REPORT:

Single Point Mooring Safety and Performance

Prepared for

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MAY 2019

EXECUTIVE SUMMARY

A Single Point Mooring (SPM), also known as a single buoy mooring, is a buoy anchored offshore that serves as a mooring point as well as an interconnection for tankers loading or offloading liquid products. SPMs typically consist of the buoy body, mooring and anchoring elements, product transfer system, and supporting components. There are currently 38 different types of SPMs. The Texas Gulf Terminals Project Deepwater Port plans to utilize a Catenary Anchor Leg Mooring (CALM). A CALM is the most common type of SPM and is capable of handling Very Large Crude Carriers (VLCCs). A CALM consists of a floating buoy anchored to the seabed by catenary chain legs which are secured to anchors or piles. One or more elastic mooring hawsers hold the tanker captive to a turntable which is mounted on top of the buoy by means of a bearing. The bearing allows the turntable to freely weathervane so that the tanker can take up the position of least resistance to the prevailing weather at all times. Fluid product is transferred via the CALM to or from the tanker by floating and subsea hose systems. When the tanker moves off station, due to the effects of wind, wave and current, certain anchor legs are lifted. This generates a restoring force which tends to return the system to the equilibrium position.

There are currently 646 SPMs utilized throughout the world as they require less investment in comparison with traditional port systems and facilities. Over 200 SPMs are similar in design or usage to the proposed Texas Gulf Terminals Project. Sixteen SPMs are located in the U.S. Of these, the two facilities most representative of the Texas Gulf Terminals Project are Barbers Point, installed in 31 meters of water two miles south of Oahu, Hawaii in 2012; and the Louisiana Offshore Oil Port (LOOP), installed in 35 meters of water 16 miles southeast of Port Fourchon, Louisiana in 1980. In the last ten years, SPMs have been built for operations in Argentina, Australia, Brazil, Japan, Romania, Spain, and Thailand, among other countries.

RSJ searched accident and spill records from the International Tanker Owners Pollution Federation (ITOPF); the Bureau of Safety and Environmental Enforcement (BSEE) Bureau of Ocean Energy Management (BOEM), and the Minerals Management Service of the U.S. Department of Interior; National Oceanic and Atmosphere Administration (NOAA) Office of Response and Restoration; U.S. Coast Guard; U.S. Department of Transportation; and the National Transportation Safety Board. This broad search for SPM incident data was then followed by a more focused site-specific search of all United States SPMs. Based on the available data, RSJ determined SPMs have been safely and effectively utilized for oil and gas loading/offloading operations for almost 60 years.

Single Point Mooring Fleet Overview

Based on data contained in *The Offshore Logistics Register 2018 (*Clarksons Research, 2018)[1], there are currently 646 SPMs in the global fleet today throughout all regions of the world. The first SPM was constructed in 1959 by Gusto Shipyard (now SBM Offshore) for Shell Oil.[2] **Table 1** depicts the annual number of SPMs added each year beyond 1977. Approximately five more SPMs are under construction that will be active in the next 2-3 years.

TABLE 1

RSJ searched accident and spill records from the International Tanker Owners Pollution Federation (ITOPF); the Bureau of Safety and Environmental Enforcement (BSEE) Bureau of Ocean Energy Management (BOEM), and the Minerals Management Service of the U.S. Department of Interior; National Oceanic and Atmosphere Administration (NOAA) Office of Response and Restoration; U.S. Coast Guard; U.S. Department of Transportation; and the National Transportation Safety Board. This broad search for SPM incident data was then followed by a more focused site-specific search of all United States SPMs. Based on the available data, RSJ determined SPMs have been safely and effectively utilized for oil and gas loading/offloading operations for almost 60 years.

[1] Clarksons Research Services. (2018). *The Offshore Logistics Register 2018*. London, England.
[2] https://www.sbmoffshore.com/who-we-are/history/#2

Depths of Single Point Moorings

CALMs are usually located in water depths between 20 to 100 meters and are connected to a shore storage facility (tank farm) or to offshore production platforms by means of a submarine pipeline. Since early 2000, the CALM design has been used and adapted to deepwater conditions, greater than 1,000 meters. For this application, the CALM is used as an offloading system for a deepwater Floating Production Storage and Offloading unit (FPSO). The Texas Gulf Terminals Project SPM will be located at a depth of approximately 30 meters. **Table 2** depicts the depths of all existing SPMs.

TABLE 2

Depth (meters)	# of SPMs
0-19	50
20-39	267
40-59	73
60-79	47
80-99	46
100-124	29
125-149	17
150-199	6
200-299	4
300-499	18
500-749	7
750-999	9
1000-1249	11
1250-1499	12
1500-1999	4
>= 2000	4

**42 SPMs no data for depth*

Locations of Single Point Moorings

SPMs are utilized throughout the world as they require less investment in comparison with traditional port systems and facilities. In the last ten years, SPMs have been built for operations in Argentina, Australia, Brazil, Japan, Romania, Spain, and Thailand, among other countries. **Table 3** lists the general regions of the globe the current 646 SPMs are located.

TABLE 3

Region	# of SPMs
North America	44
NW Europe	64
South America	67
Mediterranean	78
West Africa	85
Middle East	123
Asia Pacific	185

A review of the Clarksons Research Register identified over 200 SPMs located throughout the world that are similar in design or usage to the proposed Texas Gulf Terminals Project. The remainder of this report focuses on the SPMs located or planned within the waters of the United States.

Single Point Moorings in the United States

The following SPMs are located in the United States:

- **Barbers Point SPM**
- **Louisiana Offshore Oil Port SPMs (SALM 102, 103, 104A)**
- **Cascade / Chinook STP (BW Pioneer FPSO STP)**
- **Phoenix Turret (Helix Producer 1 Floating Production Unit (FPU) Turret)**
- **Stones Turret (Turritella FPSO BTM)**
- **Gulf Gateway Energy Bridge STL LNG Terminal**
- **Northeast Gateway A; Gateway B (Northeast Gateway Deepwater Port – LNG Import)**
- **Neptune LNG North Buoy (STL LNG Buoy); Neptune LNG South Buoy (STL LNG Terminal)**
- **Worldwide Use #1 SPM; Worldwide Use #2-#7 SPM**
- **Worldwide Use CALM**
- **Delfin LNG SPM (*MARAD Approved Deepwater Port – License Issuance Pending*)**

Of the sixteen U.S. SPMs, the following three are related to offshore oil and gas production:

Cascade / Chinook STP (BW Pioneer FPSO STP): Submerged Turret Production Mooring (STP) installed in 2010 in the Gulf of Mexico (Walker Ridge Block 249) in approximately 2,600 meters of water. The BW Pioneer, with an oil storage capacity of 500,000 bbl, was installed in February 2010. It is equipped to process up to 80,000 bbl/day of produced fluids and 16 MMscf/day of gas. Petroleo Brasileiro SA (Petrobras) became the first oil company to operate a Floating Production Storage and Offloading (FPSO)-type production system in U.S. waters (operational Feb 25, 2012). The Cascade and Chinook fields employ shuttle tankers to transport produced oil and use self-sustainable submerged pumps and risers in the production train.

Phoenix Turret (Helix Producer 1 Floating Production Unit (FPU) Turret): Installed in 2010 in the Gulf of Mexico (Green Canyon Block 237) in approximately 670 meters of water. The Helix Producer I can produce 30,000 bbl/day of oil, 70 million cubic feet of gas, and 50,000 bbl/day of water.

Stones Turret (Turritella FPSO BTM): Installed in the Gulf of Mexico (Walker Ridge Block 551) in a record 2,896 meters of water. It is the largest disconnectable buoy. The Turritella, with an oil storage capacity of 800,000 bbl and processing capability of 60,000 bbl/day of oil and 15 MMscf/day of gas, arrived on site in early 2016. Production began in September 2016.

All three SPMs have the ability to disconnect the turret mooring system in order for the FPSO/FPU to vacate the area to avoid severe weather.

Of the sixteen U.S. SPMs, the following six are related to Liquified Natural Gas (LNG) import or export:

Gulf Gateway Energy Bridge STL LNG Terminal: Installed in the Gulf of Mexico 116 miles offshore of Louisiana in 91 meters of water in 2005. It served as an LNG Import Facility Deepwater Port with an average throughput capacity of 500 million standard cubic feet per day. The facility was decommissioned in 2012 "due to the dramatic shift in the supply-demand balance in the United States from the proliferation of shale gas."

Northeast Gateway A; Gateway B (Northeast Gateway Deepwater Port – LNG Import): Two buoys installed in 2007 13 miles south-southeast of Gloucester, Massachusetts in approximately 90 meters of water. It serves as an LNG Import Facility Deepwater Port with an average throughput capacity of 400 million standard cubic feet per day and a peak throughput of 800 million standard cubic feet per day.

Neptune LNG North Buoy (STL LNG Buoy); Neptune LNG South Buoy (STL LNG Terminal): SPMs were installed in 2009 10 miles south of Gloucester, Massachusetts in approximately 81 meters of water. It serves as an LNG Import Facility Deepwater Port with an average throughput capacity of 500 million standard cubic feet per day and a peak throughput of 750 million standard cubic feet per day. The U.S. Army Corps of Engineers said Neptune LNG filed for a permit to decommission the facility in March 2017. The September 4, 2018 Federal Register published notice to notify the public of a license amendment and continuation of a suspension of port operations at the Neptune Deepwater Port through June 2022.

Delfin LNG SPM (*MARAD Approved Deepwater Port – License Issuance Pending*): The project will make use of an existing subsea pipeline system to transport LNG from the current platform in Cameron Parish, Louisiana, to four floating LNG vessels (FLNGVs), which are moored roughly 50 miles offshore in the Gulf of Mexico. The platform will serve as the connection point for the Enbridge Offshore Pipelines system. The FLNGVs will be moored to a single point mooring system located near the platform. In addition, they are expected to receive and cool the natural gas on-board to -260°F in order to convert it into liquefied natural gas (LNG). The LNG will then be transported to international customers directly from the FLNGVs via LNG carriers.

The Worldwide Use #1 SPM, Worldwide Use #2-#7 SPM, and Worldwide Use CALM are part of a U.S. Department of Defense program of Rapidly Deployable SPMs for the Naval Sea Systems Command. They were developed in the 1980s and can be installed in water depths of 10-20 meters. The systems are mobile and can be installed and operational along with a pipeline within 48 hours.

The final two SPM projects are the most representative of the Texas Gulf Terminals Project Deepwater Port plans: Barbers Point and the Louisiana Offshore Oil Port (LOOP). Both sites load/unload liquid product via their respective SPMs.

Barbers Point SPM:
The Barbers Point SPM is a CALM buoy serving Par Hawaii Refining LLC located approximately 2 miles south from Oahu, Hawaii in 31 meters of water. The current CALM was installed in 2012 to replace a Single Anchor Leg Mooring (SALM) in the same location. The installation date of the original SPM cannot be determined, but throughput data exists beginning in 1987. Tankers of up to 150,000 dead weight tons (dwt) carrying up to 800,000 bbl of crude oil can discharge over the SPM. It takes about 48 hours to discharge a load. 60% of all petroleum products enter Hawaii via this location.

The SPM buoy's top deck is designed to swivel, allowing a tanker to act like a weathervane and remain head-on in the wind. The tanker is secured to the mooring by an 18-in. circumference double hawser. In addition, a 4,000 hp chartered tug pulls on the tanker's stern during loading and unloading operations to prevent the vessel from riding up on the mooring. In crude oil unloading operations, three floating hoses 840 ft in length connect the tanker to the mooring and submarine hoses, which in turn are connected to the under-water pipelines going to the refinery's storage area.

The previous SPM (which was a different type of SPM than the one planned at the Texas Gulf Terminals Project) was the site of the following accidents / spills[3,4]:

- 1987 - 100 bbl spill: split hose
- 1989 - 200 bbl bunker oil from ship and 400 bbl crude from damaged buoy; Exxon Houston broke free from SALM and grounded
- 1990 (January) Texaco Connecticut collided with buoy; 400 bbll spill
- 1990 (November) Grounding of the Texaco Connecticut; None of the cargo or fuel tanks were breached resulting in minimal oil spilled (likely residual oil from bilges of pump room that was breached)
- 1998 Tesoro 117 bbl hose spill

The facility was located in state waters and lacked more stringent federal oversight regulations for deepwater ports at the time, however additional measures have since been implemented that have prevented a recurrence of accidents and spills at the existing SPM. Some of those safety measures include:

- Tight weather operating windows which give vessels more time to suspend operations and leave the mooring or delay approach in case of bad weather or sea conditions.
- Maintenance of vessel engines on immediate standby.
- Use of a geographical positioning system to establish precise ship location, speed, and direction.

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[3] National Transportation Safety Board. (1990). *Marine Accident Report. Grounding of the U.S. Tank Ship Star Connecticut, Pacific Ocean, Near Barbers Point, Hawaii, November 6, 1990*.
[4] County of Santa Barbara / U.S. Army Corps of Engineers. (1992). *Draft EIR GTC Gaviota Marine Terminal Project, Supplemental Environmental Impact Report / Statement*. Part C Environmental Analysis System Safety p. C.5-98.

- Monitoring with a remote device the ocean current and wind speed/direction at the mooring.
- Employment of breakaway couplings for each floating hose string of the SPM, which seal oil in the hoses in the event a tanker inadvertently breaks away.
- Continuous monitoring of the strain being placed on the mooring system.
- The crude oil unloading rate and strain on the hawser are monitored in the pumphouse. The system is so sensitive that the effect of up-and-down wave action on the hawser strain can be seen on the screen. The warning system is alarmed to 75% of what is considered the allowable stress, which is about a 25% discount over the maximum.
- The SPM and floating hoses are part of a rigorous maintenance program.

Louisiana Offshore Oil Port SPMs (SALM 102, 103, 104A):
The Louisiana Offshore Port, also known as the LOOP Marine Terminal, consists of three SPMs. It is permitted/licensed as a Deepwater Port: Oil Import/Export Facility with a maximum throughput capacity of 1.2 million barrels per day. The SPMs were installed in 1980 in approximately 35 meters of water 16 miles southeast of Port Fourchon, Louisiana in the Gulf of Mexico. The facility has survived six hurricanes with no damage thus far. Operations shut down for only four days during Hurricane Andrew.

There have been no major oil spills at LOOP since operations began in 1981. On average, less than 0.00000011 barrel of oil has spilled per million barrels of oil transported. For over three and a half decades, LOOP has safely and successfully received, stored and delivered more than twelve billion barrels of crude oil to U.S. refineries while protecting the communities and natural environment of southern Louisiana.[5] LOOP credits the following for their environmental, health, and safety record:

- Continuously monitoring the integrity of its pipelines with a real time computer-based leak detection system capable of identifying the size and location of any leak in terms of leak rate, barrels lost and location.
- Having real time information from the sophisticated line surveillance system noted above facilitating a rapid response to a leak event thus minimizing the environmental impact by isolating the source of the leak and dispatching repair and clean-up crews.
- Periodic in line inspections of its crude oil pipeline utilizing a “Smart Pig”.
- Weekly integrity checks by divers of marine hoses utilized for transporting crude oil from offloading vessels to the LOOP pipeline system.
- Weekly overflights for visual inspections of the pipeline corridor.
- Visual inspections within the pipeline using a robotic system with remote video monitoring capabilities.
- Utilizing a fleet of sophisticated vessels that patrol the Port area and support the marine operations. The largest of these vessels, the LOOP Responder, is a 7,000

[5] https://www.loopllc.com/Environmental-Awareness/Environment

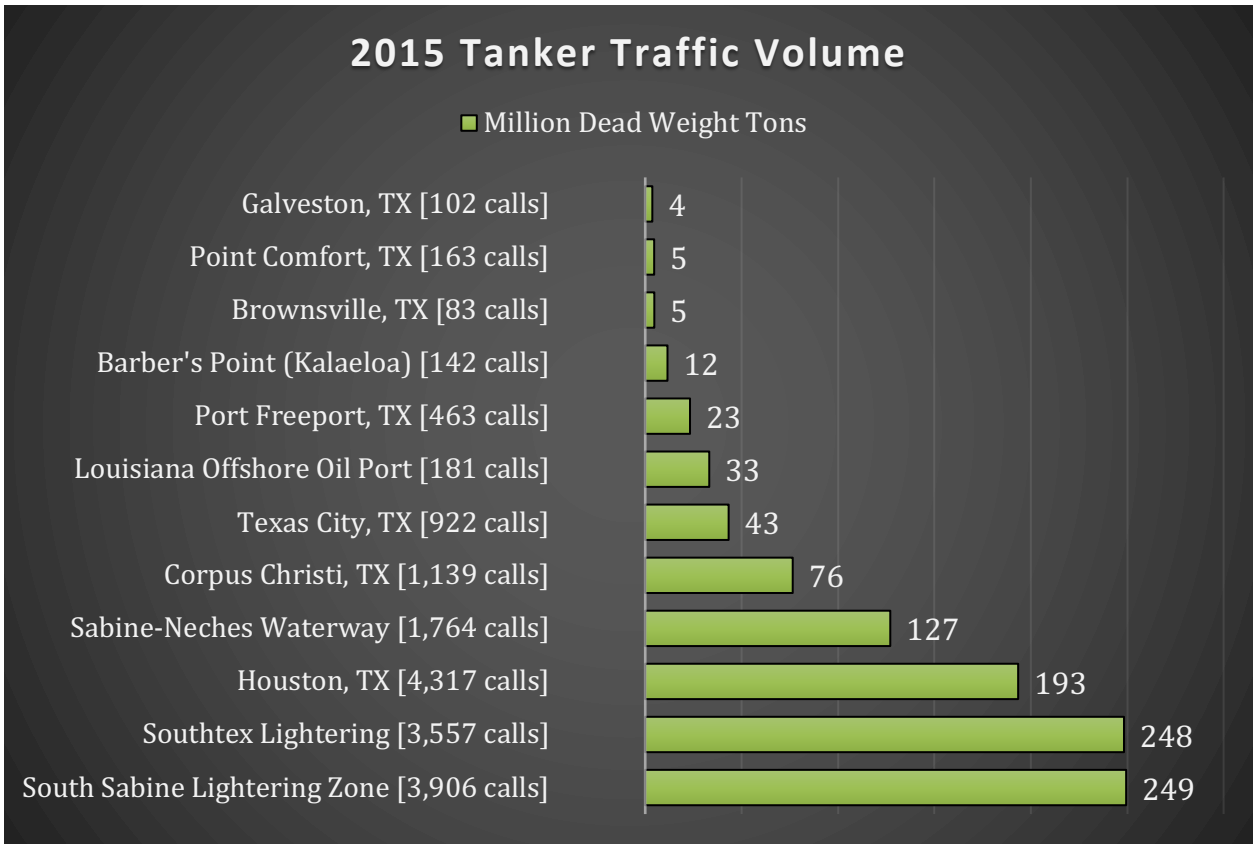
– horsepower tractor tug capable of assisting any supertanker if it loses power or steering while entering/offloading/exiting the LOOP restricted safety zone.

- Maintaining an array of oil containment, recovery and remediation equipment capable of responding to an incident or oil release.
- Maintaining a Facility Response Plan that accommodates changing realities and new technologies.
- Reinforcing readiness and instilling good operating practices by testing its Facility Response Plan during annual “spill drills” that simulate potential incidents.
- Working closely with federal, state and local agencies during annual drills and throughout the year to integrate resources and plan responses to theoretical accidents.

Associated Tanker Traffic Overview

The most recent data available from the U.S. Department of Transportation Maritime Administration is from 2015 and is depicted in **Table 4** below. A map of the ports is included as **Figure 1**. Included along with Barbers Point and LOOP SPMs are all Texas regional ports and lightering zones. With only one deepwater port in the Gulf of Mexico, the bulk of all tankers must go through the lightering zones to offload product to ships small / shallow enough to enter Texas Ports.

TABLE 4

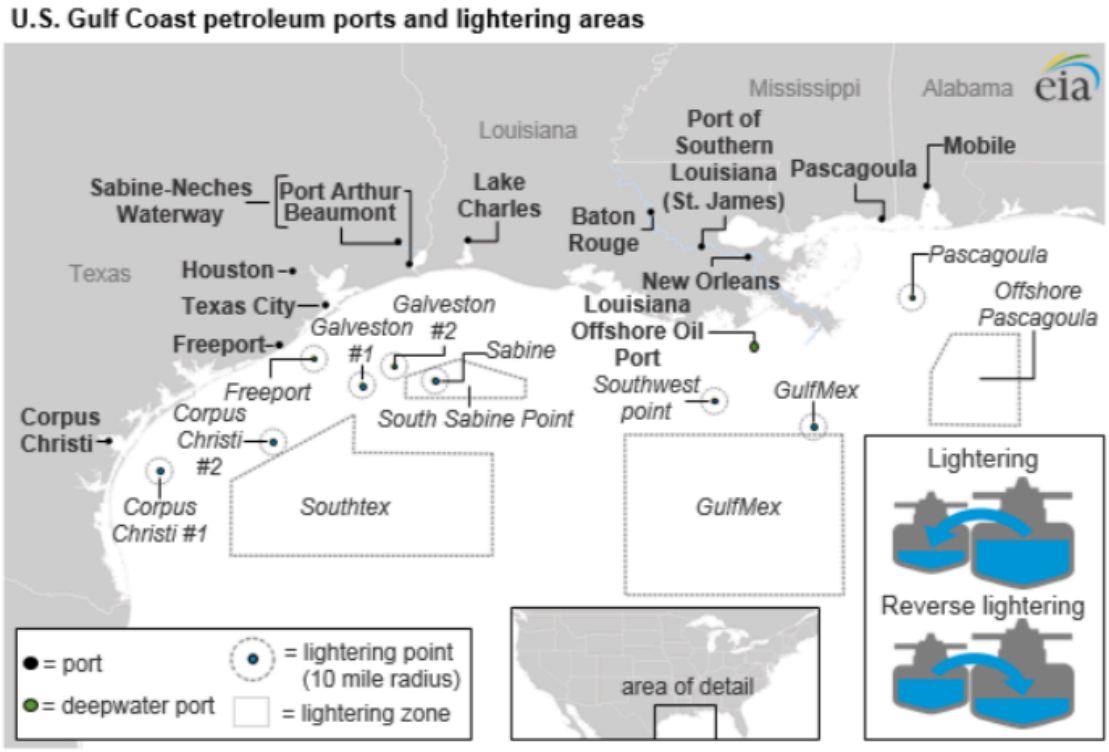


Spills and accidents are reported to many different organizations federally and internationally. A centralized clearing house of consistent accident or spill data does not exist. Data collection responsibilities overlap and shift amongst federal agencies historically as well as regionally. However, a review of several publicly available spill / accident reports, databases, and news articles indicates both SPMs and lightering operations are relatively safe resulting in only sporadic small spills historically. Marine accidents in general have also been significantly minimized and trending downward since the early 1990s[6] due to industry self-policing (operating and maintenance procedures),

[6] Bureau of Safety and Environmental Enforcement. (2016). *2016 Update of Occurrence Rates for Offshore Oil Spills*. U.S. Department of Interior.

new regulations, increased federal oversight, training requirements, and new technologies. Each event (call) carries similar risk probabilities therefore less calls would create less opportunities for an accident to take place. Obviously larger ships can carry more product but a higher percentage of larger ships are double-hulled (reducing risk of leaks/discharge) with more and more single-hulled ships retiring each year due to the International Convention for the Prevention of Pollution from Ships (MARPOL Convention) requirements for certain ships constructed after 1996.

FIGURE 1



Source: U.S. Energy Information Administration