LNG TANDEM OFFLOADING SYSTEM

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Abstract

Marine loading arms for handling LNG have been supplied by FMC Loading Systems™ for forty years. FMC SOFEC™ has provided offshore vessel mooring systems for over thirty years. Through this experience, an LNG offloading system using proven components from these two related technologies provides for LNG transfer rates up to 15,000 m^3 LNG/hr in seas up to 4.3 m significant wave heights. The new tandem mooring arrangement provides increased vessel safety and higher availability through increased vessel separation and by the methods of berthing the LNG carrier. Improved economics are achieved by the reduced need for large tug auxiliary vessels, and also by the reduced need for thrusters and DP controls on the LNG carrier.

Concepts for tandem offloading of LNG have been in development for over ten years by FMC Loading Systems. Model basin testing has been done in industry JIP studies. A large-scale working model has been tested using vessel motion data from the model basin tests. The new yoke system that utilizes a duplex mooring yoke has been model basin tested for operation in harsh offshore environments.

In 2003 FMC Energy Systems launched an improved LNG offloading concept that provides significant advantages to tandem moored LNG transfer. This new concept utilizes a new revolving crane arrangement to add separation distance between vessels, simplify access for maintenance and reduce the overall elevation height of the system. The revolving crane swings the pantograph back on board the FPSO for parking but does not take up any more deck space than the previous stationary boom concept. LNG transfer is accomplished with the crane boom securely locked in the outboard position. The duplex yoke maintains the LNG carrier motion within the operating envelope of the pantograph with the crane boom fixed. No movement of the crane boom is required while offloading. Another advantage of this concept is variable boom height capability that allows for greater relative draft change between the two vessels. If large draft changes of the vessels are not involved, then further simplification and lower cost will result from a non-adjustable height boom.

1.0 Introduction

Offshore transfer of liquefied natural gas (LNG) from one vessel to another is a technical and operational challenge, but side-by-side (SBS) transfer of liquid hydrocarbons and minus 48C° LPG is commonplace and is a proven practice in mild environments. Also well known is tandem (one vessel directly behind the other) transfer of oil through floating hose systems for floating production systems to oil tankers. However, transferring LNG at minus 160°C between two vessels is not common, and has not been done at all in a production capacity in any serious weather locations. SBS transfer of LNG with conventional loading arms has been proposed and studied for many years; and model testing and full size loading arm testing have been performed by FMC Loading Systems to prove those systems are satisfactory for moderate environments. Vessel motion is the limiting factor in the severity of environment that these systems can successfully operate in, especially during the flange connection phase of the operation. One example of an exposed weather LNG terminal facility that experiences fairly constant wave frequency vessel motion is the Shell Bruni loading terminal. This is a facility about 3km offshore, located on a jetty without a breakwater, where LNG was originally transferred through a tandem loading system consisting of multiple degree-of-freedom flexing LNG piping arrangement connected with cryogenic swivel joints. The original loading system served for over twenty years. The facility now operates with conventional FMC loading arms that utilize constant motion cryogenic swivel joints to load LNG.

The technology for transferring LNG between two floating vessels is a crucial component in floating LNG facilities now in the planning stage. One of the primary applications for this technology is the floating hydrocarbon production unit for field developments where large quantities of gas are present. Unfortunately, many of the largest offshore gas fields are situated in areas of unfavorable weather, such as in the Timor Sea and offshore South Africa. There are some in the industry that consider offshore LNG transfer technology to be a “blocking” technology, or at least one more hindrance to the progress of some major LNG projects. Although the general weather conditions at some promising offshore West Africa locations are not severe, a persistent sea swell is expected to cause undesirable vessel roll motions during LNG loading. An LNG transfer system that provides maximum operational availability and safety is needed as a part of commercial justification of several LNG production projects.

Berthing an LNG carrier to another floating vessel, and remaining moored there for 12 to 24 hours will require perfected berthing procedures and robust dependable equipment. A series of developments by FMC Energy Systems in the evolution of tandem vessel berthing and LNG transfer equipment has led to the system described in this paper, a system ideally suited for environments such as West Africa and other locations where a tandem LNG transfer system is the preferred solution.

2.0 Developing the Tandem Offloading System

2.1 Early Developments – The First Boom to Tanker (BTT)

The Shell Bruni LNG facility was the first boom-to-tanker system, and operated successfully for over twenty years. Although this loading system was mounted at the end of a jetty, not on a floating vessel, the system was required to connect with a moving vessel and load LNG while the vessel underwent wave frequency motion in its spread mooring. See Figure 1.

Figure 1: Shell Bruni LNG Loading Facility

The Bruni facility is now operated with conventional FMC LNG loading arms that incorporate constant motion cryogenic swivel joints as illustrated in Figure 2.

Loading arms for a typical ship-to-ship transfer system arranged in a side-by-side berthing is shown in Figure 3.

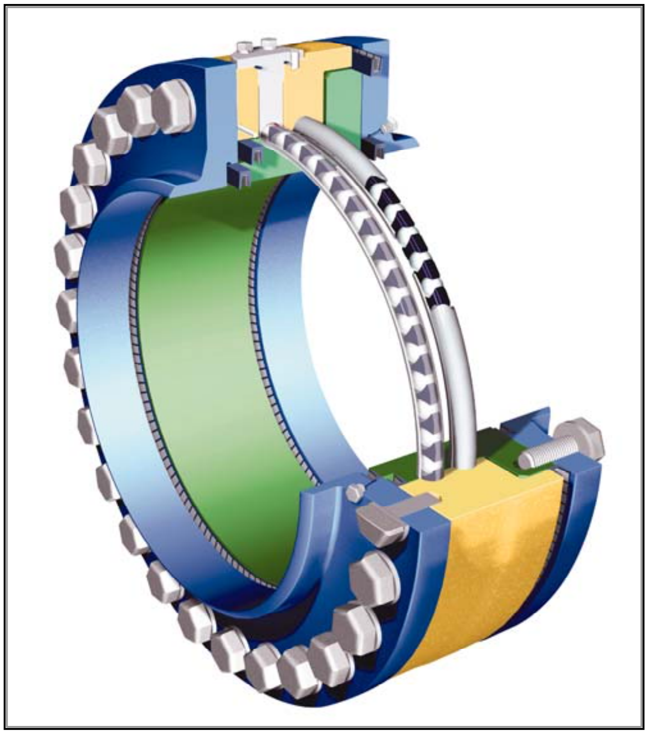

Figure 2: Chiksan Cryogenic Constant Motion Swivel Joint

Figure 3:Offshore Ship-to-Ship Transfer Loading Arms

2.2 Boom to Tanker (BTT) for Tandem Ship to Ship LNG Transfer

All of the proposed BTT ship-to-ship LNG transfer systems utilize the piping pantograph as the flexible piping component that allows relative motion between the vessels. Constant motion cryogenic swivel joints and stainless steel pipe provide all required degrees of freedom of motion. Figure 4 illustrates the original BTT system concept. A carrier connection manifold system is required on the bow of each LNG carrier. Because the system used a nylon hawser to connect the vessels, large sway motions of the carrier required the crane boom to follow the motion of the carrier bow manifold. Otherwise the manifold travel could over-reach the physical limits of the pantograph, especially when combined with significant vertical vessel motion.

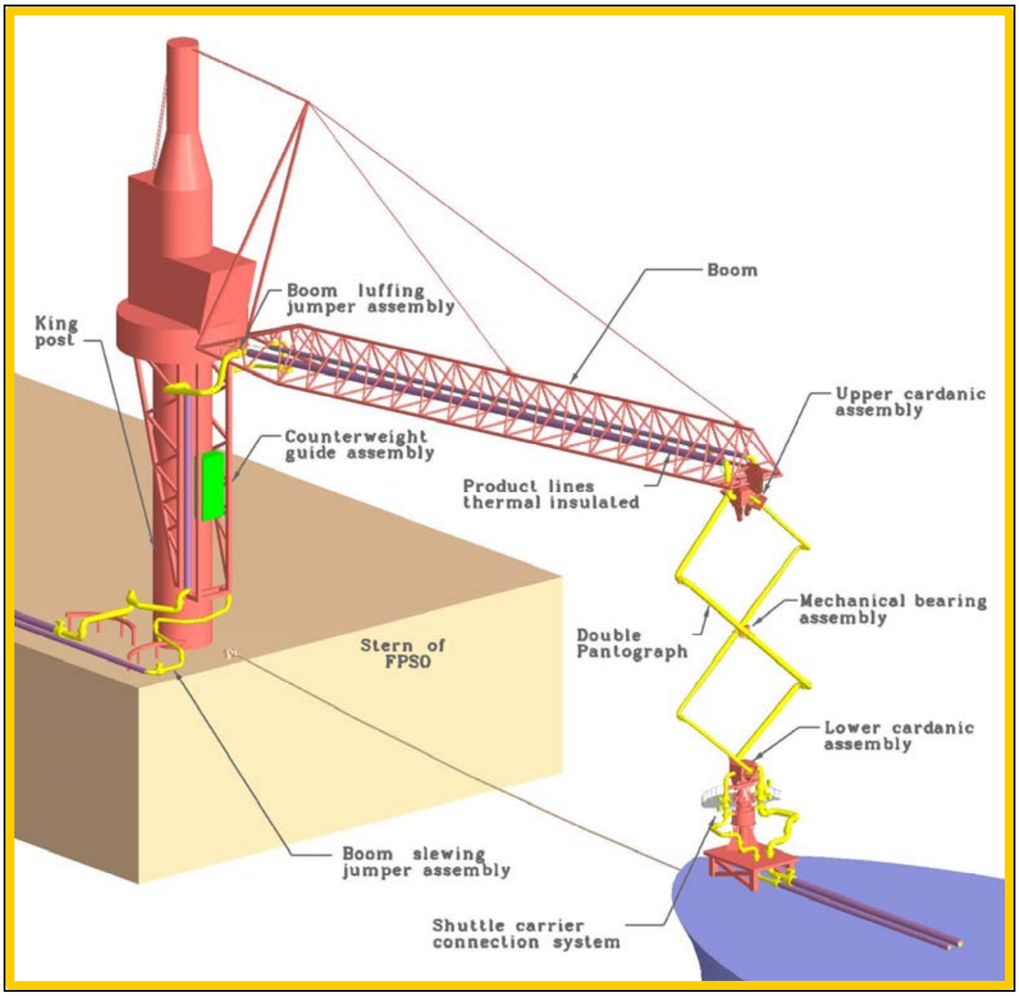

Figure 4: BTT for LNG FPSO

Figure 5 shows the one fifth of actual size working model of the BTT system that is on display and is operable at the FMC Loading Systems factory in Sens, France. This working model includes a computer controlled motion table that operates to simulate motion between the two vessels.

Figure 5: One-Fifth Scale Working Model of BTT

2.3 Methods for Berthing the LNG Carrier

Three methods have been evaluated for berthing, or connecting, the LNG carrier to the LNG FPSO. The original BTT system concept used a nylon hawser to connect the vessels, but this method has little resistance for side-to-side motions, and was limited to moderate sea states. A conventional soft yoke system was evaluated and found to allow about 36% of the hawser moored vessel motions, still excessive unless the pantograph boom follows the LNG carrier motion. A new yoke concept, the "duplex yoke" was developed to further minimize the lateral relative motion between the two vessels. This made it possible to keep the pantograph support boom stationary with respect to the FPSO. For comparison, and with all other variables equal, the lateral motion allowed by the duplex yoke is only about ±10.5m relative to the FPSO. Refer to Figure 6 for an illustration of comparative motions between the three methods

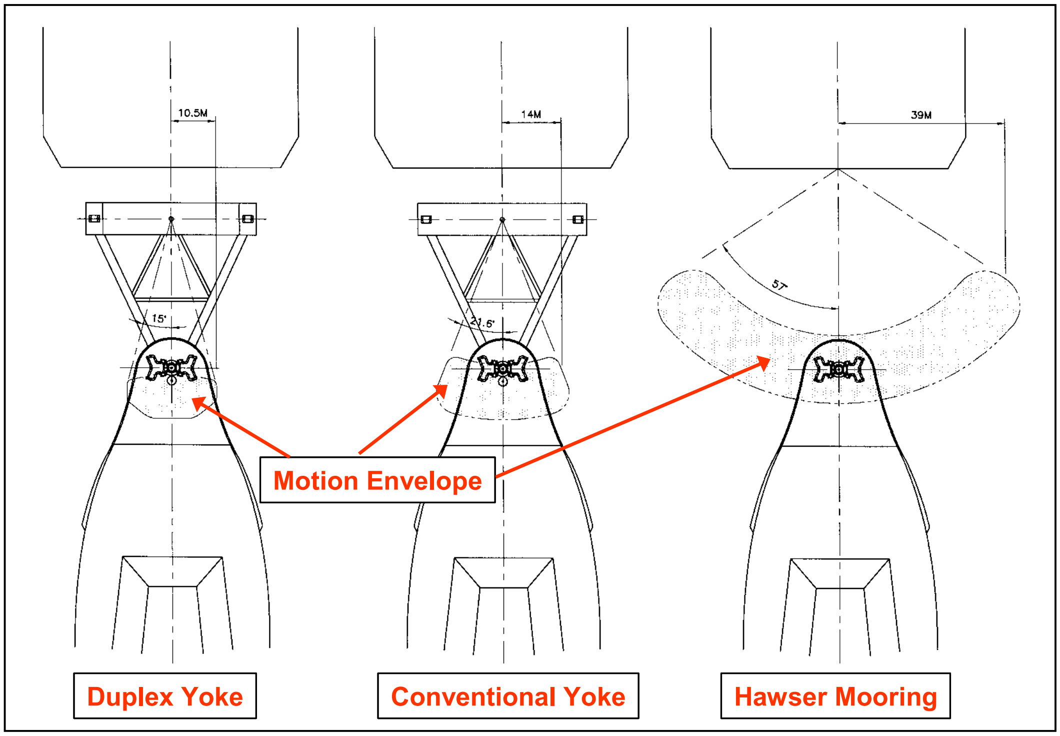

Figure 6: Motion Envelopes at LNG Carrier Manifold

Figure 7 shows the duplex yoke for connecting the LNG FPSO to the LNG carrier while the carrier is loading LNG.

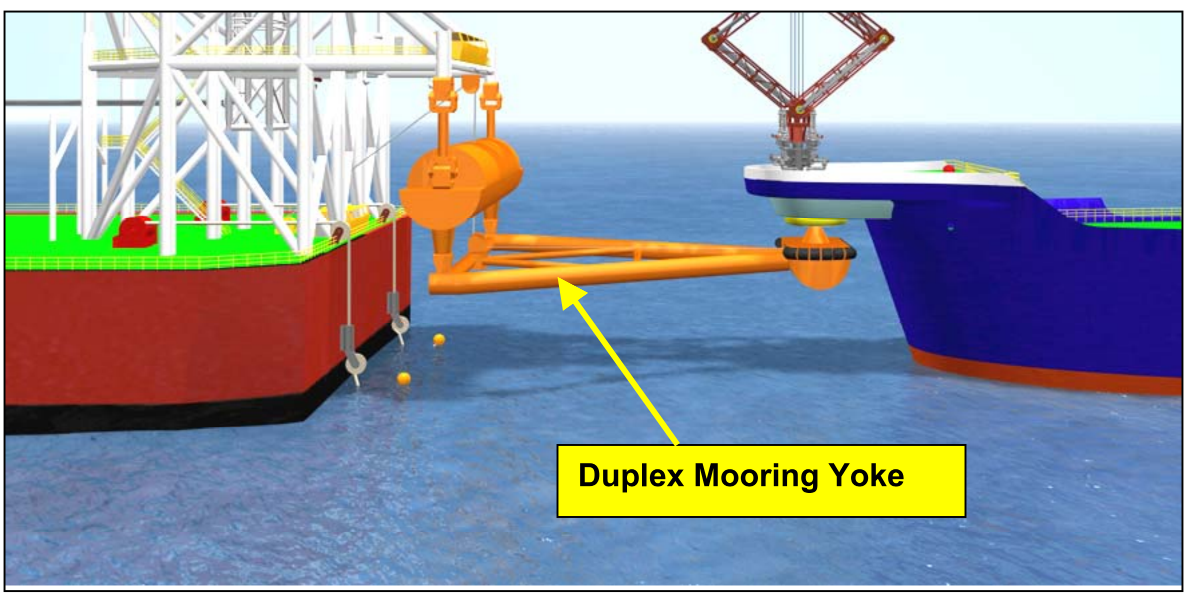

Figure 7: Duplex Yoke Mooring System

2.5 Stationary Boom Concept for Tandem Offloading

The stationary boom concept is illustrated in Figures 8 and 9. In this system, the piping pantograph remains suspended at the end of a stationary boom. When the pantograph is not being used it is retracted upward and a service platform moves out to surround and secure the pantograph. Any service or testing of the pantograph would be done from this platform.

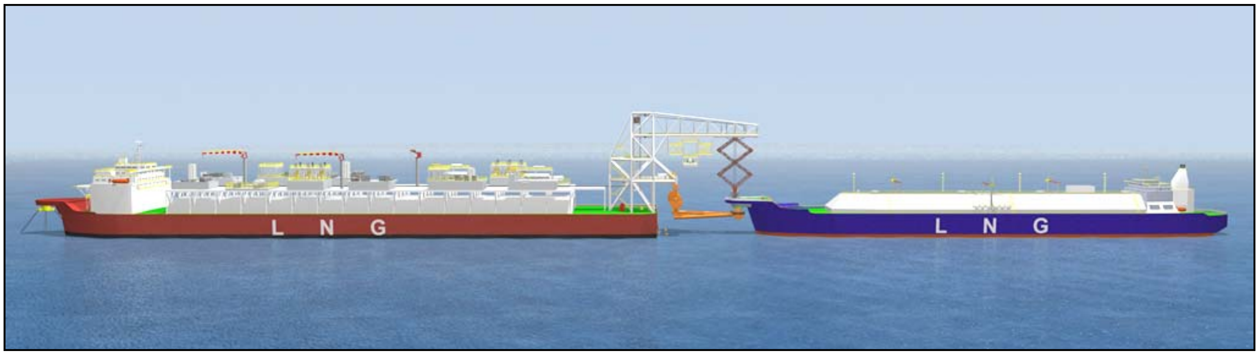

Figure 8: LNG FPSO with Stationary Boom Tandem Loading System

Figure 9: Stationary Boom Tandem Offloading System in Operation

3.0 Revolving Boom Tandem Offloading Loading System

The latest evolution of the tandem offloading system is illustrated in Figures 10, 11, and Figure 12. This concept retains the advantages of the stationary boom when in operation, that advantage being the boom does not follow the motions of the LNG carrier. In this case, the boom is locked in the outboard position and does not rotate while loading LNG. The rugged box construction of the boom safely allows for all required roll motions and side loads applied to the piping pantograph. However, the boom can be raised or lowered ± 4.5 meters to allow for large variations in draft of the two vessels. When the system is not loading an LNG carrier, the boom can be revolved around 180° to secure the boom onto a boom-rest. Then all necessary inspection and maintenance work is readily done on board the FPSO, as illustrated in Figure 13.

Figure 10: LNG FPSO with Revolving Boom Loading System

Figure 11: Revolving Boom Tandem Loading System

Figure 12: Revolving Boom Tandem Offloading System

Figure 13: Tandem System in Parked Position

3.1 Comparison of Stationary Boom and Revolving Boom Tandem Loading Systems

The improvement between system configurations is evident in Figure 14.

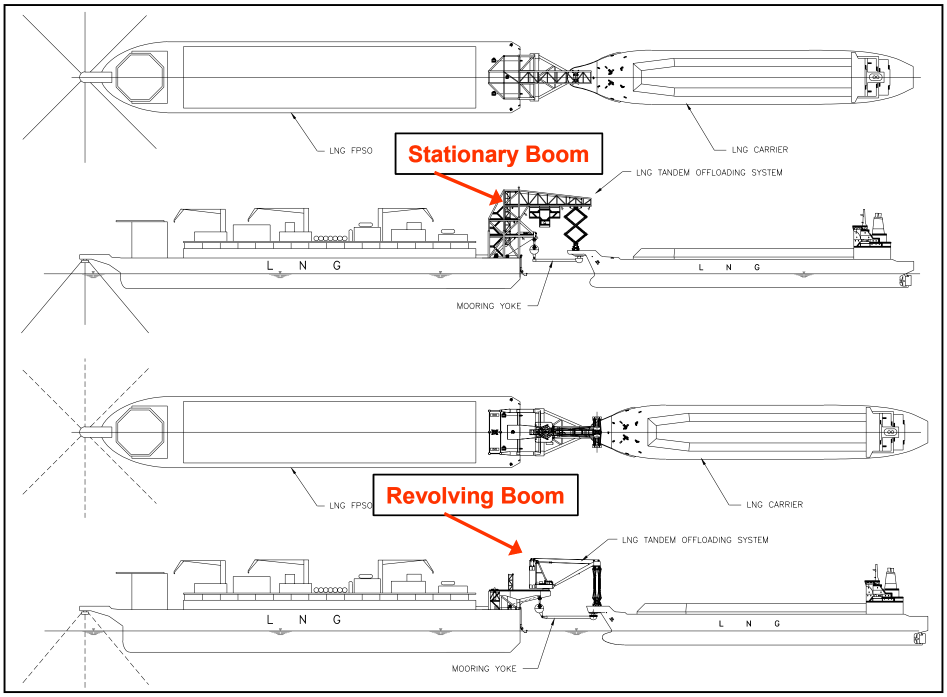

Figure 14: Comparison of Stationary Boom and Revolving Boom Systems

3.2 Advantages of the New Revolving Boom Concept

Concept improvements over the stationary boom concept include the following advantages:

- There are 16m (23%) added clearance between the two vessels
- Between vessel perpendiculars measures 75 meters
- The overall height of the structure above waterline is reduced 10m (15%)
- The boom height is adjustable ± 4.5 m, to provide for large variable draft difference between the two vessels
- Boom swings 180° to park piping pantograph onto service platform for improved safety and service access
- Because of the outboard location of the boom swing bearing, no additional deck space is required over the space previously needed for the stationary boom concept.

4.0 Conclusion

The FMC Energy Systems revolving boom concept for tandem LNG transfer between two vessels offers reliability and safety for operation in harsh sea conditions. The system is comprised of components based on service proven equipment and this feature allows for the shortest possible time for designing, classing, construction, and commissioning.