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Design, Fabrication, Installation and Operation of a Single Anchor Leg Mooring (SALM) Tanker Terminal in 300 Feet of Water

By

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ABSTRACT

This paper will cover the design, fabrication, installation and operation of a Single Anchor Leg Mooring (SALM) system which is presently functioning as a tanker loading terminal and is an integral component of an offshore oil production field located in nearly three hundred feet of water. The paper will deal with the design and installation techniques which were used to adapt this system to the deep water application and with the operational performance of the system. The SALM is used to permanently moor a tanker which is receiving product directly from the production platform. Included will be a discussion of the unique problems encountered during the design and installation of this very deep water mooring system and with the unique but increasing application of an SPM as part of an offshore production field.

References and illustrations at end of paper.

INTRODUCTION

Within the past several years, the Oil Industry has experienced the necessity to search for and develop oil fields in geographic locations which are increasingly remote. These locations are not necessarily suitable for economic development by conventional methods and therefore require the utilization of new techniques in order to achieve production at acceptable costs.

One of these techniques is the implementation of a tanker loading terminal as an integral part of the field production equipment. This can allow for direct load-out of the oil into transport tankers and negate the necessity for lengthy and expensive submarine pipelines and related shoreside equipment.

Typically, the loading terminal may be a Single Point Mooring (SPM), located one and one-half to two miles from the production platform and connected to the platform by a length of submarine pipeline. A shuttle tanker moored to the SPM will receive product through the pipeline and will, when loaded, carry the product to the specified point of discharge for further processing, while another shuttle tanker is being loaded at the SPM.

Alternatively, a Slave Tanker, or floating storage vessel, may be permanently moored to the SPM continuously receiving the crude oil production and discharging the product into separate shuttle tankers for transport to discharge ports. Utilization of such a Slave Tanker eliminates the necessity for "shutting-in" the production periodically, as in the case when shuttle vessels are repeatedly moving on and off the mooring.

Historically, SPMs have been used as transfer terminals for oil products being moved to or from shore stations. As such, the systems have normally been located in sheltered waters and in relatively shallow depths. Integration of these systems into an offshore production complex subjects the facilities to much more extreme environmental conditions and often require their installation in significantly deeper water than heretofore experienced.

In order to function properly in such an environment, the Single Point Mooring Facility must be properly designed and fabricated. Additionally, system design and installation sequence must be coordinated to insure a properly executed installation utilizing techniques which are applicable to exposed location, deep water construction operations.

This paper describes the Design, Fabrication, Installation and Operation of an SPM Terminal which was recently installed in the Tembungo Field in nearly 300 feet of water, 50 miles offshore in the South China Sea. This Terminal, a Single Anchor Leg Mooring (SALM) system, serves as part of an offshore production facility and is designed for permanent mooring of a floating storage vessel which will function as a terminal for smaller shuttle tankers as previously described.

DESIGN OF THE SALM

The Tembungo SALM Terminal is designed to provide a permanent offshore mooring for continuous loading of a 94,000 DWT floating storage vessel. The basic characteristics of the terminal system are illustrated in Figure 1. Shuttle tankers will moor alongside the storage vessel for transfer of crude oil and transport of the crude oil to the market. As a permanent mooring facility, the SALM is designed to safely moor the 94,000 DWT vessel in seas up to 21 feet significant wave height (39 feet maximum wave height), combined with 65 MPH winds and a current velocity of 2.0 knots, acting perpendicular to the wind and wave direction. (NOTE: Currents acting parallel to wind and wave direction are less critical.)

The SALM Terminal, with a tanker moored, constitutes a large "spring mass" system. The "spring system", which includes the Buoy, Single Anchor Leg and the Mooring Hawser, assumes the energy created by the displacement of the "mass" (the tanker) as it responds to waves, winds and currents. The peak forces developed in the Mooring Hawsers and transmitted into the load-carrying components of the system are basically dynamic forces developed as the tanker oscillates with slow sway, yaw and surge motions. The magnitude of these peak forces is governed by the elastic characteristics of the mooring system, which determines the rate of energy absorption and thus the peak forces. The elastic characteristics are, in turn, governed by the force vs. displacement characteristics of the Buoy and Anchor Leg System combined with the elastic characteristics of the Mooring Hawser.

System Parameters which govern the rate of energy absorption are:

1. Net buoyancy of the Mooring Buoy
2. Distance from the Shaft Universal Joint to CB of Buoy
3. Length of Riser Shaft
4. Net buoyancy of Riser Shaft
5. Distance from Base U-Joint to CB of Riser
6. Length of Mooring Hawser
7. Elastic characteristics of Mooring Hawser

The corresponding peak forces were evaluated by an energy/force correlation method developed by Exxon Research and Engineering Company and Exxon Production Research Company in conjunction with a series of over 400 model tests in irregular seas.

This method relates peak mooring forces to the maximum energy absorbed by the mooring system while a vessel is moored to a Single Point Mooring under given sea and current conditions. The energy absorption capacity required for varying tanker sizes and wave and current conditions has been established by an extensive series of model tests with tanker sizes ranging up to 500,000 DWT. The basic concepts of this method are described further in OTC Paper No. 1536 by N. R. Maddox.

Design of the Tembungo SALM to meet the operational requirements and yet adapt itself to state-of-the-art installation techniques at the deep water location required sound, innovative engineering. Specifically, it required the development of an anchoring system suitable for economic installation at the 296 foot depth and of heavy duty hydraulic actuated structural connections for joining major components underwater.

The SALM Mooring Base provides the anchoring force necessary to hold the vessel on station. Obviously, this anchor force must provide a significant safety factor beyond predicted loadings and must be capable of being installed in a manner which insures that the design conditions are met.

Previous SALM installations have utilized a torispherical Mooring Base which is held in position by piles driven through sleeves in the Base and grouted in place. These installations have been set in water depths less than 150 feet and driving of the piles was accomplished with the use of conventional pile hammers and followers. In the 300 foot water depth at the Tembungo site, it was anticipated that pile driving would be extremely difficult and that problems inherent to lengthy followers, underwater stabbing of the piles and grouting operations would create unacceptable installation difficulties.

Fortunately, the soils data which had been obtained at the installation site showed that the bearing capacity of the underlying soils strata was adequate to support a gravity anchored structure and that such a structure would be acceptable from all aspects of design. The decision was therefore made to utilize a gravity base concept in lieu of anchor piles.

With this decision in hand, a plan was developed for a gravity base consisting of a large 80 foot diameter by 20 foot tall steel structure which would be placed onto the seafloor and subsequently filled with a ballast material to achieve the required in-place anchor weight. The Mooring Base includes eight radial buoyancy tanks to provide flotation and to facilitate installation and a circumferentially mounted, hinged skirt to provide protection against the scouring effect of current and storm waves. The in-place weight of the Base, with ballast installed, exceeds 2000 tons. The steel structure itself weighs almost 300 tons. The basic design of the Mooring Base is illustrated in Figure 2.

Mounted on a center pedestal in the Mooring Base is the Base Universal Joint (Figure 4). This U-Joint is permanently affixed to the lower end of the Riser Shaft and is attached to the Mooring Base by a hydraulically actuated set of large key blocks which can be set (and retracted) underwater. The U-Joint allows the Riser Shaft to pivot through a 60° angle (with respect to vertical) in all directions. The U-Joint weighs approximately 35 tons and the bearing pins are 16 inches and 14 inches in diameter.

The 8.5 foot diameter by 185 foot long Riser Shaft weighing 120 tons (Figure 3) pivots about the Base U-Joint and extends upward from the Base to the point 78 feet below the surface. This Riser Shaft is predominantly a structural member serving as part of the Single Anchor Leg which carries the mooring loads to the Anchor Base. Additionally, the Riser houses the 10 inch crude oil piping from near the seafloor to the Fluid Swivel Assembly mounted on top of the Riser Shaft.

The Fluid Swivel Assembly mounted on top of the Riser (Figure 5) consists of a load-carrying Center Shaft and a Fluid Swivel Housing. The Housing rotates about the Center Shaft so that the cargo hose can follow the tanker as it weathervanes about the Mooring Buoy. Mooring loads carried through the Center Shaft are isolated from, and therefore, have no effect on the Swivel Assembly or the Flexible Hoses.

The Mooring Buoy (Figure 3) is a 22 foot diameter by 36 foot deep cylindrical structure weighing 120 tons and providing over 250 tons of net buoyancy. The Buoy is designed for safe submergence to a depth of up to 110 feet and is anchored to the top of the Riser Shaft by a length of 6 inch Oil Rig Quality Chain. Integral to this Chain Leg are two Universal Joints (Figure 4), one at the base of the Buoy, the other just atop the Riser and an Anchor Chain Swivel to permit the weathervaning rotation of the Buoy and the moored vessel. Large rubber fenders are attached to the periphery of the Buoy to protect it from damage should the tanker overrun the mooring. Experience has proven that in cases where a tanker may accidentally overrun the Mooring Buoy, the Buoy will simply be pushed underwater and resurface without damage to any vital parts of the system.

Mooring Hawsers attached to the mooring brackets on the Buoy are shackled to bitts on the tanker to complete the mooring hook-up.

Crude oil flows to the tanker through a flexible hose running from the Fluid Swivel Assembly on top of the Riser Shaft through a flexible hose to the tanker manifold. A steel Hose Arm connects the flexible hose to the Fluid Swivel. This Hose Arm provides a moment arm to facilitate turning the Swivel; additionally, it is vertically swiveled to allow relative oscillations of the Riser Shaft and the hose string to occur without inducing detrimental strain to the hose system. This location of the connection of the hose system to the mooring facility at a point well below the effect of surface wave motions is a primary difference between the SALM and other SPM systems, and accounts for superior performance with respect to maintenance of the hose system and Fluid Swivel components.

Flotation beads and adjustable buoyancy tanks are used to set the desired "reverse S-curve" profile of the hose as it rises from the Swivel to the surface. This curvature provides an ideal transition zone which damps surface induced forces on the hose and prevents these forces being transmitted to the Fluid Swivel.

FABRICATION

Design of the SALM insured that available fabrication techniques could be employed. The large structural components (Base, Buoy and Riser Shaft) are straightforward shipyard-type fabrication and therefore adaptable to construction at available facilities near the installation site. The remainder of the system components are of a size and weight that does not preclude long distance transport and therefore can be fabricated at centralized facilities and transported to the assembly area.

The Base, Buoy and Riser for the Tembungo SALM were constructed at a shipyard in Singapore, as was the Lower Universal Joint. Fabrication specifications basically conformed to the applicable AWS, AISC, ASME and API codes. Welding quality and material composition were insured by on-site inspection and testing personnel.

The fabrication and erection techniques made maximum use of the facilities and capabilities of the shipyard and allowed for sub-component fabrication at established shop locations with final erection and sub-component assembly taking place at a waterfront assembly area.

The Buoyancy Chambers in the Mooring Base were fabricated in an enclosed heavy fabrication shop making use of automatic welding and positioning equipment. Segments of the Riser Shaft and Mooring Buoy were assembled in a similar manner, as were the heavy weldments at the center of the Base and at either end of the Riser Shaft.

Final assembly of the equipment was accomplished adjacent to the waterfront. Careful consideration was given to the layout of the three pieces, as no land-based lifting capabilities were available which could handle the finished component weights. The Riser was assembled close to the water and the Base and Buoy were both assembled on skid-ways so that they could be moved to the water's edge for load-out using a sea-going crane.

Construction of the Universal Joints, Fluid Swivel Assembly and Chain Swivel required a large amount of thick plate fabrication and close tolerance machining. As such, assembly of these pieces was accomplished in high-quality shops with the required capabilities. Quality Control was again extremely strict, with particular emphasis being given to the special problems inherent to thick plate welding and large component machining.

The Buoy and Shaft Universal Joints were fabricated in the U. S. as was the Fluid Swivel Assembly. Following completion and testing, these units were shipped to Singapore. The large Base Universal Joint, with the hydraulically-actuated assembly to latch onto the Mooring Base, was fabricated in Singapore.

All other components of the SALM, including the Anchor Chain Swivel, Fluid Swivels, Mooring Hawser, Hoses, Anchor Chain, etc., were purchased in accordance with specifications from suppliers in the U. S. and overseas.

In general, all moving parts i.e., Chain Swivel, Fluid Swivels and Universal Joints are overlaid with monel and employ the use of dual seals, both internally and externally. The bearings in the Fluid and Chain Swivels are life-lubricated, as are the bushings and thrust washers used in the Universal Joints.

The submerged SALM components are designed for maximum life in the seawater environment. Thus far, the experience record of the SALMs installed offshore Libya in 1969, and off Okinawa in 1971, substantiate the validity of the design. There have been no failures or replacements of any of these components, and maintenance has been restricted to visual observation and operational testing.

The 6 inch Anchor Chain was proof-tested to 2,440,000 lbs. following fabrication and was certified by Lloyds. The Anchor Chain Swivel was proof-tested twice to 900 tons and was rotated and torque-tested when axially loaded to 600 tons.

Following completion of Fabrication, all of the SALM components were shipped to Singapore where they were assembled, tested and prepared for load-out. All of the connections which were to be made offshore were tested repeatedly to insure proper fit-up. To the largest extent possible, the offshore construction personnel and divers who would be involved in the installation work were present during these assembly tests. Operational sequences were thoroughly reviewed and tested, and finalized procedures were established.

This type of on-shore "dress rehearsal" is a very necessary activity and pays definite dividends when the equipment is offshore and installation commences. Particularly with regard to underwater activities, prior familiarization with the equipment and the exact installation sequence will save time and money and, most importantly, prevent construction errors which might compromise the functional integrity of the finished product.

For this Project, the following proof tests, assembly trials and component assembly were accomplished prior to load-out:

A. The Hose Arm Assembly was attached to the Fluid Swivel Assembly and the entire unit was tested under hydrostatic pressure and for rotational resistance.

B. The Fluid Swivel and Hose Arm Assembly was connected to the top of the Riser Shaft with sixteen (16) 2-3/4 inch high strength bolts. Additionally, the cargo piping was connected and the entire assembly, from the end of the Hose Arm to the base of the Riser Shaft, was hydrostatically tested.

C. The Lower Universal Joint was trial-fit to the Mooring Base and the hydraulically actuated locking blocks were positioned. This fit-up was practiced on three separate occasions.

   The U-Joint is lowered into a large welded bracket at the center of the Mooring Base. Guidelines are used for initial line-up and guideposts on the Base insure the final proper alignment. Once in position, four sliding key blocks in the U-Joint lower weldment are hydraulically driven into mating posts on the Mooring Base to affix the two pieces together. After the key blocks are set, wedges are placed behind them so they are mechanically locked into position.

D. The Lower Universal Joint was attached to the lower end of the Riser Shaft with sixteen (16) 2-3/4 inch high strength bolts and the hydraulic control circuitry was connected and tested.

E. The Riser Shaft Universal Joint was trial-fit to the top of the Fluid Swivel Center Shaft. This attachment is accomplished by lowering the U-Joint onto the Center Shaft so that eight tapered holes on each assembly are in line. Tapered pins are then hydraulically driven into the holes. Locking bolts are used to insure that the tapered pins do not work loose during operation.

INSTALLATION

Installation of the Tembungo SALM took place during the Summer of 1974. The production platform and the 10 inch submarine pipeline which would connect the production facilities to the mooring system were in place, the line having been laid on bottom and tested.

Installation activities included placement of the SALM on location in the near-vicinity of the pipeline, connection of the pipeline to the SALM, installation of the floating hoses and mooring assemblies onto the SALM and hydrostatic testing of the entire assembly from the end of the hose through the SALM and pipeline and back to a flange on top of the pipeline riser at the production platform.

Construction equipment committed to the Project included a 275 foot by 78 foot Work Barge with living quarters and an American 9310 Crawler Crane, a 200 foot by 50 foot Launch Barge and auxiliary cargo barges and tug boats. Diving equipment onboard the Work Barge consisted of a Diving Bell System with two double-lock decompression chambers, a surface decompression chamber and related mixed-gas and air diving apparatus.

The installation site was approximately 50 miles offshore and over 850 miles from the fabrication and assembly yard in Singapore. Water depth approached 300 feet and sea currents exceeding 2 knots were encountered. The exposed location was subjected to continuous swells and periodical storms resulted in sea conditions exceeding 8 - 10 feet.

The installation sequence called for the Mooring Base to be carried to location, launched into the sea and then lowered into position next to the pipeline. The pipeline manifold would then be connected to the submerged line and ballast placed into the Base while the Launch Barge returned to Singapore to pick up the Riser Shaft, Buoy and auxiliary equipment.

Following return of the barge and cargo to location, the Riser Shaft was to be launched and locked into position on top of the Base, the Mooring Buoy and Anchor Leg Assembly connected to the top of the Riser and the loading hose and mooring lines connected and tested.

The Launch Barge was a unique piece of equipment specifically designed to carry large loads offshore and to launch these loads into the sea, thus negating the requirements for a large capacity offshore Crane Barge. Additionally, the Launch Barge has two lifting horns extending from the bow. A winch positioned at each horn provides a lifting capability of 200 tons per horn or 400 tons total. These winches were utilized to lower the Mooring Base to the seafloor.

The cargo deck of the Barge is 140 foot by 50 foot with vertical columns, located both fore and aft, extending some 20 feet above the cargo deck. Once on location, a ballast system integral to the Barge is used to submerge the Barge onto these columns, thereby submerging the cargo deck and allowing the load to be floated off the deck and clear of the Barge.

All of the major SALM components i.e., Base, Riser and Buoy contain integral flotation chambers which provide buoyancy and stability while in the water. The capabilities of the intended construction equipment were maximized so far as possible by the final design of the SALM.

When the SALM fabrication was complete and the installation equipment prepared, the first load-out commenced. At this time, the pipeline manifold, subsea pipeline connector and most of the hose was loaded onboard the Work Barge. Simultaneously, the 300 ton steel Mooring Base was loaded onto the Launch Barge. This load-out was accomplished by lifting the Base with a 300 ton stiff-leg barge and setting it onto the Launch Barge. Prior to load-out, the Base was skidded from the fabrication site to a position directly adjacent to the waterfront.

Both Barges then moved to the installation site where the Work Barge anchored into position above the end of the pipeline. Upon arrival of the Launch Barge and Mooring Base, the Base was prepared for launching. All rigging connecting the Base to the Barge was removed and the launching operation commenced.

During the launch, the Launch Barge was moored behind a tug. Ballast was pumped into the Barge so that it submerged on its fore and aft columns. When the cargo deck was approximately 4-1/2 feet below water, the SALM Base floated free and was pulled clear of the Barge. The Barge was then secured alongside the Work Barge and the Base towed into position in front of the Launch Barge and beneath the lifting horns. Rigging was secured between the lifting (lowering) lines of the Launch Barge bow horns and the Base.

Valves were then opened in the Base to allow water to flow into the structure and the Base settled until it was floating entirely on the radial flotation tanks. The surface flotation tanks were then flooded, causing the Base to become negatively buoyant, suspended beneath the bow horns and held by the barge lowering wires.

During the operation, a local squall caused the sea conditions to increase with wave heights up to 6 - 8 feet. The Barge and Base began to heave out of phase causing severe loads on the lifting wires. Fortunately, the situation was brought under control without severe damage occurring to any of the equipment.

The Base was then lowered to a point 5 - 8 feet off bottom and divers descended in the Bell to orient it with respect to the pipeline. Orientation was accomplished by moving the Cargo Barge on its anchor lines.

Once in position, the Base was set on bottom, rigging removed and the Scour Protection Skirt deployed by removing the restraining wire which held the skirt up against the Base.

The Launch Barge then returned to Singapore for the second load-out while the pipeline manifold was set and connected to the pipeline and ballast was placed into the Base. A hydrocouple-hydro-ball was used to connect the pipeline manifold to the sea line.

Ballast material for the Base was 4 inch to 9 inch granite stone which was loaded onto barges in Malaysia and towed to location. At the site, the Gravel Barge was secured alongside the Work Barge and ballast was placed into the Base through a 270 foot long, 20 inch diameter steel chute. The chute had two dredge-pipe ball joints, 100 feet and 200 feet below the surface to provide flexibility and was supported at the surface by a free floating buoy welded to the top of the chute. Ballast material was then fed into the chute via a conveyor from the barge which deposited ballast into a hopper at the top of the chute. At the Base, ballast was directed by moving guidelines and the Cargo Barge so that the ballast was deposited uniformly within the Base.

A total of 2,650 cubic yards of ballast was handled with 2,300 cubic yards being required to fill the Base. Approximately 15% was spilled outside the Base itself. Throughout this operation, visual observation was conducted from within the Diving Bell with occasional diving excursions being made to verify ballast placement.

In Singapore, the Launch Barge loaded out the Riser Shaft, Buoy and the remainder of the SALM components. The Fluid Swivel Assembly and Hose Arm were mounted on top of the Riser and the Lower U-Joint was affixed to the base of the Shaft. The Buoy U-Joint was welded onto the Buoy Center Shaft in the yard. Once on location, the Anchor Chain and Anchor Chain Swivel were attached to the Shaft U-Joint and the entire assembly connected to the Buoy Universal Joint on the Buoy.

The Barge was ballasted down and the Riser Shaft pulled free. The Riser and Buoy had been placed onto the Launch Barge in such a manner so as to insure that the Riser would float off at a shallower depth of submergence than would the Buoy, thereby allowing one component to be launched at a time.

With the Riser floating horizontally in the sea, water was pumped into the lower chamber causing the Shaft to rotate to a vertical position. With the lower chamber filled, the top of the Riser floated 12 feet out of the water.

Guidelines were then attached to the Shaft to guide the Lower Universal Joint into position on top of the Base. The crane on the Work Barge was rigged to the lifting pads at the top of the Riser Shaft and water was pumped into the upper chamber so that the Riser would take on a negative buoyancy.

The Riser was then lowered onto the Base with the crane. During the operation, the seas picked up again and movement of the Riser required that it be set on bottom away from the Base until the seas slackened. When the weather improved, the Riser was picked off bottom, positioned over the Mooring Base and lowered into position with the Universal Joint setting into the center weldment of the Base.

The Shaft is free standing and once in position, all lifting lines were removed by divers. Divers then actuated the hydraulic cylinders in the Base U-Joint to lock the U-Joint onto the Mooring Base. Back-up wedges were inserted and the assembly completed. All water was removed from the Riser upper chamber and the fill ports blocked off.

Next, the Buoy was launched into the sea with the Anchor Chain, Chain Swivel and Riser U-Joint suspended below the Buoy U-Joint. Water was pumped into the four lower chambers in the Buoy causing it to rotate to an upright position. At this point, the Buoy was submerged several feet below its design draft, thus providing the necessary slack to allow the Shaft U-Joint to be locked on top of the Riser Shaft.

To accomplish this, the Shaft U-Joint was supported by the crane and lowered on guidelines into position atop the Center Shaft. Divers then inserted the eight tapered pins locking the two components together. These pins were set with hydraulic rams and safety-locked in position with lock bolts.

The water in the lower compartments of the Buoy was then pumped out causing the Buoy to gain significant positive buoyancy and set the required pretension into the Mooring System.

Hoses were installed between the Riser Shaft and the pipeline manifold and from the Hose Arm up to the surface. The contour of the hose as it rises from the Hose Arm to the surface was properly set by adjusting the buoyancy in the four hose buoyancy tanks.

A pressure test was initiated and when the pressure held over a 24-hour period, the system was accepted by the Operator. The construction equipment was released and the SALM lay ready for the first tanker mooring and production from the Field to begin.

OPERATION

The SALM was completed and accepted in early September, 1974; approximately one month later, the first tanker arrived at the mooring. This vessel remained moored for several weeks until it was loaded, at which time production was discontinued while the vessel delivered its cargo to port. Production resumed when the vessel was back on the mooring. Duration of each vessel on the mooring will decrease as daily production rises and eventually, it is expected that the permanent storage vessel may be moored to the SALM.

This type of service is not typical for SPMs. Normally, tankers are connected to the Buoy for relatively short durations with several mooring and un-mooring operations occurring each month. Adaption of the Terminal to fit the mooring and cargo transfer requirements of a variety of vessels creates logistics problems for the Mooring Master and unfamiliarity with the berth can cause occasional difficulties.

Under standard mooring systems, the vessel is rarely left on the Buoy if weather worsens and seas build up above ten feet. The large diameter hoses are subject to damage at the tanker rail in bad weather and maneuvering of a VLCC near a buoy in bad weather induces risks which are best avoided.

In a production buoy situation such as Tembungo, the ability to get onto and stay on the buoy during adverse weather is much more important. Without a tanker moored to the SALM, production must be shut-in, therefore every effort must be made to maintain the mooring and loading operations on a continual basis.

System design has, of course, been considered as a factor which affects operational performance. Beyond that, it is necessary that the personnel who operate the Terminal understand both the system capabilities and the potential problem areas. Problems inherent to "permanent mooring facilities" are somewhat different to those faced at a conventional Terminal and it is expected that experience with the particular equipment in the particular environment will soon dictate operational techniques and procedures.

Mooring and loading operations are facilitated by the fact that the same vessels are continually calling on the Terminal and both tanker crew and Terminal Operators are familiar with the techniques required for successful operations. The smaller diameter hose is more easily handled and functions better under adverse conditions and except in rare instances of extremely adverse weather, the SALM is functioning in an environment far less strenuous than the conditions for which it was designed.

Operations at Tembungo have thus far been successful. Tankers using the SALM have been successfully moored and maintained on the moor as required. Production has been maintained and the crude oil has been delivered to the Market as planned.

CONCLUSION

The short operational history of the Tembungo SALM has resulted in relatively consistent production since the Field was prepared to produce. The SALM was designed, fabricated and installed within a time frame which allowed the earliest possible initiation of production and all problems inherent to deepwater, exposed location installations were successfully overcome.

This system is a good example of the successful use of a Single Point Mooring as an integral component of an Offshore Production System allowing early and economical production without the time-consuming and costly installation of a lengthy underwater pipeline.

REFERENCES

Maddox, Notley Roger: "An Energy Basis For The Design Of Open-Ocean Single-Point Moorings", 1972 Offshore Technology Conference, May 1 - 3, 1972, OTC 1536.

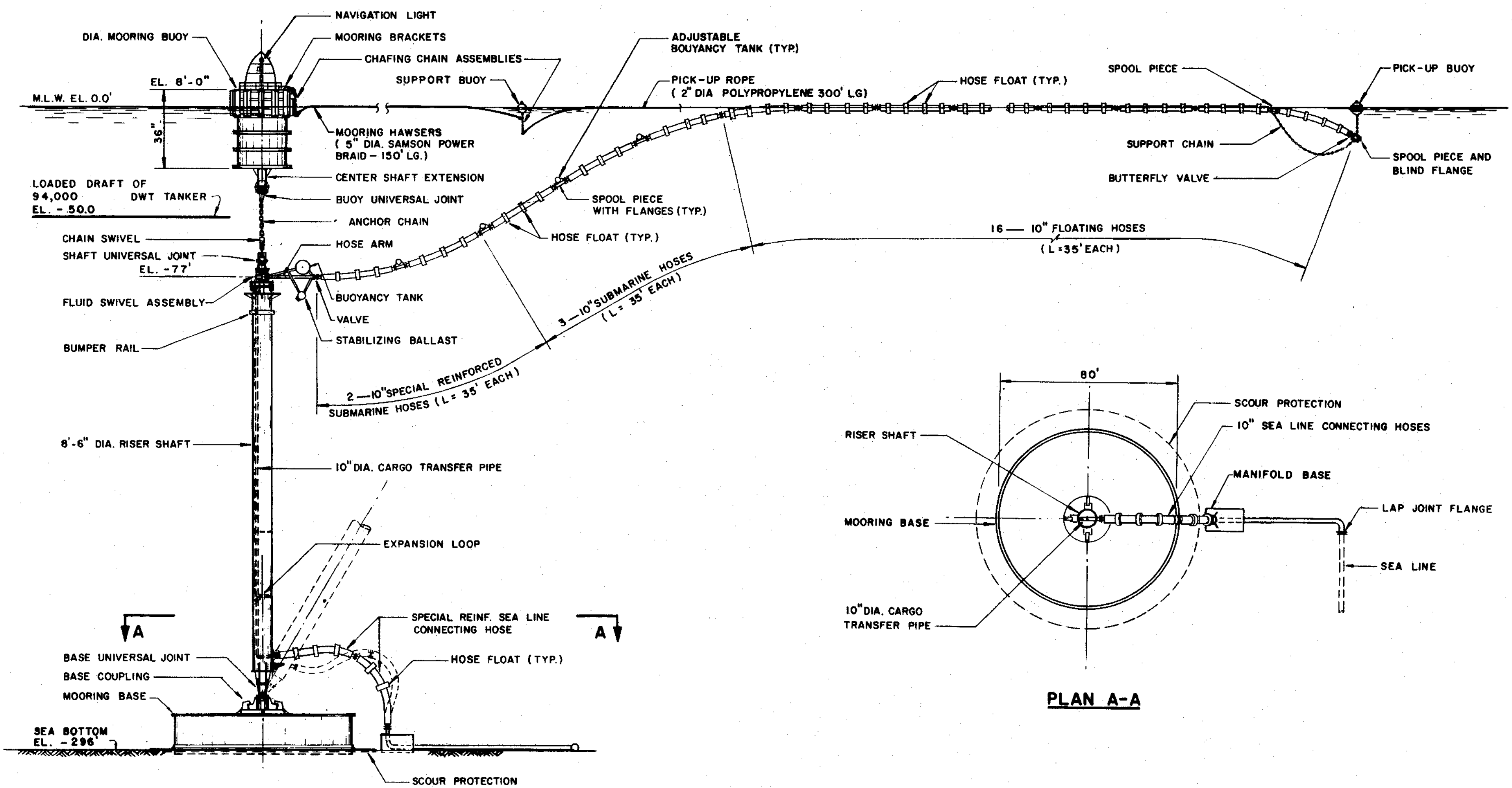

Fig. 1 - Tembungo SALM general arrangement.

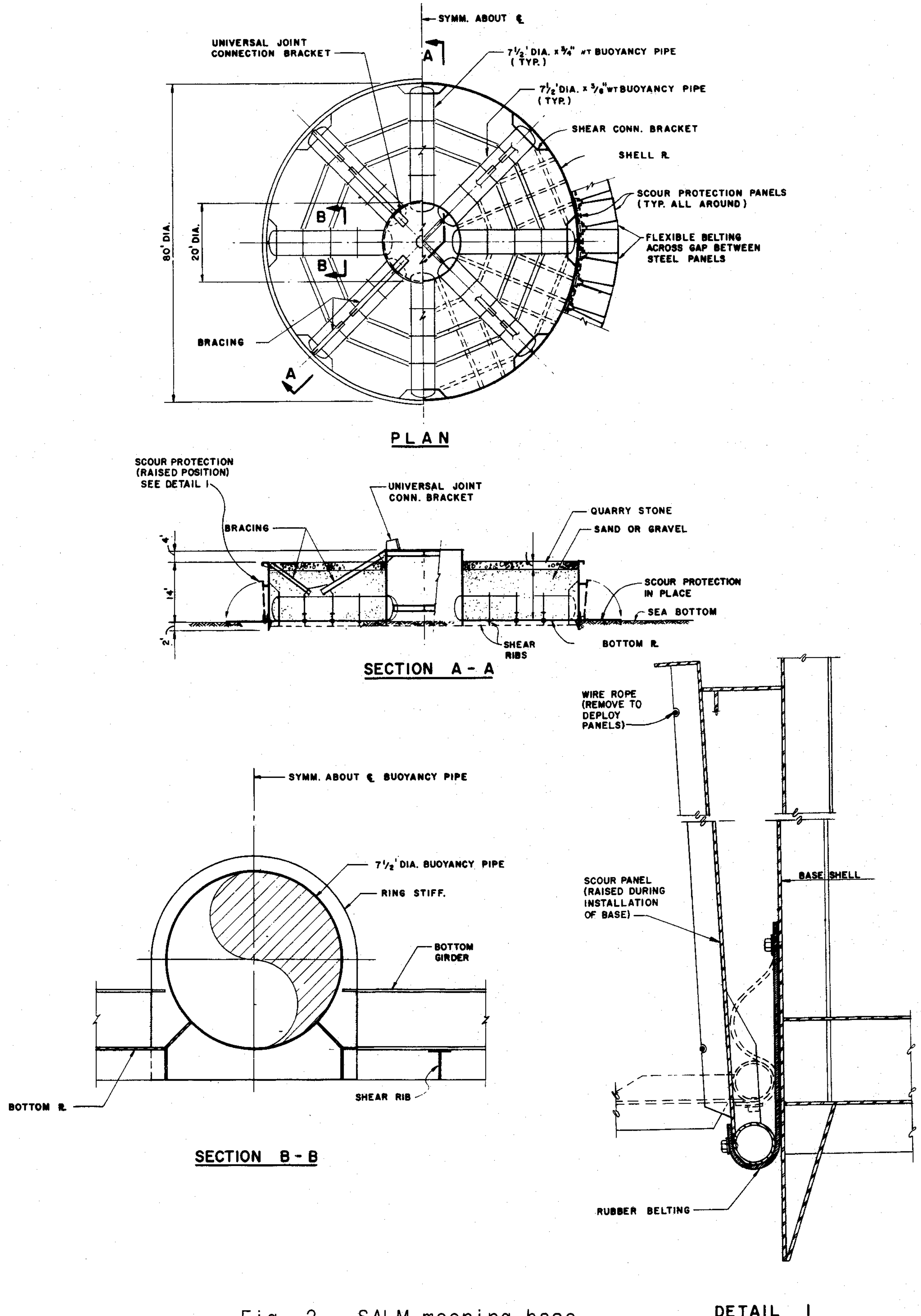

Fig. 2 - SALM mooring base.

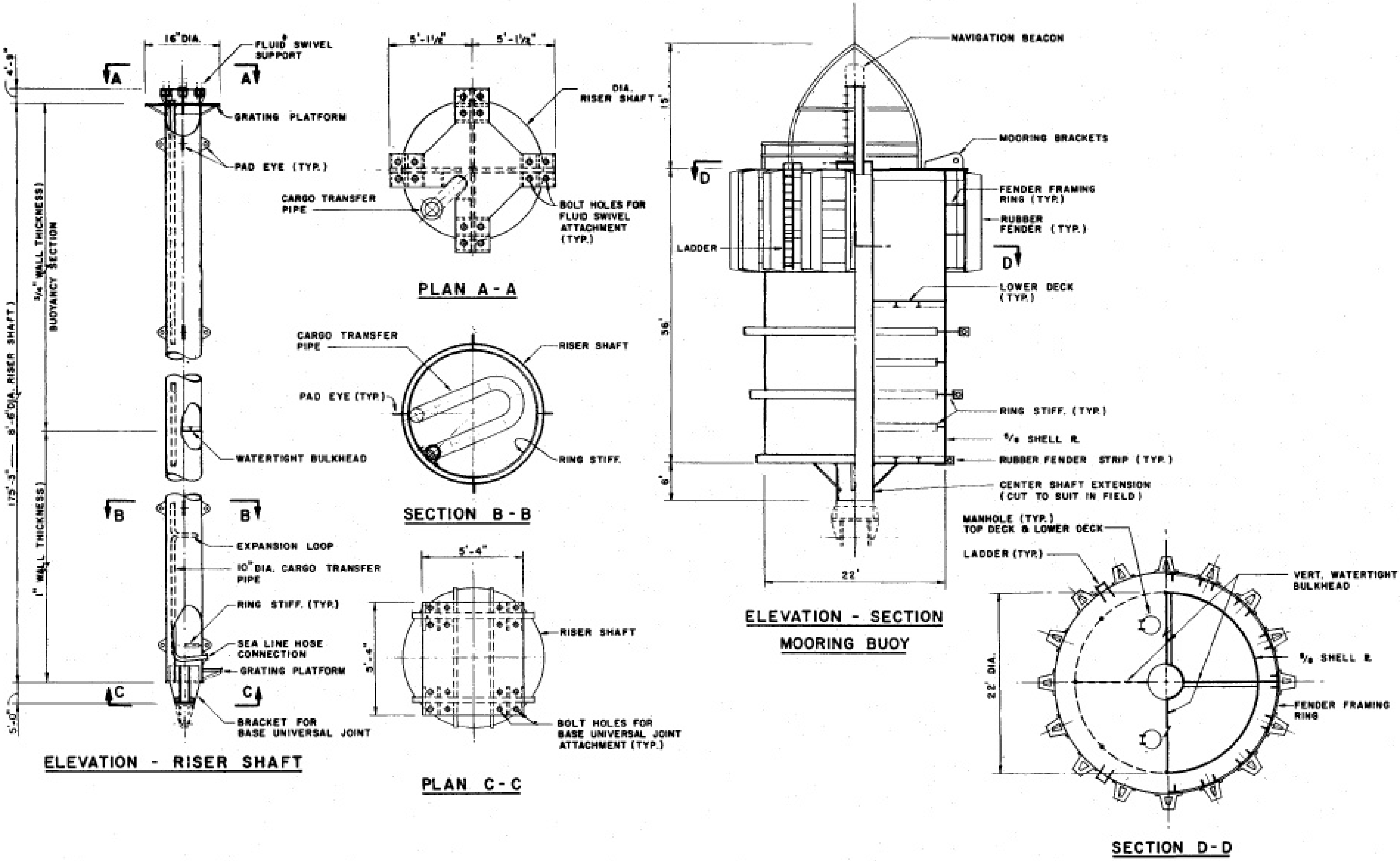

Fig. 3 - SALM riser shaft and mooring buoy.

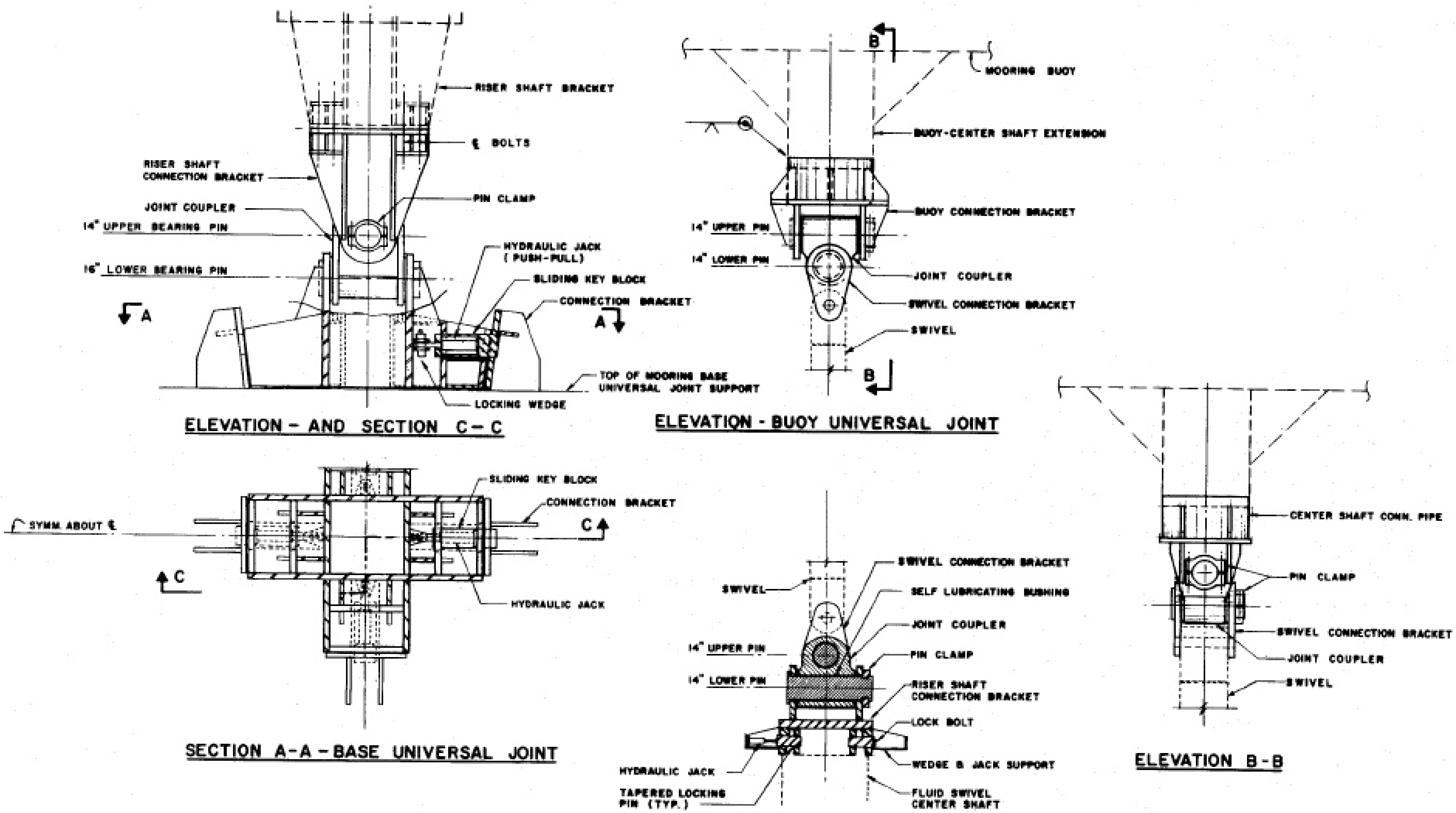

Fig. 4 - SALM universal joints.

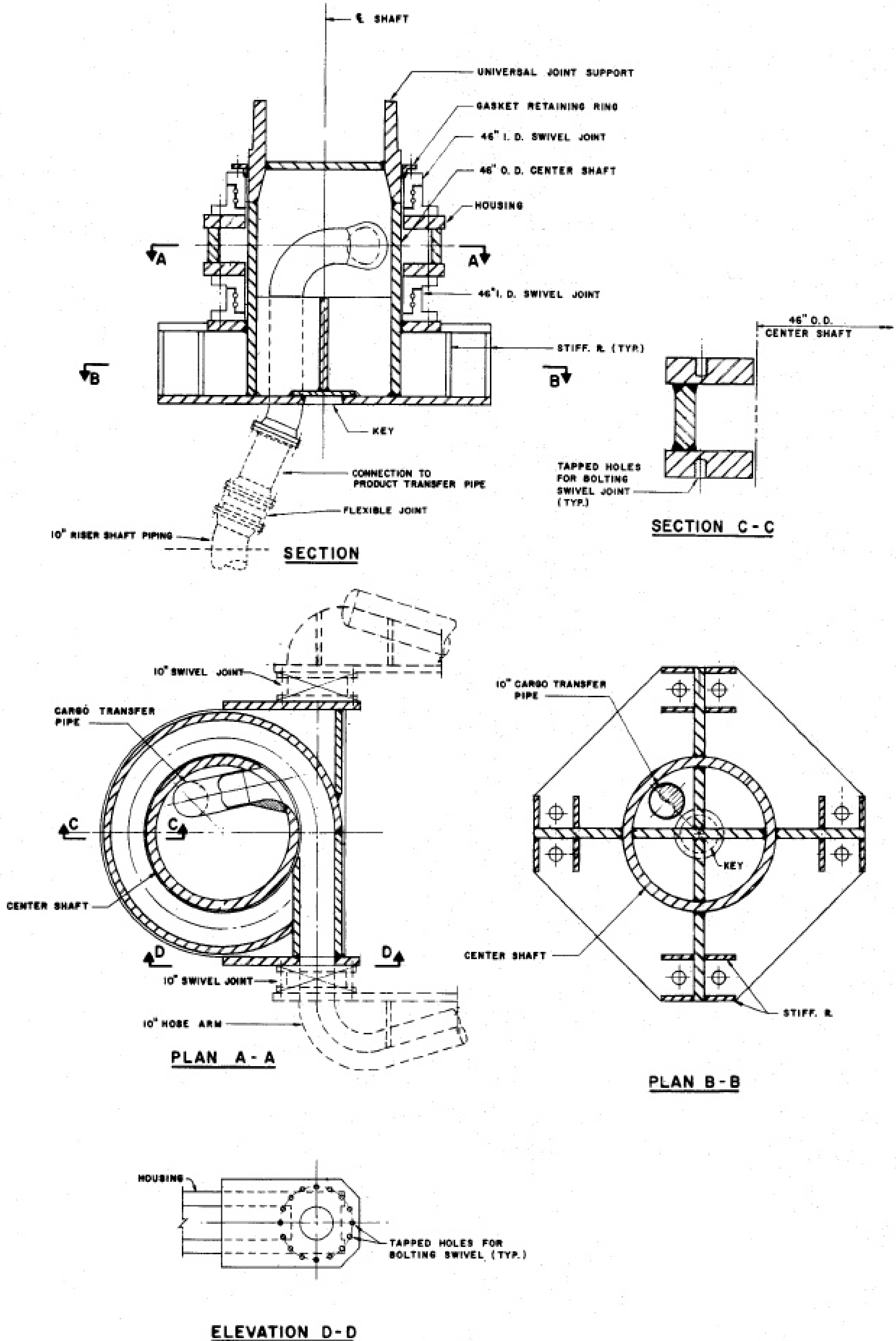

Fig. 5 - SALM fluid swivel assembly.