT via a Lease Automatic Custody Transfer (LACT) equipped on the FSOU and a floating hose.

(3) Mooring System

As a result of evaluation of field size, environmental condition of the field (water depth, typhoon prone area, high velocity current), the disconnectable turret mooring system has been chosen considering the economic benefit.

The mooring system is an internal turret type as shown in Figure 4. A turret shaft is located inside of a moon pool which is integrated as a part of tanker hull structure and is supported with an upper main bearing and lower bearings. The upper bearing is three race roller bearing conforming one unit and located at the tanker main deck level. The lower bearings are segmented auto adjustable type with self lubricated bearing surface. Radial loads only are resisted by the lower bearing. Both radials and vertical loads are resisted by the upper bearing.

Anchor lines are connected to a spider buoy with chain support trunnions. The spider buoy is connected at the lower part of the turret shaft with a hydraulic connector/tensioner unit which allows to disconnect the spider buoy instantly with control valve operation. The hydraulic connector / tensioner is located in dry space for easy maintenance. When disconnected the spider buoy remains under water at 35m below sea surface. The spider buoy is hybrid construction with steel and syntactic foam to obtain required reserved buoyancy for support of the riser & anchor legs while disconnected.

All powered components to facilitate both connection & disconnection of the mooring system are located on the turret. Electrical power for the hydraulic power unit is provided via an electrical swivel (slip ring assembly) located atop the swivel stack. Hydraulic power & controls are available on the turret for chain jacks, retrieval winch, connector tensioner, riser retrieval winch and the turret rotational drive to be used for alignment during re-connection.

After re-connection of the turret to the mooring system, the interior of the turret is pumped dry. In-service inspections & maintenance can then be easily carried out with assistance of the utility systems provided in the turret.

(4) Operation philosophy

On the upper part of the turret shaft a retrieval hydraulic winch and a chain jack unit for reconnection of the spider buoy.

Under the law of Chinese government, once a typhoon approach in critical range from Lufeng 13-1 platform, evacuation of production personnel on the platform will be commenced. The oil production on the platform is stopped accordingly. After the production shutdown flushing of crude oil in the flowline between the platform and FSOU is carried out. Once flushing is completed, the rest of preparation for disconnection of mooring system on FSOU takes less than a hour. The disconnection itself only takes few seconds.

The disconnection preparation includes the following works:

- Shut down of the process facility at the platform
- Flushing of the flowline/riser with diesel oil
- Function check of the disconnection system
- Disconnection of the riser
- Disconnection of the offloading floating hose
- Reactivation of the tanker propulsion system and auxiliary machinery for sailing
- Evacuation of FSOU
- Fill ballast water in the turret shaft

These preparation works will take few hours, therefore the decision to commence the preparation work should be done well in advance of actual disconnection.

In case of typhoon approach, the preparation works shall be started when a typhoon gets into a certain radius circle with a center at the platform location (so called yellow zone).
Disconnection shall be conducted when the typhoon gets into a certain radius circle (so called red zone). The FSOU will sail away from the site to safe area for evacuation. Once the weather comes back to normal condition the FSOU returns to the site and is reconnected to the mooring system.

(5) Flowline and Riser

One 6"(ID) flexible dinamic riser with "Lazy S"

configuration and one 6"(ID) flexible flowline connected on the sea bed were installed between the platform and the FSOU.

The flowline and the flexible riser were insulated with 33mm thermoplastic PVC insulation (3 layers) and 22mm (2 layers) insulation respectively.

Estimated temperature drop time from 65°c to 55°c after production shutdown was 3 - 4 hours with these insulation.

High current velocity of 2.39 m/s has significant impact on riser and flowline design. Interference between the riser and anchor lines and seabottom was carefully checked. One (1) layer of insulation for the flexible riser was deleted to reduce current drag force. Stability analysis of the flowline was performed to verify that the submerged weight of the pipe is sufficient to meet the required stability criteria.

(6) FSOU Hull System

No. 1 center cargo tank was converted to accommodate internal turret mooring structure. The forward half of No.1 center cargo tank was modified to a void space and the aft half of the tank was left as a cargo tank by conversion of a swash bulkhead to an oil tight bulkhead.

In order to treat unexpected non-spec crude oil transferred from the platform, No.2 port and starboard wing tanks were converted to settling tanks. The tanks were designed to treat the crude oil contains up to 10% of BS & W. Separated water in settling tanks is periodically transferred by stripping system into the slop tank.
Water content in crude is monitored by BS & W monitor on the LACT (Lease Automatic Custody Transfer) unit.
The LACT unit provided equipped with three (3) meter runs, each 12,500 BBL/hr capacity, and one (1) 12,500 BBL/hr Bidirectional Stationary Prover for design offloading rate of 25,000 BBL/hr.
Crude oil transfer piping on FSOU is electrically heat traced to prevent crude oil solidification in the piping when production stops for FSOU disconnection. All cargo tanks and slop tanks are provided with heating coils. Those piping including the LACT unit and offloading floating hose are flushed with diesel oil after offloading.

A helicopter deck for "Super Puma" or "Sikorsky S61" helicopter was provided at stern deck of FSOU close to accommodation space.

Existing accommodation was utilized without large modification for 37 personnel.
The FSOU is currently operated with 29 operation crew.

The offloading floating hoses consist of 16" mainlines and 12" tanker rail hoses and are installed at an offloading station located on the FPSO stern port side. The offloading hose assembly is disconnected and towed away by a work boat to safe area in the event that the FSOU is disconnected.

The principal particulars of the FSOU are listed in Table 1.
General arrangement of the FSOU is shown in Figure 5.

(7) Tanker Conversion

Tanker conversion work has been carried out at Sembawang Shipyard in Singapore.
Turret structure had been constructed at Nippon Steel Co.(NSC) in Japan and transported to Singapore for installation. Turret support structure has been fabricated in sections and installed in No.1 center cargo tank to facilitate the approx. 500m tons structure as shown in Figure 6.

At the design stage, FEM analysis has been carried out to ensure the converted structure maintain enough strength with large circle of hole on main deck and bottom. The smooth load transfer from turret structure to the tanker hull through upper bearing support structure at main deck level and lower bearing support structure at bottom level has been verified with the FEM analysis.

The structural conversion weight is approx. 600m. tons including cropping out of existing tanker hull structure for installation of the turret support structure.

The installation of turret support structure and turret shaft were carried out by the following procedures.

- Cropped out the existing tanker structure at afloat condition
- Turret support structure was divided into 5 sections and prefabricated prior to the installation into the tanker hull
- 1st dry docking
- No.1 section (lower bearing support structure) has been installed
- A temporary bottom cover utilizing existing bottom structure has been fitted.
- Once major welding of the No.1 section to hull structure was done, the tanker was dock-out
- No.2,3&4 sections have been installed subsequently at afloat condition.
- No.5 section (Upper bearing support structure) has been finally installed within allowable tolerance
- Turret shaft inserted into hull by a floating crane and supported on temporary blocks.
- 2nd dry docking

- Bottom plate has been cut and hydraulic jacks have been set under turret shaft
- Turret shaft lowered
- Lower bearings was installed with final alignment
- Upper bearing installed
- Rotation check has been carried out using turret driving mechanism
- Dock-out

The above activities took approx. 3.5 months.

Since no dock blocks can be arranged in turret area hull structure, the tanker bottom structure around turret where dock blocks attached as well as dry dock local strength under the turret to hold whole turret weight was carefully examined and protected.

As soon as the turret shaft was installed and fixed on the upper bearing, Equipment / Machinery in and on the turret shaft such as a connector / tensioner, a chain jack, a spider buoy retrieval winch, hydraulic system, electrical system, ventilation system, dewatering system were commenced to be installed.

The connector / tensioner is hydraulic controlled and retractable so that the easy maintenance can be made.
The 450 metric ton capacity chain jack is located inside of the turret shaft at near main deck level.
The hydraulic control panel for the connector / tensioner, the chain jack, the spider retrieval winch is located at control deck in the turret shaft.
To avoid future operation problem, attention was paid for installation of hydraulic system which was the key system for this disconnectable mooring system operation.
Especially the hydraulic piping was flushed / cleaned to NAS 8 grade.

Subsequently to the major equipment / machineries installation in and on the turret shaft, turret upper structure including swivel support frame, positioning system mast and turret surrounding structure above main deck were installed.

All equipment / machinery on the FSOU were pre-commissioned before sailing from the conversion shipyard to the installation site.

(8) Life Extension Work

The FSOU was designed based on that the converted FSOU will be dry docked at every 5 years.

Life extension work was carried out for entire hull structure and tanker existing system to be utilized after conversion. The tanker hull structure was closely examined and gauged. Hull structure renewal in wing ballast tanks was major structural repair work. Machinery and equipment including main engine system were thoroughly overhauled, inspected and repaired as required. Piping system was also inspected and corroded parts were replaced or repaired. Large amount of boiler water tubes was replaced.

SCHEDULE CONTROL

The FSOU was delivered and installed on schedule 18 months after the contract. As shown in Fig 7 critical path of the project schedule was the mooring system procurement, manufacturing, construction and installation.

Since turret major mechanical components were manufactured in the U.S.A. and Europe, turret structure and the spider buoy were built in Japan and tanker conversion was done in Singapore, careful and close schedule control was required.

The one of main concerns was a mating trial of turret shaft, spider buoy and the hydraulic connector / tensioner. These were fabricated at different locations and difficult to be mobilized due to their size, weight and tight fabrication schedule.
This problem was overcome by fabricating a special test bed and mobilizing the turret shaft bottom module, the spider buoy top module and the hydraulic connector / tensioner in one place for pre-mating, dimension check and full load test before each structure module was entirely assembled at each fabrication shop.

Turret shaft was delivered to Sembawang Shipyard on the planned date without any delay.

F(P)SO system conversion/construction work is complex of many components from different suppliers/vendors spread world wide. One of key components for schedule control is technical interface between each system and components. It will also avoid producing inconceivable cost.

ACKNOWLEDGMENTS

We wish to express our thanks to JHN Oil Operating Co. and China Offshore Oil Nanhai East Corporation for their cooperation throughout the project execution, and also to project team of SOFEC, Inc. and Sembawang Shipyard for their great assistance.

REFERENCES

- R.A. Hall, C.O. Etheridge, P.F. Poranski, and L.T. Boatman, SOFEC, Inc. and M. Kawase, MODEC, Inc.:"Installation, Testing, and Commissioning of a Disconnectable Turret Mooring for FSOU Vessel in a Typhoon - Prone Area", Paper 7442 Offshore Technology Conference 1994.

Table 1
PRINCIPAL PARTICULARS

Design Criteria

(1) Water Depth : 141m

(2) Sea Condition
- Extreme Operating Condition
  - FSOU Moored to SPM

Significant Wave Height : 8.0 m

- Extreme Condition - Disconnected Mooring Buoy & Chain Line(100 year storm)

Significant Wave Height : 14.4 m
Current Speed : 2.39 m/s

- Reconnection and Disconnection Criteria

	Reconnection
Significant Wave Height :	3.5 m
	Disconnection
Significant Wave Height:	7.4 m

(3) Crude Properties

Specific Gravity	:	API 30.5 deg.
Pour Point	:	38 °C
Viscosity (cp) at 116°C	:	3.6
Sulfur (%)	:	below 0.1

Classification

American Bureau of Shipping

ABS + A1 Floating Storage System (Disconnectable)

ABS + Offshore Installation - Undersea Pipeline

FSO Barge

(1) Principal Particulars

Vessel Name	: Nanhai Shengkai
Length (O.A.)	: 259.1 m
Length (P.P.)	: 247.0 m
Breadth	: 40.6 m
Depth	: 22.3 m
Draft (design)	: 16.84 m
Deadweight	: 121,361 mt
Oil Storage Capacity	: Approx. 880,000 bbl
Accommodation	: 37 persons
Original Tanker	: 'SEA QUEEN' built by Mitsubishi Heavy Ind., Hiroshima Shipyard, on 1975

(2) Major Equipment

Cargo Pump	: 3,000 cu.m/h x 3
Inert Gas System	: provided
Crude Oil Washing System	: provided
Ballast Pump	: 2,500 cu.m/h x 1
Cargo Heating System	: for all tanks (cargo and slop tank)
LACT Unit	: 25,000 BPH
Cargo Offloading Arrangement	: andem Mooring : 50 m Nylon Hawser (Double Grommet)
Cargo Offloading Hose	: 16"/12" - 242 m Floating Hose
Main Engine	: Mitsubishi Sulzer 9 RND 90 MCR 26,100 ps x 122 RPM
Boiler	: 65t/h x 1
Power Generator	: 750 kw (D/G) x 3
Deck Crane	: 2.1 ton x 32 m x 1
Helicopter Facility	: for Super Puma or Sikorsky S-61N

Mooring System

(1) Type

Disconnectable Internal Turret Mooring System

(2) Major Component

Anchor Chain/Wire	: 8-ORQ 4" chain +4" wire
Anchor	: 8 - 25 ton Bruce Anchor
Flexible Riser	: Lazy S configuration, insulated
Swivel	: Inline Swivel for Crude Oil, Multi-pass Electrical Swivel, Air Swivel

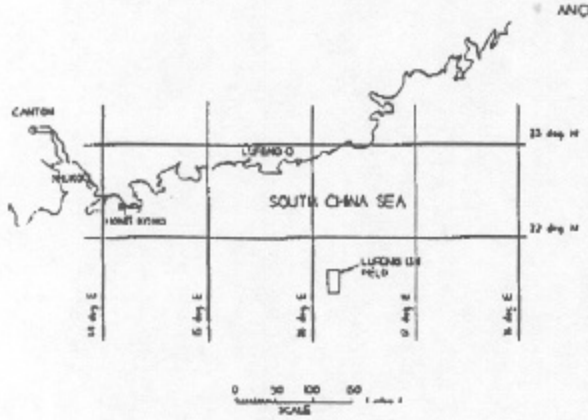


FIGURE 1 FIELD LOCATION

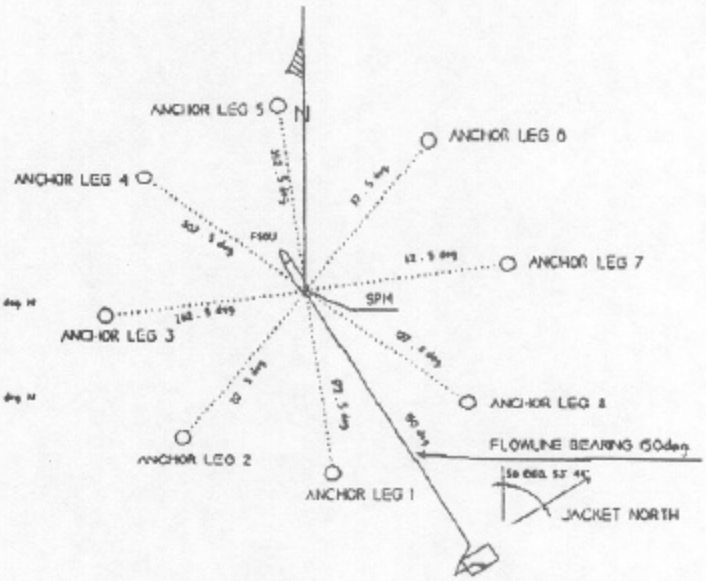
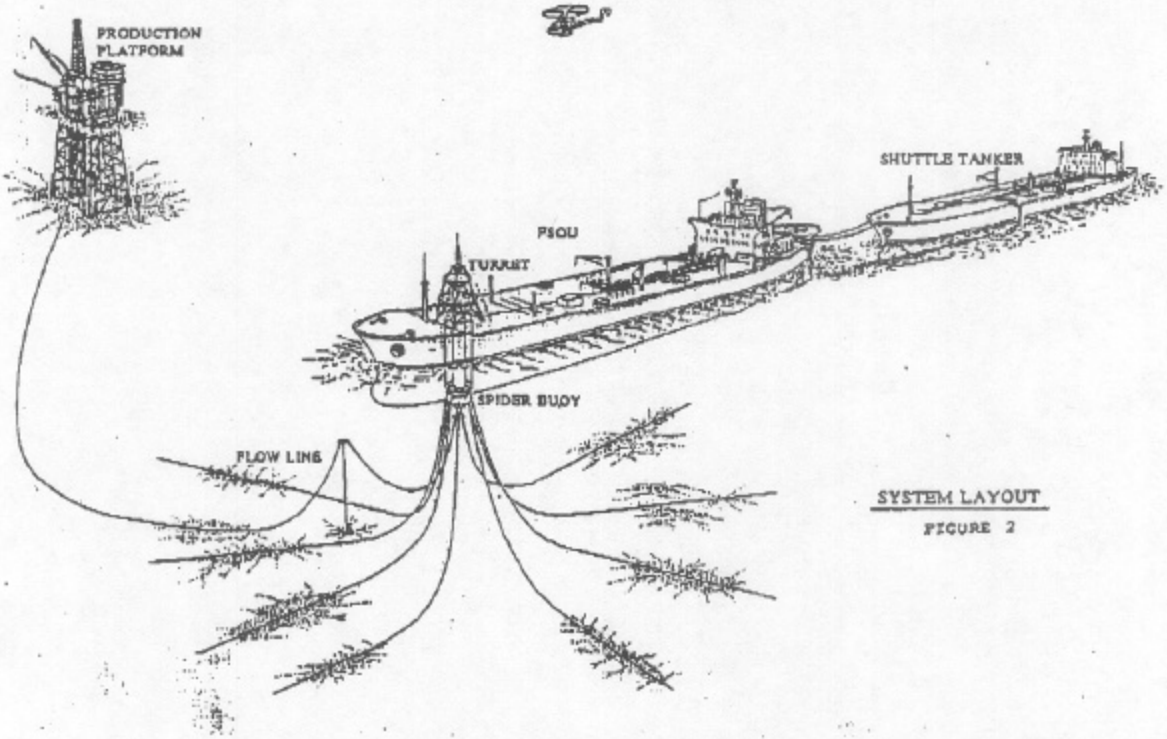


FIGURE 3 FIELD LAYOUT



SYSTEM LAYOUT

FIGURE 2

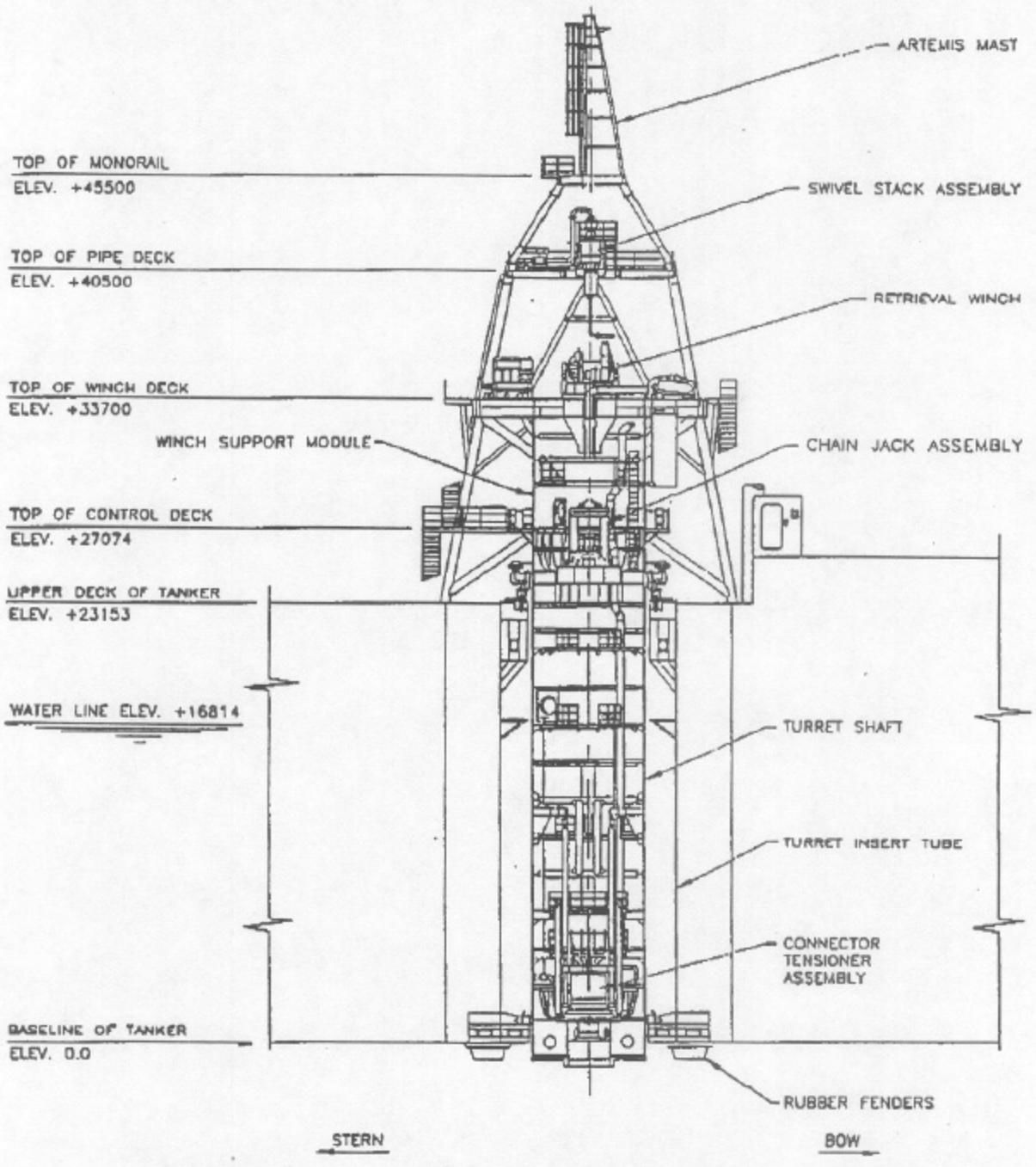
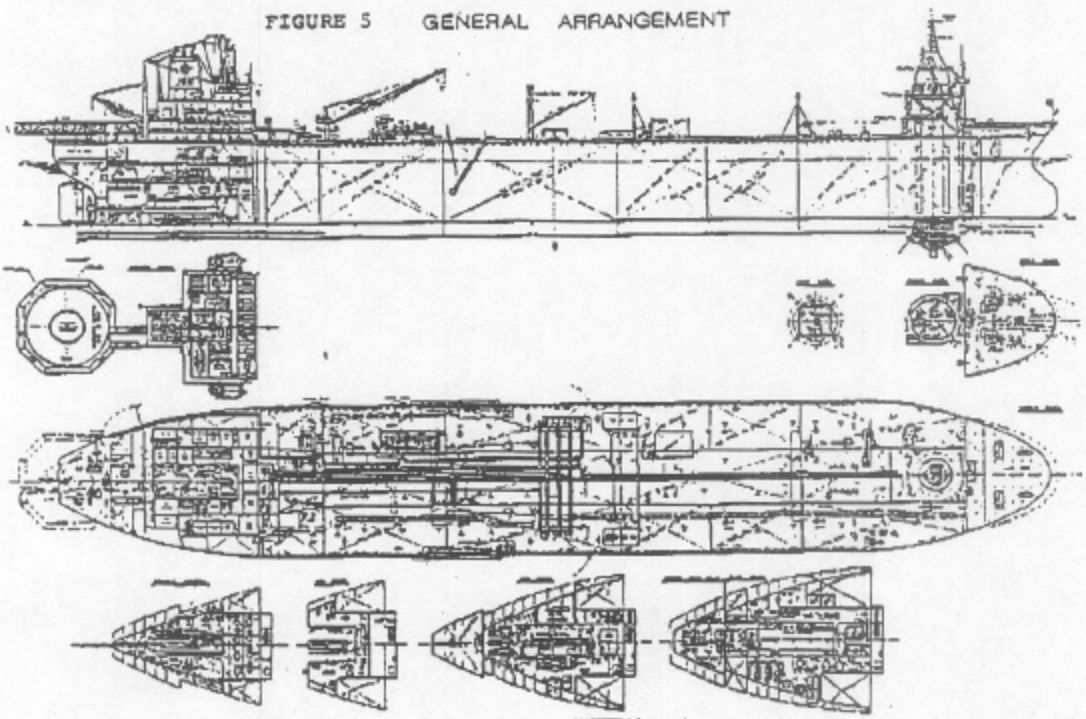


FIGURE 4 – ARRANGEMENT OF "ON-VESSEL" MOORING SYSTEM

FIGURE 5 GENERAL ARRANGEMENT



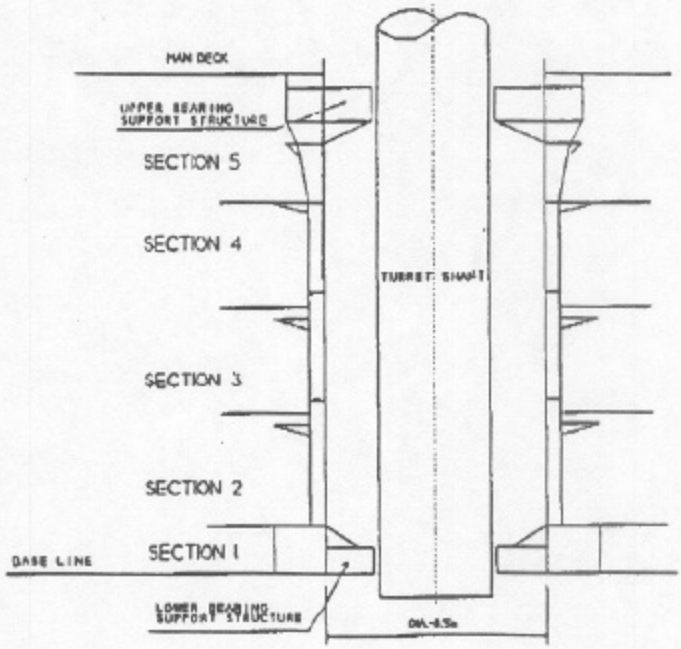


FIGURE 6 TURRET SUPPORT STRUCTURE LAYOUT

Figure 7 JHN FSOU PROJECT - EXECUTION SUMMARY

Row #	Task Name	Duration	Start	End
1	MAJOR MILESTONE EVENT	537.00 d	Feb/17/92	Aug/07/93
2	Contract Award	0.00 d	Feb/17/92	Feb/17/92
3	Tanker Arrival at Shipyard	0.00 d	Dec/16/92	Dec/16/92
4	Sail Out from Shipyard	0.00 d	Jul/22/93	Jul/22/93
5	Mechanical Completion at site	0.00 d	Aug/07/93	Aug/07/93
6	MOORING SYSTEM	522.00 d	Feb/17/92	Jul/22/93
7	Model Test	23.00 d	Feb/17/92	Mar/16/92
8	Engineering	304.00 d	Feb/17/92	Dec/16/92
9	Procurement	345.00 d	Apr/15/92	Mar/25/93
10	Spider Buoy Fabrication / Construction	331.00 d	May/30/92	Apr/26/93
11	Spider Bouy Transport	5.00 d	Apr/26/93	Apr/30/93
12	Turret Shaft Fabrication	294.00 d	Jun/01/92	Mar/21/93
13	Turret Shaft Transport	11.00 d	Mar/22/93	Apr/01/93
14	Turret Shaft Installation	90.00 d	Apr/02/93	Jun/30/93
15	Test & Precommissioning	22.00 d	Jul/01/93	Jul/22/93
16	TANKER CONVERSION	522.00 d	Feb/17/92	Jul/22/93
17	Basic Engineering	304.00 d	Feb/17/92	Dec/16/92
18	Detail Engineering	326.00 d	May/20/92	Dec/31/92
19	Procurement	381.00 d	Jun/15/92	Jul/16/93
20	Conversion Work / Overhaul Work	217.00 d	Dec/16/92	Jul/26/93
21	Dry Dock - 1st	20.00 d	Feb/01/93	Feb/26/93
22	Dry Dock - 2nd	18.00 d	Apr/20/93	May/05/93
23	Test & Precommissioning	22.00 d	Jul/01/93	Jul/22/93
24	FLOW LINE	351.00 d	May/15/92	Apr/30/93
25	Design / Engineering	185.00 d	May/15/92	Nov/15/92
26	Fabrication	166.00 d	Nov/16/92	Apr/30/93
27	INSTALLATION	89.00 d	May/01/93	Aug/07/93
28	Installation Spider Buoy & Flow Line	56.00 d	May/01/93	Jun/25/93
29	FSOU Sailing to Site	9.00 d	Jul/22/93	Jul/30/93
30	FSOU Hookup & Commissioning	8.00 d	Jul/31/93	Aug/07/93