THE NIGERIAN ESCRAVOS LIQUEFIED PETROLEUM GAS (LPG) FLOATING STORAGE & OFFLOADING (FSO) PROJECT

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INTRODUCTION

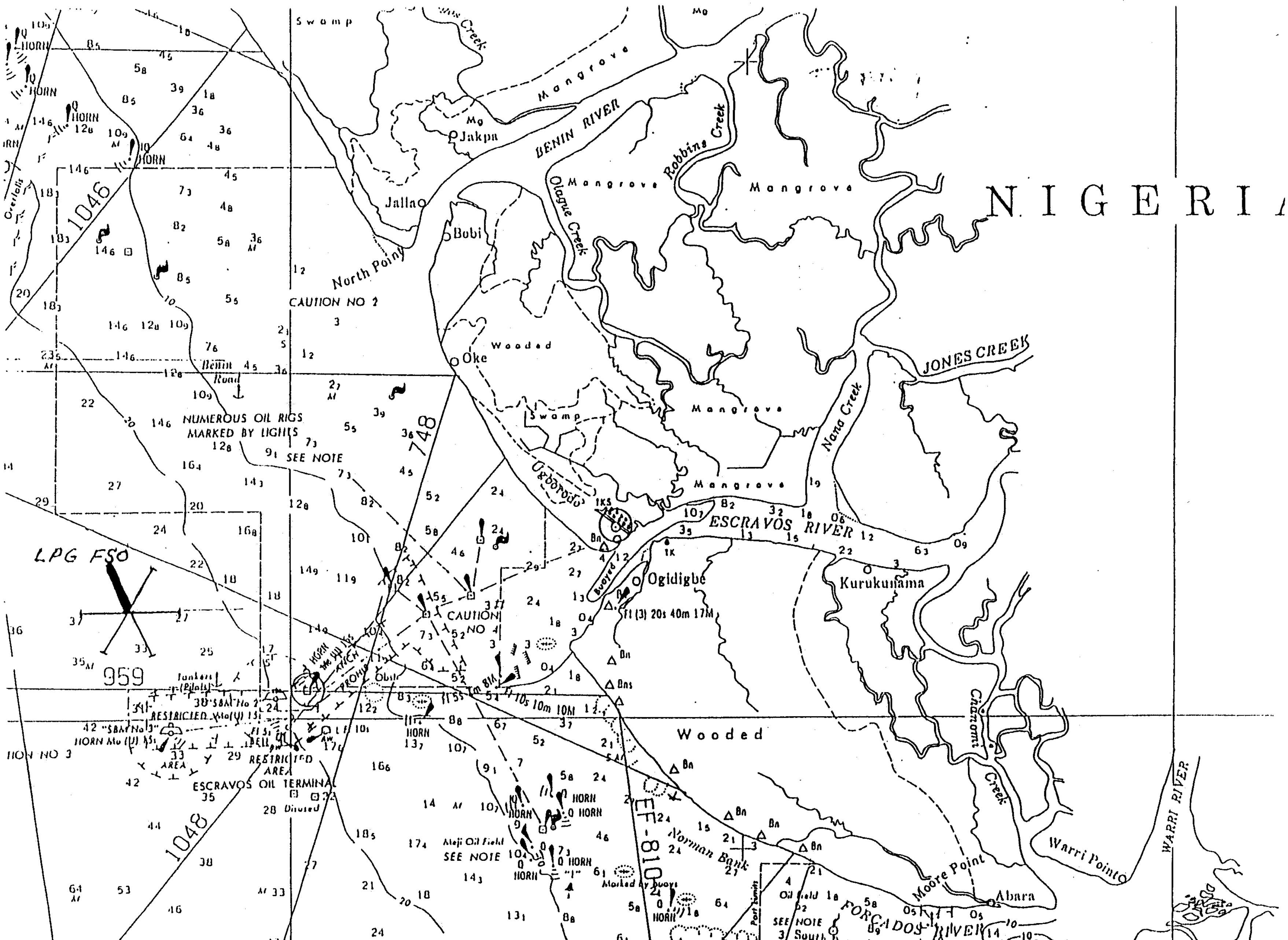
Natural gas has been flared for many years offshore of West Africa, which is a waste of Africa's natural resources of energy. Times are changing. A bold step has been taken by Chevron Nigeria Ltd/ Nigerian National Petroleum Company in the development of the oil and gas fields around Escravos, Nigeria. Gas will soon be sent to market rather than flared. Currently produced oil, gas and water from offshore fields is separated on the production platforms. Produced salt water is cleaned and returned to the sea, while the associated gas is flared. Oil is sent ashore via subsea pipeline to a tank farm for storage prior to being loaded into tankers for shipment to market.

As a result of this new project, associated gas will be pipelined to shore for processing and then shipped to market, rather than flared offshore. The gas will be route to a gas extraction plant where it will be separated into 1) condensate, 2) natural gas and 3) liquefied petroleum gas (LPG). The condensate will be sent to the crude oil tank farm for storage and then shipped to market by tanker. Natural gas (methane & ethane) will be routed into a gas transmission system for domestic consumption within Nigeria. Finally, mid range hydrocarbons (primarily propane and butane) will be liquefied into LPG at the extraction plant and then routed back offshore to an LPG Floating Storage and Offloading (FSO) vessel for storage and sales.

Several alternatives for LPG storage and sales were considered by the CNL/NNPC joint venture, including onshore storage, with off loading through conventional jetties or offshore marine terminals. However, based on the heavy costs required for maintaining adequate shipping channels at the mouth of the Escravos River, and the high costs and significant technical issues to be resolved in transporting the LPG to an offshore marine terminal, it was concluded that the offshore LPG FSO clearly provided the most attractive alternative.

A new build LPG FSO has been under construction for the past year by the general contractor Escravos FSO Inc. (A subsidiary of Mitsui & Co.) with subcontractors MODEC (technical project management), IHI-Aichi Works (shipyard construction) and SOFEC (mooring system design and supply). The vessel will leave the shipyard in Japan in late 1996 for installation offshore Nigeria in mid- 1997.

This paper will give an overview of the LPG FSO.


NIGERIA
BENIN RIVER
Robbins Creek
Olague Creek
Mangrove
Jakpa
Jalla
Bobi
North Point
Oke
Wooded
Swamp
Ugborodo
JONES CREEK
Nana Creek
ESCRAVOS RIVER
Ogidigbe
Kurukunama
Chanomi Creek
Warri Point
WARRI RIVER
Wooded
Norman Bank
Moore Point
Abara
FORCADOS RIVER
South Point
LPG FSO
959
1046
1048
748
EF-810
CAUTION NO 2
CAUTION NO 4
NUMEROUS OIL RIGS
MARKED BY LIGHTS
SEE NOTE
Benin Road
RESTRICTED AREA
ESCRAVOS OIL TERMINAL
Meji Oil Field
SEE NOTE
Marked by buoys
Oil field
SEE NOTE
HORN
Fl (3) 20s 40m 17M

LOCATION

The new vessel is proposed to be located some 33 kilometers offshore west of the mouth of the Escravos River, Nigeria at: Latitude 5 degrees, 33 minutes, 29 seconds North and Longitude 4 degrees, 54 minutes, 39 seconds East, in a water depth of about 28.5 meters. The attached navigation map shows the location. The ocean floor has a very gradual slope in this area. Soils are highly plastic clay recently deposited from the river delta. Layers of clay at the mud line are very very soft and significant soil shear strength does not appear until 23 meters below mud line. Long piling are required to go far below mudline to reach consolidated clay for an anchoring system for the FSO.

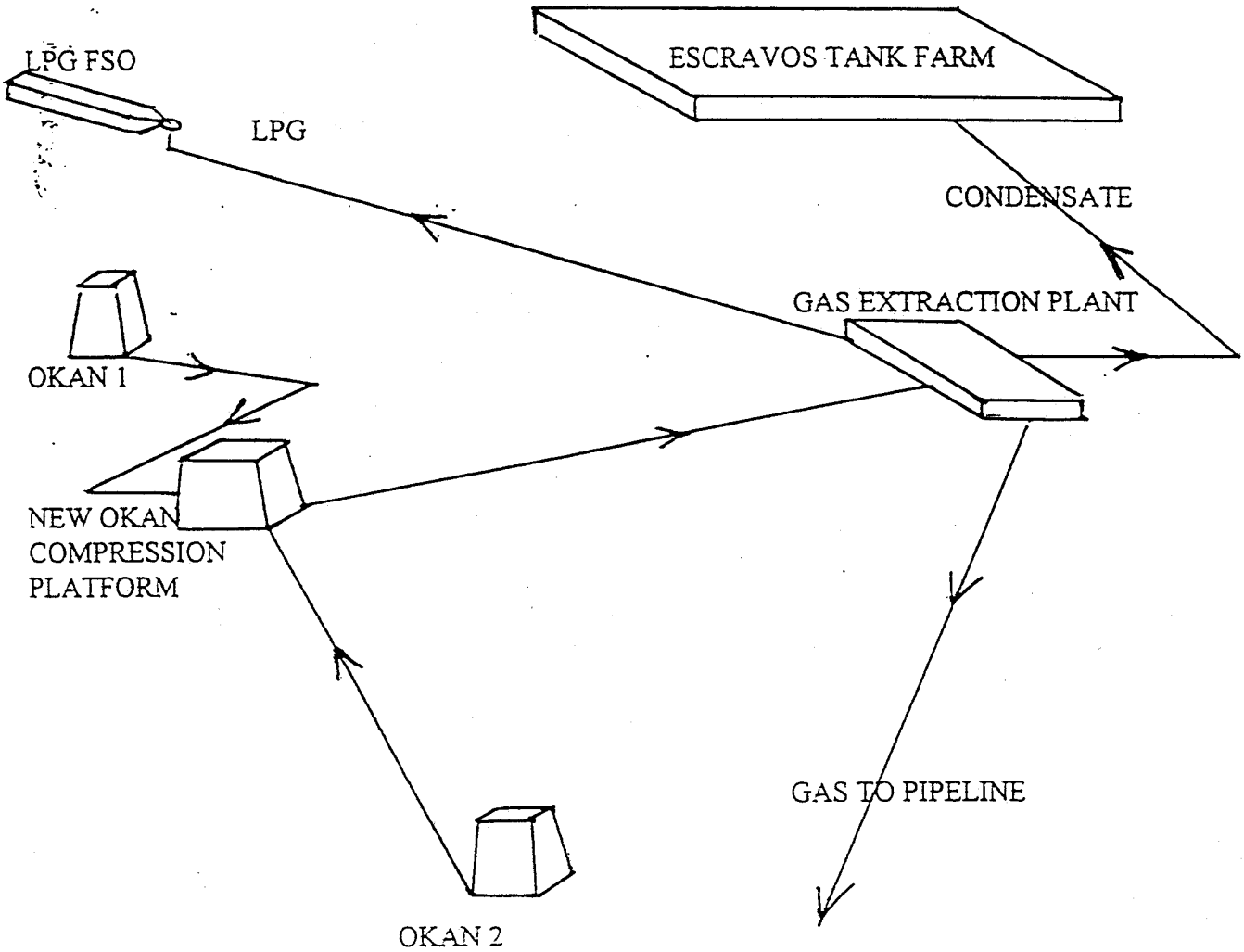
FIELD LAYOUT

The attached sketch shows the overall planned field layout for the Escravos Gas Project. Gas produced in the offshore Okan Field will be sent by pipeline to the new Okan Compression Platform for compression and then will be pipelined to shore to the Gas Extraction Plant. Here the gas stream is separated into condensate,. natural gas and liquefied petroleum gas (LPG) streams. After the LPG has been compressed into liquid form, it will be pipelined offshore to the LPG FSO for refrigeration to lower its vapor pressure. The LPG will be stored onboard at near atmospheric pressure and at low temperatures. A dedicated export tanker will be utilized to periodically off-load the LPG from the LPG FSO. The export tanker will be moored to the FSO via hawser located at the stern of the LPG FSO. A specially designed cold product temperature floating hose will be used to transfer the LPG from the FSO to the export tanker.

PROCESS DESCRIPTION

The LPG stream primarily consists of propane and butane. It will be compressed to liquid at 17 bars pressure at the onshore extraction plant and pipelined 33 kilometers to the FSO where it will be refrigerated and stored at near atmospheric pressure. The LPG FSO cargo pumps and refrigeration and reliquefaction equipment are being furnished by Kvaerner. Four refrigeration cooling units will be installed on the FSO to lower LPG vapor pressure. A production capacity of 3,180 cubic meters per day can be achieved. The refrigeration plants have oil injected screw type Howden compressors. The reliquefaction plant features three direct type Labyrinth piston units manufactured by Sulzer. Three sets of LPG storage tanks provide a capacity of 54,000 cubic meters at 98% of full storage capacity. Tanks are independent self supporting prismatic IMO Type B, with a design temperature of -49 degrees centigrade and a maximum design pressure of 0.28 bars. Tanks are externally insulated with 100 mm thick synthetic resin polyurethane foam panels, and the tanks are supported by hard plywood blocks. Six Kvaerner deep well cargo transfer pumps are installed, which have a capacity of 530 cubic meters per hour per pump, allowing the FSO to unload to the export tanker in about 20 hours, utilizing a specially designed low temperature floating hose.

ESCRAVOS GAS PROJECT



VESSEL DESCRIPTION

The new build vessel currently under construction at the IHI - Aichi Works shipyard is significant in that it is the world's first purpose built LPG FSO storage vessel fabricated from steel. The principal particulars are as follows:

LOA	163.8 m
Beam	36.0 m
Depth, Molded	23.4 m
Design Draft	10.85 m
Deadweight	37,000 mt
Gross Tonnage	40,000 t
Accommodations	50 people
Classification	American Bureau of Shipping
Certification	ABS +100A1
Regulations	IMO, IGC, SOLAS, MARPOL, COLREG, API, OCIMF, SIGTTO
Design Life	30 years

The FSO also meets the Nigerian port regulations of the Department of Petroleum Resources, Nigerian Maritime Authority, and the Nigerian Port Authority. The vessel is scheduled to leave the shipyard in late 1996 and be installed offshore Nigeria in early 1997.

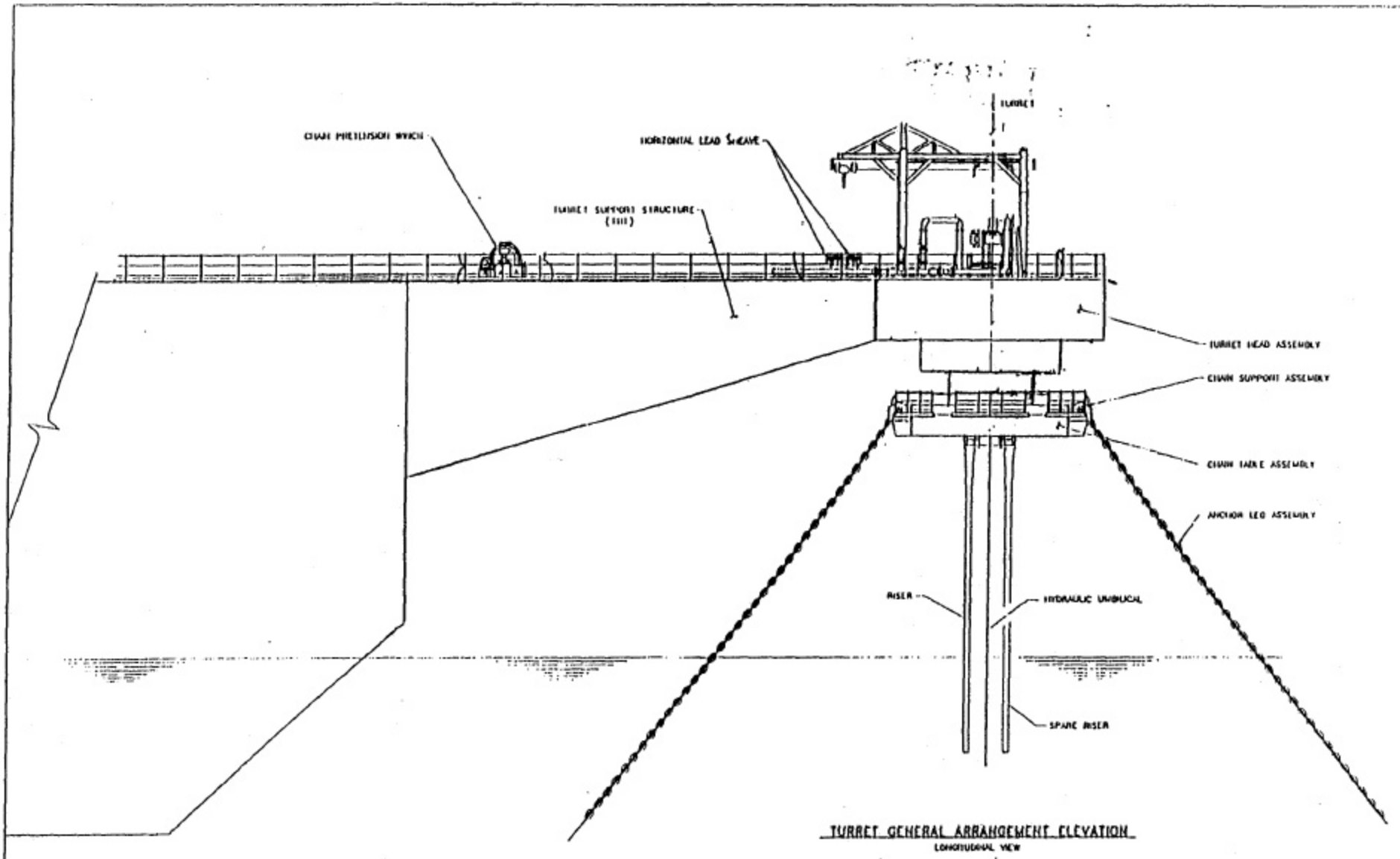
ENVIRONMENTAL DESIGN CRITERIA

Weather conditions offshore Nigeria are relatively mild compared with areas far away from the equator. The external turret mooring system for the FSO is designed for a 100 year storm for wind, wave and current environmental conditions. Environmental design criteria used to design the FSO and its mooring system are:

Water Depth	28.5- 30 m
Wave Hs	3.0 m
Wave Period	15-17 seconds
Current	1.2 knots
Wind Velocity	30 m/sec
Tide	1.2 m

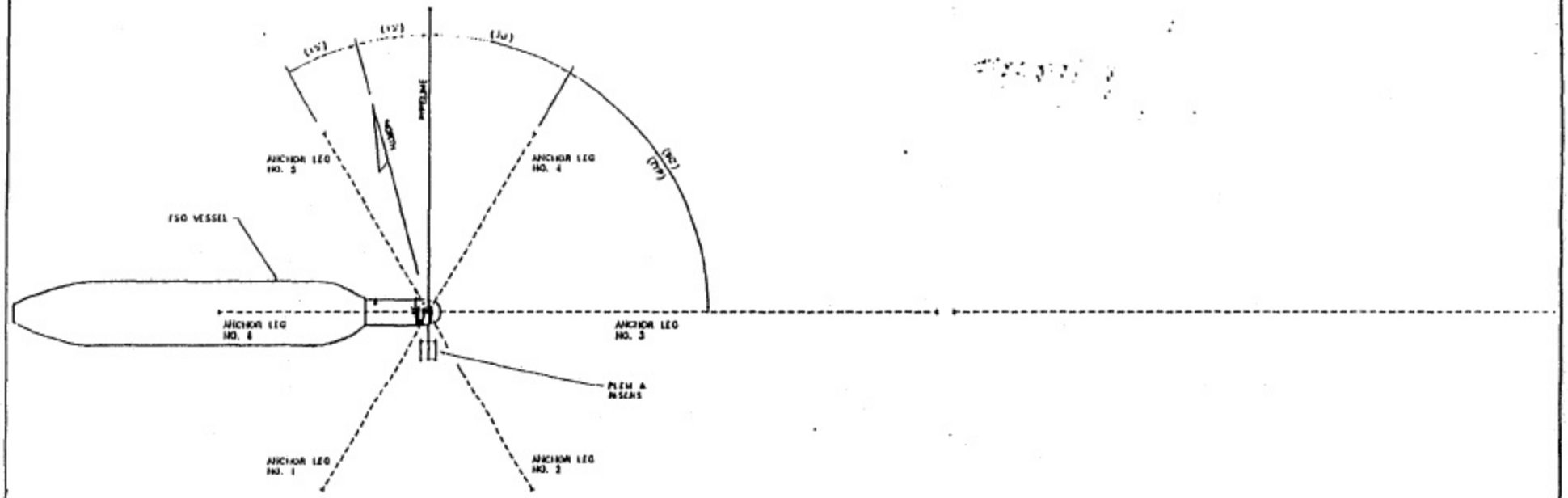
MOORING SYSTEM

While deep water depths and severe environmental conditions certainly pose many challenges to the designer, in some instances very shallow water depths may be equally or even more challenging. Long flat mooring lines are required for shallow water mooring systems. The Escravos FSO will feature an external turret weathervaining mooring system designed and built by FMC SOFEC. The turret will be cantilevered from the bow of the new built barge in order to avoid interference between the mooring chain and the vessel's keel. The environmental

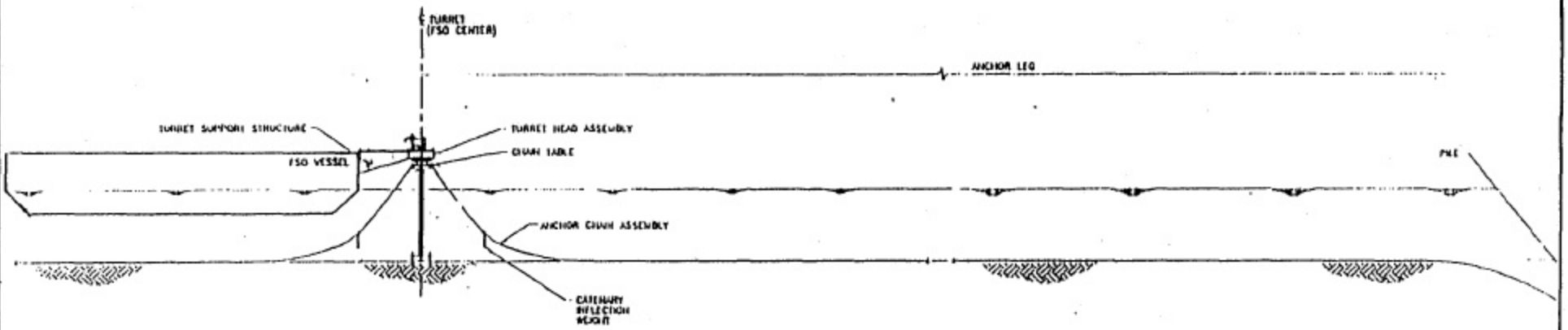


TURRET GENERAL ARRANGEMENT ELEVATION

LONGITUDINAL VIEW



PLAN VIEW OF SYSTEM GENERAL ARRANGEMENT



ELEVATION OF SYSTEM GENERAL ARRANGEMENT

conditions off of the coast of Nigeria are characterized by fairly benign wind, wave and current conditions, however, there is a fairly consistent swell along the coast which can frequently exceed 2-1/2 meters significant wave height for extended periods of time. This maximum swell combined with very light associated wind and current creates a unique design condition. The swell can be at 90 degrees to the wind and waves, which makes the design environment unusual with troublesome vessel motions. Because this environment provides for very little mean offset of the FSO vessel, the relatively large swell induced low frequency vessel excursions in the upstream direction give rise to potential interference between the anchor legs and the FSO keel. The anchor leg configuration and outboard location of the turret must then be optimized to eliminate interference. Ideally a fairly soft mooring with a low preload would be considered to maximize the separation between the anchor legs and the vessel's keel in still water conditions. Since the maximum allowable excursions of the riser system in this shallow water depth are severely limited, the mooring system must also be stiff enough to limit the extreme FSO offsets.

The Escravos environment has a specified maximum operating condition (5 year return period) that is nearly identical to the survival conditions (100 year return period). This is combined with the fact that the LPG export tanker (80,000 cubic meters capacity) is even larger than the moored LPG FSO (55,000 cubic meters capacity). This results in a situation where many of the design values are governed by the maximum operational condition. Extreme downstream offsets of the tandem moored vessels in maximum operating conditions can be even greater than the offsets of the FSO alone in survival conditions. The resulting anchor leg design involved a ration of required strength that is somewhat larger than normally required for turret moored systems. The design of the mooring system included extensive model tank testing to verify computer generated analytical results. Components of the mooring system included :

Anchor Piles	(6) - 915 mm diameter x 29.5 m pipe
Anchor Legs	(6) - 3 inch Grade 3 chains
Flexible Riser	(2) - 8 inch production line in a Lazy-S configuration
Swivel	(2) - 8 inch production line, 47.5 bar, torodial
	(1) -Hydraulic Swivel, 3,000 psi, 4-1/2 inch

PHOTOGRAPHS

A series of color slides are included in the presentation to show :

1) Model Tank Testing of the moored LPG FSO with shuttle tanker attached
2) External Turret Mooring System Fabrication and Loadout
3) Swivel Construction
4) Offshore Installation of the Mooring System Anchor Piles and PLEM
5) Shipyard Construction of the LPG FSO

SUMMARY

This unique Escravos LPG FSO will be installed in early 1997. It will be a significant step in the effort to put out the gas flares and conserve Nigeria's natural resources.

BIOGRAPHY

Mr. Bev Edwards
Regional Sales Manager for Africa
FMC SOFEC

Mr. Edwards received a B.S. in Civil Engineering and an M.S. in Civil Engineering from Oklahoma State University and is a registered Professional Engineer in Texas. He has over 30 years of experience in structural design, project management of offshore oil and gas facilities and marine construction equipment, mostly offshore West Africa.

PROGRAMME

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