Offshore Loading May be Economic Solution to Baltimore Canyon Oil

If oil is found, loading from offshore mooring systems into tankers could start cash flow sooner than a pipeline. The investment is relatively small...

By R.H. Gruy
Sofec, Inc.

The concept of offshore tanker loading has been around for many years but has only really come into vogue as a viable concept for offshore oil production in the past six to eight years.

The technology that makes offshore tanker loading an attractive and realistic proposition is the Single Point Mooring, or SPM, technique for mooring and loading (unloading) tankers.

The SPM idea has been around for 20 years and there are about 200 installations around the world today. The idea itself is simple: moor a tanker in the open ocean by its bow lines only so that it is free to "weathervane" 360° about the mooring point and thus stay oriented bow-on into the seas. This attitude reduces tanker motions and allows cargo loading (or unloading) operations to continue even in very rough seas.

While the majority of the existing SPM installations serve as import or export terminals for moving oil to or from shore stations, the SPM idea has gained wide industry acceptance as an integral part of the offshore production complex.

The decision to utilize an offshore tanker loading scheme will typically hinge on one of two economic considerations:

- To bring a field onstream earlier than would be possible with a pipeline and shore terminal.
- To allow the development of marginal fields which have insufficient recoverable reserves to justify a pipeline system.

An offshore loading system in conjunction with a floating (or fixed) production facility constitutes what is popularly called an "early production system."

The election to use offshore loading makes it possible to ship crude and receive income as soon as oil is available for a relatively small investment. Thus, production from initial wells can be generating a cash flow while the drilling program continues with delineation of the reservoir.

Even if the economics can support the cost of constructing a pipeline system, this project may take several years to put into operation. Offshore loading insures income during this time. Assuming a pipeline is installed, the SPM will allow oil production to continue in the event of pipeline failure or problems at the shoreside terminal.

There are fields producing oil (and income) today that could not have been economically developed without offshore tanker loading, i.e., the cost of a pipeline system could not be justified.

The principal advantages of offshore tanker loading are:

- Low first cost.
- Accelerated project cash flow.
- Minimum "in place" investment, i.e., the SPM is mobile and can be removed and reused at other offshore locations (this is easier with some types of SPMs than with others).
- Flexibility of operation; tankers can be directed to the market place which best serves the needs of the country and/or producer.
- The technology is available and proven.

The Baltimore Canyon area, unlike most areas of the world where oil is found and where offshore loading is largely employed, has an adjacent market place complete with refineries and distribution networks. While this would appear to favor pipelines to transport offshore oil, the foregoing arguments remain valid. In the event of a major commercial find, permits for pipelines and agreements with existing distribution systems could take years.

Additionally, any decision to install a pipeline may logically be postponed until several fields are discovered and a single trunkline to serve all or most of them is justified. If the fields are marginal in the light of conventional economics, offshore tanker loading could prove to be an attractive investment and would provide a supply of domestic oil to East Coast refineries.

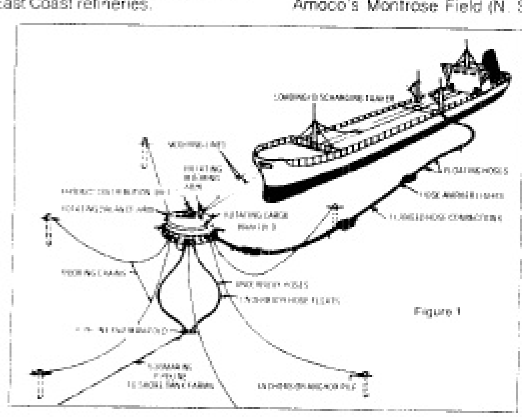


Figure 1

Current SPM applications include:

- Shuttle-type "filling stations" which replace the typical pipeline to shore and return pipeline to near shore tanker loading facilities with a deepwater terminal located at the production site.
- Same as above except floating storage is provided to enhance recovery economics.
- Floating process plus storage to eliminate the supporting production platform.

Shuttle tanker "filling station": In this application, the SPM is installed after the first one or two wells are drilled and tested. The SPM will be installed in conjunction with a drilling-production platform or a floating production facility. A short pipeline, typically about 1-1½-mi. long, will be laid from the beginning to the SPM. Oil, following separation on the platform, is pumped through this pipeline up through the SPM and into the moored shuttle tanker.

When the tanker is full, production is shut-in while the loaded tanker departs the berth and a second empty tanker comes into the berth. Depending on market logistics, two or three tankers will typically be required. The tankers will usually be modified for bow loading of crude oil and for mooring via single hawser. "Self Mooring" traction winches may also be desirable in some cases.

The time lost between tankers will depend primarily on sea conditions, which may be sufficiently rough to prevent the tanker from achieving a mooring for several hours or even days, and/or to prevent SPM maintenance activities. This type of "on-off" operation requires minimum first cost but may be undesirable for two principal reasons:

- Reservoir damage due to frequent shut-ins.
- Excessive downtime and hence, deferred production due to waiting on weather to moor the shuttle tanker or to perform maintenance functions.

Operations of this type are currently being utilized at several locations around the world including BNOC's Thistle Field (N. Sea), Amoco's Montrose Field (N. Sea), Hamilton Bros. Argyll Field (N. Sea), Shell-Exxon's AUK Field (N. Sea), and Esso-Malaysia's Tembungo Field (S. China Sea).

The efficiency of this type of operation can be improved by adding a second SPM or by incorporating offshore storage. Phillips' Ekofisk Field (N. Sea) is a classic example: first, two SPMs, then offshore storage and finally, a pipeline. The cost of either of these alternatives may be justified if the reservoir could potentially be damaged or recovery impaired by repeated shut-ins, or if weather conditions are such that significant production may be deferred. Mobil's Beryl Field (N. Sea) enjoys high efficiency (efficiency = crude loaded/field production) because of the large storage capacity built into the platform.

Floating Storage System: The SPM can be used to permanently moor a tanker which is used as a floating storage facility. This type of operation, while not a new idea, has gained increasing industry acceptance in recent years partly because of the advent of rigid yoke technology. The rigid mooring yoke replaces the traditional soft hawser connection between buoy and tanker and thus eliminates problems previously created by the tanker drifting into the buoy.

The yoke will also offer improved tanker stability, especially with respect to yawing motions and some improvement in alongside mooring operations can be expected even though tanker roll is not significantly damped. The additional cost of a rigid yoke system must be justified in the light of production economics which consider production rate, field life, frequency of offloading and the environmental conditions present at site.

Floating storage may be considerably cheaper than building storage into the platform or providing storage via floating or bottom-supported tanks such as DUPETCO's Fateh Field (Dubai) & Phillips' Ekofisk Field (N. Sea). While the viability of this concept is the subject of much debate in extremely rough weather areas like the N. Sea (Shell-Exxon's Fulmar Field will be the first in the N. Sea to use floating storage), it has been proven in many other parts of the world. Oil may be offloaded by mooring a shuttle tanker alongside the storage tanker using pneumatic fenders.

Operations of this type are currently employed at several locations around the world, including Elf-Aquitaine's Ashtart Field (Tunisia), Total's Abu-al-bu-Koosh Field (Arabian Gulf, Abu Dhabi), Esso-Malaysia's Pulai Field (S. China Sea), Cities Service's Poleng Field (Java Sea), Total's Bekapai Field (Makassar Strait), Elf's Kole Field (Cameroon), Crescent's Sharjah Field (Arabian Gulf), Shell's Amposta Field (Spain), Shell's Castellon Field (Spain), Amerada Hess Arzanah Field (Arabian Gulf, Abu Dhabi), and Agri Petco's Bonsu Field (Ghana).

Several operators prefer to use a second SPM for export rather than utilizing the alongside mooring and offloading scheme. In this operation, oil comes aboard the storage tanker or barge through one hose or piping on the SPM and is periodically pumped from the storage tanker through a separate piping system on the same SPM to a seafloor pipeline which leads to a second SPM which serves export tankers.

Operations of this type include IPAC's Cyrus Field (Persian Gulf; export facility is multiple buoy berth), IIAPCO's Cinta Field (Java Sea), ARCO's Ardjuna Field (Java Sea), Texaco's N. Apoi Field (Nigeria), ONGC's Bombay High Field (Arabian Sea, India) and Aramco's Zuluf Field (Arabian gulf; now replaced by pipeline).

Floating Process & Storage System: An advanced and somewhat controversial application of the SPM is the permanent mooring of a tanker or barge which serves not only as a floating storage facility but also as a self-supporting process plant. In this application, the wells are completed at the seafloor via wet-trees or atmospheric dry wellhead chambers. Live crude is produced through the SPM and into the process plant via sub-sea flow lines which connect to a central manifold on the seafloor.

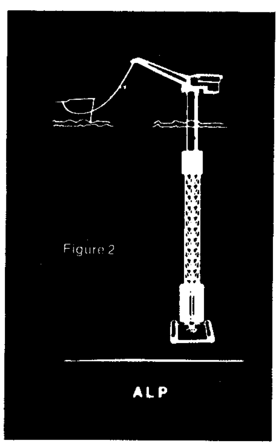
Separate fluid conduits are provided in the product swivel of the SPM to allow bulk production and well testing operations. Hydraulic and/or electrical wellhead and manifold control functions are also routed through the SPM's swivel. Gas is flared off a boom on the process tanker or may be routed back through the SPM to a seafloor pipeline and then to a flare tower.

In this type of operation, a second SPM will usually be employed for receiving oil from the storage barge and transferring it to export (shuttle) tankers.

The only operation utilizing this scheme to date is Petrobras' Garoupa Field (Brazil) which is due to begin operations in the immediate future. Other floating process applications utilizing SPMs include gas liquefaction plants, ammonia plants (potential application) and LNG regasification plants (potential application).

The term "Single Point Mooring" (SPM) is a general name for an entire family of mooring and loading systems. While there are at least 12 distinct types of SPMs, all have two things in common, i.e., they all moor the tanker by its bow lines(s) only and they all have a rotary fluid transfer system. Three types of SPMs are generally accepted as viable for open ocean tanker loading:

- The Catenary Anchor Leg Mooring (CALM) *Fig. 1.* This system obtains its restoring force or elasticity from the weight of the chains (typically six or eight) that anchor



ALP

the system to the seafloor and must be lifted in order for the tanker to displace the system laterally or vertically. Oil is pumped into the rotary fluid system contained within the buoy through submarine hoses which connect at the seafloor with the pipeline end manifold (PLEM). Oil flows from buoy to tanker through floating hoses.

This CALM is the oldest type of SPM, dating back to the late 1950's, and is the most prevalent, probably representing about 75% of the total SPMs installed in the world today. The development of the CALM is usually attributed to Shell Oil Co.

- The Articulated Loading Platform (ALP) *Fig. 2.* This system obtains its restoring force from buoyancy. It is a large-diameter column which is articulated at the seafloor through a universal joint. The fluid swivel is located atop the column well above the waterline. Oil flows from the PLEM into piping inside the column through a short length of jumper hose or through swivels incorporated in the universal joint.

Loading hoses from fluid swivel to tanker may be left floating in the water or may be stored inside the column and deployed via loading boom when the terminal is occupied. This type of SPM is relatively new, with the prototype system dating back to 1969. The only current commercial application of the ALP is at Mobil's Beryl Field (N. Sea), but at least two other N. Sea installations are planned. The ALP was developed by Equipements Mecaniques et Hydrauliques" Company (EMH) of France.

- The Single Anchor Leg Mooring (SALM) obtains its elasticity from buoyancy. It is characterized primarily by its two articulation points, one at the seafloor and one at an intermediate point typically 100-150 ft below the water. This feature relieves bending moments and allows for a small-diameter riser and a highly compliant, fast response system, a SALM characteristic which helps to reduce "snatching" forces in the mooring hawser.

Oil flows from the PLEM into piping inside (or outside) the riser through a short length of jumper hose or through swivels incorporated in the lower universal joint. The fluid swivel is located atop the riser shaft. Loading hoses from the fluid swivel to the tanker may be left suspended in the water or floating on the surface when no tanker is moored.

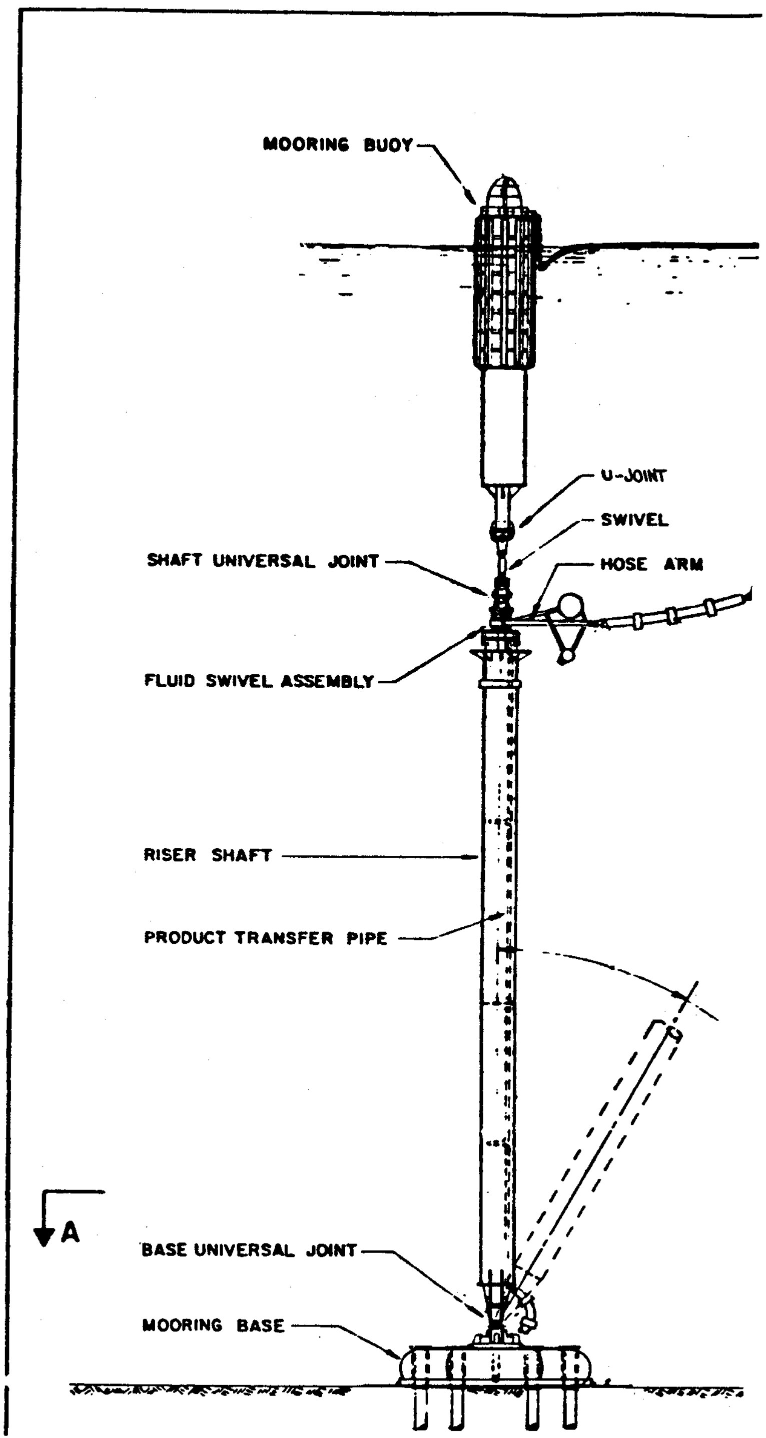
The SALM is a relatively new system, with the prototype dating to 1969. Current deepwater applications include BNOC's Thistle Field (N. Sea) 530 ft water depths, Esso-Malaysia's Tembungo Field (S. China Sea), 300 ft water depths, and Exxon's Hondo Field (Santa Barbara Channel) 450 ft water depths. The SALM was developed by Exxon Research & Engineering.

The selection of an offshore loading scheme is a very complex decision process which must consider recoverable reserves, reservoir characteristics and projected life, production rate profile, environmental conditions, seafloor soil conditions, market logistics, etc. These factors influence decisions such as floating production facilities or fixed platform, storage or no storage, floating storage vs. integral storage, alongside offloading vs. separate export SPM, etc.

With respect to the SPM itself, the key questions regarding which system to choose usually revolve around four areas:

- Safety, including vulnerability to damage by tanker collision, potential for pollution, and potential for fire damage.
- Maintenance—predicted frequency and ease of maintenance.
- Performance, including system dynamics, control of tanker motions, and system forces.
- Cost, particularly hardware, transportation, and installation.

As with all engineering problems, the final decision will be a trade-off between strong and weak features of each possible scheme. Each operator places different emphasis on certain aspects of the problem, based on past experience and personal preference. There is no one "best" answer, nor any firm and fixed guidelines for offshore tanker loading, and the possibilities will make any decision regarding offshore loading a genuine challenge. □



SALM FIG. 3