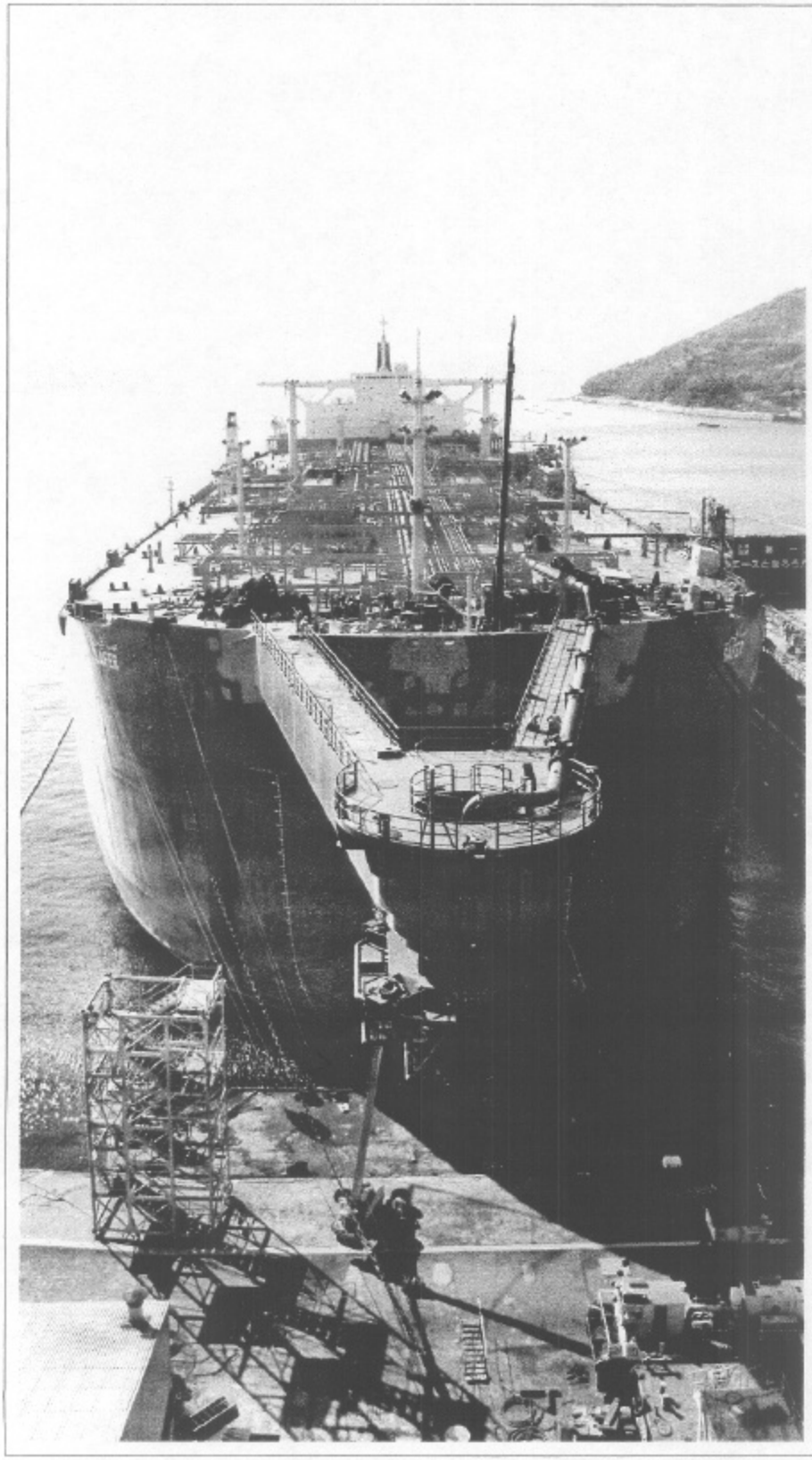
Ocean Industry
THE MAGAZINE FOR OFFSHORE BUSINESS



Technology at Work

Production

- Wireline innovation for subsea wells
- Turret mooring for giant FSO tanker
- Sea trials advance multiphase status

Platform concepts

- How TLP designs can cut project cost
- Articulated barge eases launch loads

ABOUT THE COVER. The 409,000 DWT tanker *Safer* prepares for its journey to the Yemen Arab Republic (formerly North Yemen) in Mitsui Engineering & Shipbuilding's Yura yard, Japan, after installation of the SOFEC-designed turret mooring and loading system. The floating storage and offloading system will transfer onshore production to transport tankers in 122-ft water. First oil flowed through the system on March 22, 1988. Photo courtesy SOFEC Inc., Houston.

Turret mooring completes world's largest FSO system

Unique shallow water mooring on bow of 409,000 DWT tanker is part of the 2.5 million-bbl storage and offloading system recently installed in 122-ft water off the coast of the Yemen Arab Republic

IN JANUARY 1988, SOFEC Inc. completed design and construction of a turret mooring system for Yemen Exploration & Production Co. (YEPCO). The turret mooring was constructed and mounted to the bow of the 409,000 DWT tanker *Safer* (an Arabic word meaning "journey") by Mitsui Engineering & Shipbuilding's (MES) Tamano and Yura yards. *Safer* sailed to location and was installed at YEPCO's offshore site in the Yemen Arab Republic (formerly North Yemen) where first oil flowed on March 22, 1988. Formerly *ESSO Japan,* the tanker, and its production facilities, constitute the largest permanently moored floating storage and offloading (FSO) system in the world.

Described here are details of the single point mooring (SPM) turret, how it was designed, built and installed, and how it operates. Also presented is an overview of the FSO storage and offloading system with emphasis on the crude handling risers, swivel, valves and controls.

Advantages/design criteria. The weathervaning turret mooring provides a simple and economical SPM which eliminates buoys, articulations and hinges usually associated with permanent tanker moorings. The design places all critical components above the water in accessible locations, with the main bearing location optimized to minimize reaction forces.

The FSO system presented a very difficult design problem because of the shallow water—122 ft—deep vessel draft and large wave height. However, the completed system provides permanent floating storage in excess of 2.5 million bbl thus eliminating the requirement for a major onshore tank farm. The entire facility operates efficiently in all weather conditions and requires less manning than the traditional tank farm and export terminal. And it was constructed and installed at a much lower cost.

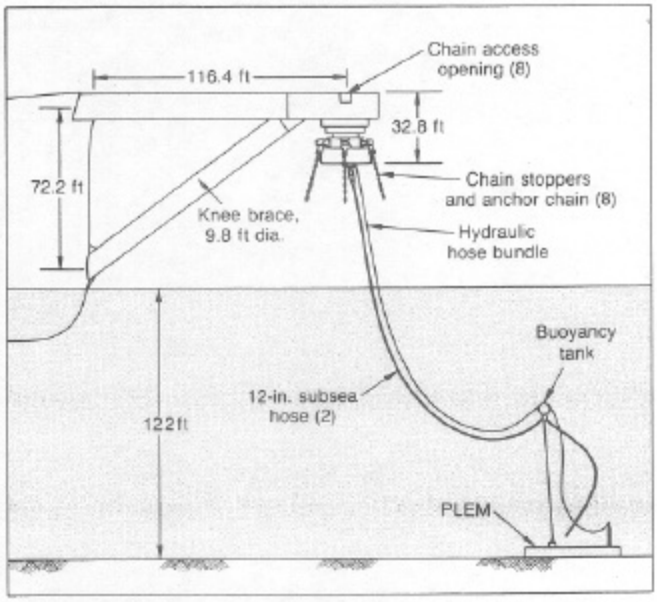
One hundred year storm design criteria for the floating storage system are:

Water depth, ft	122
Significant wave height, ft	20.5
Wave period, sec	10.45
Wind velocity, kt	59
Current velocity, kt	1.43
Design life, yr	20

The SPM is designed to survive the 100-yr storm with the FSO vessel in all draft states from fully laden to a minimally-loaded survival draft of 38 ft even keel with no export vessel moored alongside. However, alongside mooring of up to 300,000 DWT vessels is planned in conditions up to 10-ft significant wave height with 35-kt winds.

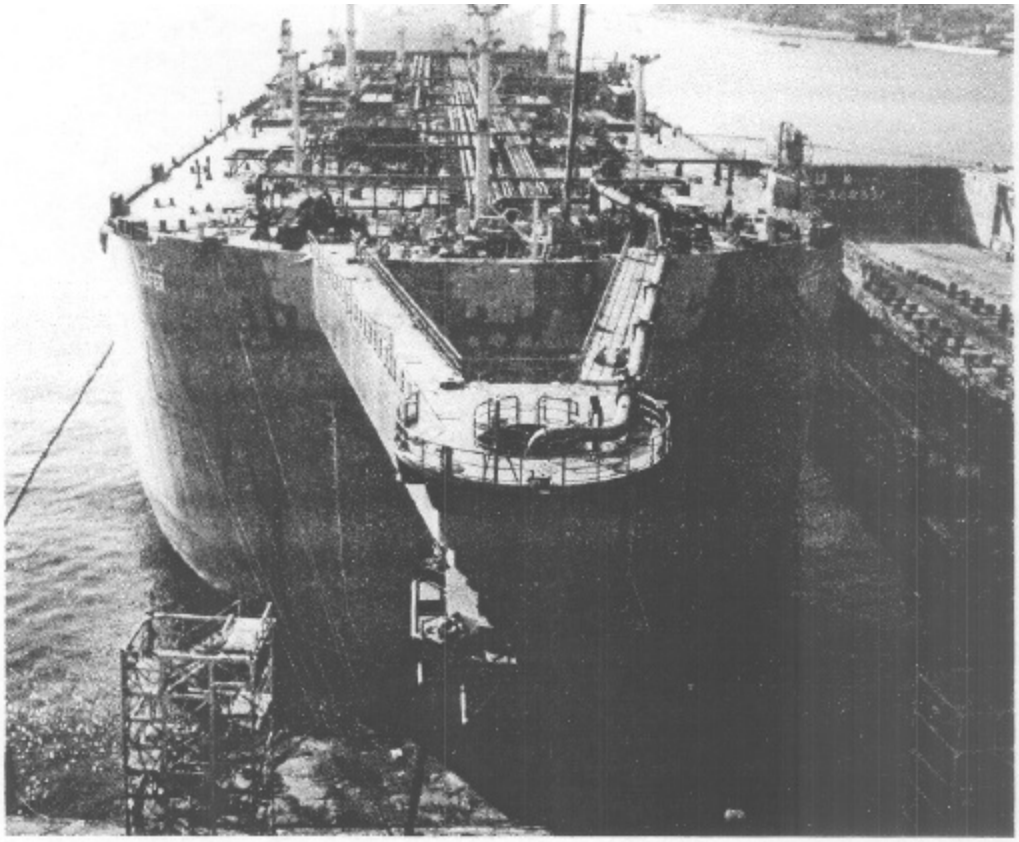
Provisions have been made for future expansion of the system to export crude and to handle ballast water through a second SPM. Crude will then be loaded at maximum rates up to 400,000 bpd, with a design export rate of 80,000 bph. Future ballast water will be processed at 25,000 bph.

SOFEC designed the complete system. Detailed structural design for the tanker attachment was provided by long-term associate MODEC (Mitsui Ocean Development & Engineering Co.). The turret mooring system is classified + A1 by American Bureau of Shipping.



INCOMING CRUDE hoses from pipeline end manifold (PLEM) and 6-line hydraulic control hose umbilical to PLEM valves. Mooring chains extend 1,110-1,444 ft to 48-in. anchor piles.

Turret description. The bow-mounted turret is attached to the tanker by two large, 3.5 × 3.0-m (11.5 × 9.8-ft), box girders extending forward some 35.5 m (116.4 ft) from the main deck level, and a tubular kneebrace extending upward and forward from below the waterline at the bow. The bow attachment was dictated in part by a project requirement that the tanker steam from the conversion yard to the site. This requirement dictated that propeller and rudder remain in-place and operational. However, once onsite, the prop shaft was locked and *Safer* was reclassed as a permanently-moored storage barge. Also the tanker had no bulbous bow, which facilitated turret attachment.



TURRET MOORING on reclassified 409,000 DWT tanker *Safer*. Visible in foreground are mooring chain stoppers on chain table below main bearing and 24-in. incoming crude line to FSO above the single-product swivel.

The turret extension provides clearance between mooring chains and tanker bow and permits the chain table to be located well above water level. This significantly improves system elasticity and provides easy access to the main bearing.

The welded steel turret housing is 35 ft in dia. with a 14-ft-dia. centerwell in which product and hydraulic control swivel units are mounted. The outer race of the chain table bearing is supported by the turret housing.

The chain table is supported from the inner race of the bearing. It is a welded steel unit, oval in shape and measuring 33.5 × 30 ft, which provides a mounting for the chain stoppers.

These stoppers which lock the anchor chain legs to the chain table serve as hawse pipes for the chains. They are mounted to the table by means of bronze-bushed trunnions which permit rotation about an axis perpendicular to the chain leg and thus greatly reduce chain wear. Each stopper is 7 ft long with 26-in. OD and weighs some 7 t.

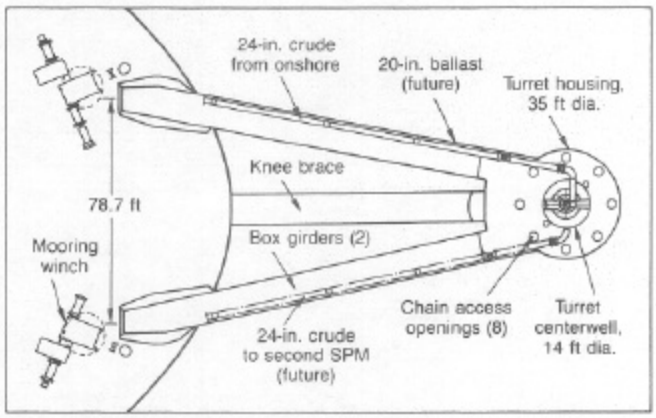
The chain table bearing is a 13.5-ft OD, three-race roller bearing. It is fully sealed in a steel housing and lubricated by an automatic system.

The complete turret was constructed (at MES) by SOFEC on an accelerated schedule which required only five months from contract through completion including mounting the turret on the tanker.

The turret mooring is actually the second complete system constructed for this project. The first unit, fabricated by AG&P in Batangas, Philippines, and attached to the tanker at Hyundai Mipo Dockyard was destroyed in a ship collision during typhoon Thelma in the summer of 1987.

Mooring/crude handling/valve control. The catenary mooring system for the turret consists of six, 6-in. dia. Ramnäs Grade ORQ chain legs arranged in an asymmetric pattern to most efficiently accommodate the distinctive regional environment. Chains range in length from 1,110 ft to 1,444 ft and are anchored to the seafloor by 48-in dia. piles.

Risers/crude oil system. Crude is routed from the pipeline end manifold (PLEM) to product piping on the SPM through two strings of 12-in. submarine hose. The hoses are



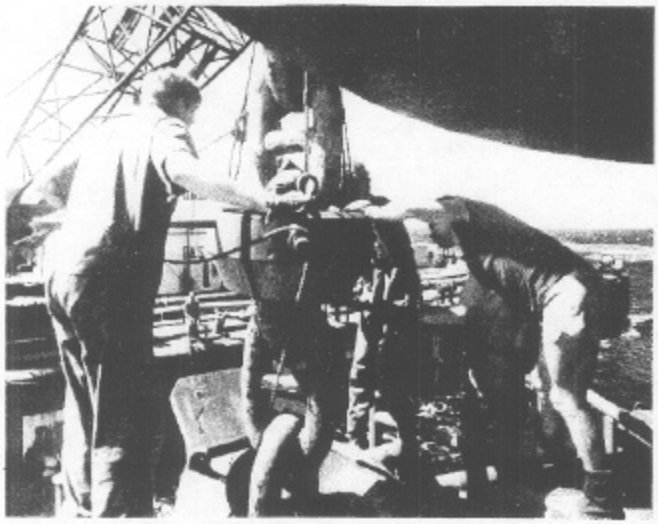
PLAN VIEW of turret mooring supported by 9.8 × 11.5-ft box girders and 9.8-ft dia. knee brace.

arranged in a Steep-S configuration supported by a bouyancy tank 67 ft above the seafloor. The hoses terminate at the SPM through universal joints which incorporate short lengths of specially reinforced hose. These joints hinge on two bronze-bushed pins mounted 90 degrees apart. The articulations allow 40-degree rotation and thus relieve bending moments, and reduce stresses in the hoses.

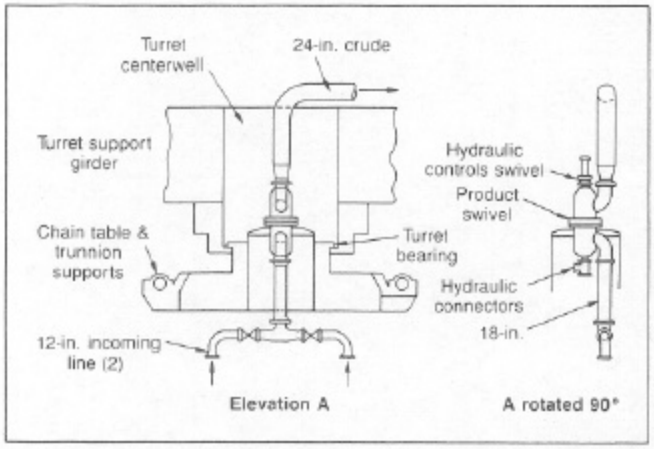
Crude is routed onboard the SPM through two, 12-in. pipe runs which combine into a common line before entering the main chamber of the product swivel. Crude exits the swivel and enters a 24-in. line routed along the port turret support girder on sliding supports to the fo'c'sle deck of the FSO and on into the cargo storage tanks. An expansion joint is included in the product line to allow for differential temperature growth.

The product fluid swivel is a single product unit with a 30-in. main body dia. The design incorporates primary and backup seals on both crude and atmospheric sides. Pressure taps between primary and backup seals at all sealing locations are used to detect any leakage past primary seals.

The lower fluid swivel body is supported from the chain



CHAIN STOPPER on 6-in. ORQ chain fits into top of 7-ft-long chain hawse pipe.



SCHEMATIC of turret bearing, product swivel and hydraulic control lines swivel in turret centerwell.

table and the upper body is attached to and rotates with the turret housing. Torque for rotation is supplied through a structural "torque arm" which prevents turning forces from being transmitted into the product piping.

The fluid swivel is mounted on a ball bearing which is connected to the central, automatic lubrication system. The entire swivel unit is 9.5 ft high and weighs 9,500 lb.

Valve control system. PLEM valves may be remotely operated from the tanker by hydraulic controls routed through a hydraulic swivel (with six, ½-in. paths) which is mounted atop and concentric with the product (fluid) swivel. A hydraulic hose bundle consisting of seven, ½-in. lines encased in a wire-armored polyurethane jacket provides the link between PLEM valve operators and the FSO. The hydraulic hose bundle is mounted in a universal joint at the chain table and is arranged in a Steep-S draped across the top of the buoyancy tank.

System installation. Anchor piles were driven by National Petroleum Construction Co. during mid-1987 while the barge was in the field installing pipelines and the PLEM. At this time, anchor chains were also installed, pretensioned, then laid on the seafloor and marked.

When *Safer* arrived, it was held on-station by tugboats while a deck winch was utilized to pull the chains into their respective chain stoppers. Once captured, the anchor lines were then pulled to proper initial tension, again utilizing the deck winch and moveable routing sheaves. Hook-up of the submarine hose system was accomplished by divers and the system was tested and brought into service. ■

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