5 SINGLE POINT MOORING SYSTEMS

This chapter describes the components, design and operational criteria, and guidelines for layout and design for SPM systems.

The capability of these mooring systems is also used during the approach of a vessel that needs to moor. The vessel will approach the tower with its bow into the dominant metocean conditions, maximising control over the vessel while minimising the need for tug assistance. It is important to note that vessels that are mooring can control the approach heading, speed, and course-made-good, with the option to abort the mooring, when prudent. A vessel that must unberth from an SPM due to operational limit constraints, must operate in unfavourable conditions and vessel headings. There is no option to abort and the designed manoeuvring area must allow for a sufficient clearance zone for any nearby platforms or structures in consideration of these events.

A simplified layout for a nearshore or protected waters SPM is shown in Figure 5.1 where the radio of a swinging circle and a manoeuvring circle are defined, mainly depending on the overall length (L) of the design vessel.

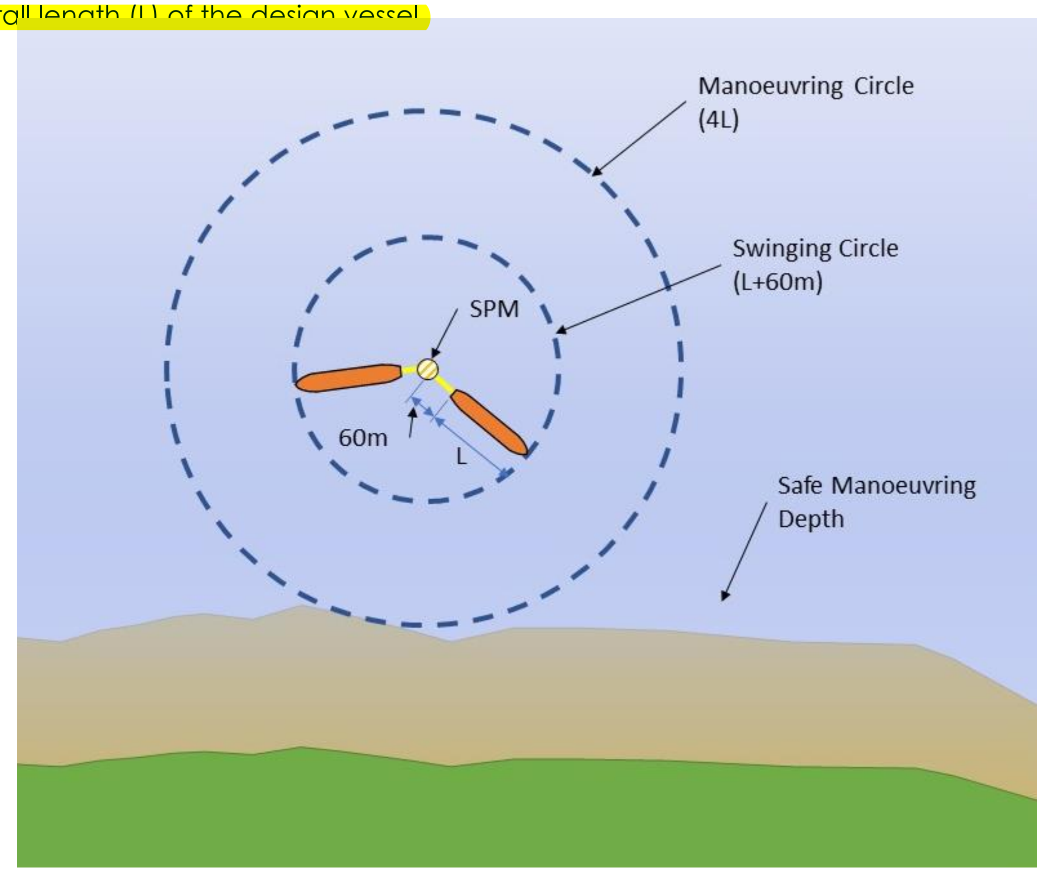


Figure 5.1: Typical nearshore or protected waters SPM layout

5.1 Catenary Anchor Leg Mooring (CALM)

5.1.1 Background

Class rules, design considerations and the safety factors to be taken into account are developed in reference standards such as (ABS, 2014), (API RP 2SK, 2018), (DNV OS E301, 2018), (ISO 19901-7, 2013), (Bureau Veritas BV NR 493, 2015).

5.1.1.1 CALM System Principle

CALM buoy systems are used in water depths ranging from approximately 20 metres to more than 1,000 metres.

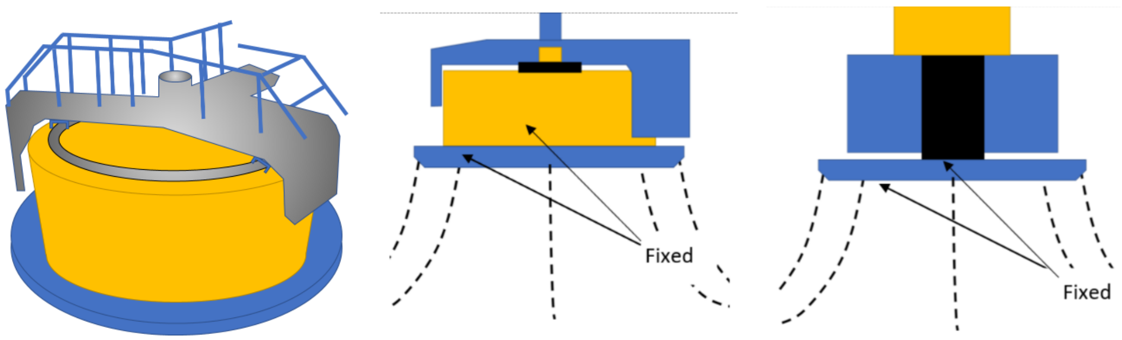
The CALM system consists of a large floating buoy, connected by multiple radially deployed chains to anchors securing the installation to the seabed.

A hawser arrangement to moor a tanker to the buoy is connected to a rotating structure located on the upper part of the CALM system. This arrangement allows for complete 360^0 weathervaning of the tanker around the vertical axis of the CALM buoy. The tanker is thus naturally oriented in the position of least resistance afforded by the combination of wind, waves and current. The weathervaning arrangement therefore allows the vessel to assume a position requiring a reduced mooring force.

The product is transferred between the CALM buoy and the tanker by a floating hose arrangement to the tanker manifold. A subsea hose system from the PLEM transports the product through a fluid swivel located at the centre of the CALM buoy, again allowing the floating hose connection on the buoy to rotate on the turntable relative to the subsea hose system.

Three fundamental designs for CALM systems have been developed based on the following:

- Wheel and rail buoy
- Turntable buoy
- Turret buoy



Wheel and rail buoy *Turntable buoy* *Turret buoy*

Figure 5.2: Different types of CALM buoys

For both Wheel and Rail and Turntable buoy types, the buoy body is the lowest 'geostationary' part of the CALM system. For the Turret buoy, the buoy body is part of the upper rotating structure which is supported on the geostationary base and turret shaft. (see Figure 5.2).

5.1.1.2 Main Elements of the CALM System

The complete CALM system comprises:

- The buoy itself comprises of:
  - An upper rotating part with:

    - Attachment point for mooring line
    - Piping and connection flanges for floating hoses
    - Handling and safety equipment
  - A mooring swivel for unlimited horizontal rotation of the buoys mobile part
  - A fluid swivel in the centre of the buoy, concentric with the mooring swivel, for the fluid passage between the pipes supported by the buoy mobile part and those located in the lower part of the buoy (fixed with respect to the seabed)
  - A lower part, geostationary with respect to the seabed connected to the anchoring system and with piping and connection flanges for submarine hoses
- Anchoring system
- Mooring line hawser to the ship
- One or more floating hose string
- One or more submarine hose string
- A submarine PLEM, equipped with an isolation valves (usually ball valve) to isolate the SPM fluid networks from the subsea pipeline network

All these elements are described in more detail in the following sections.

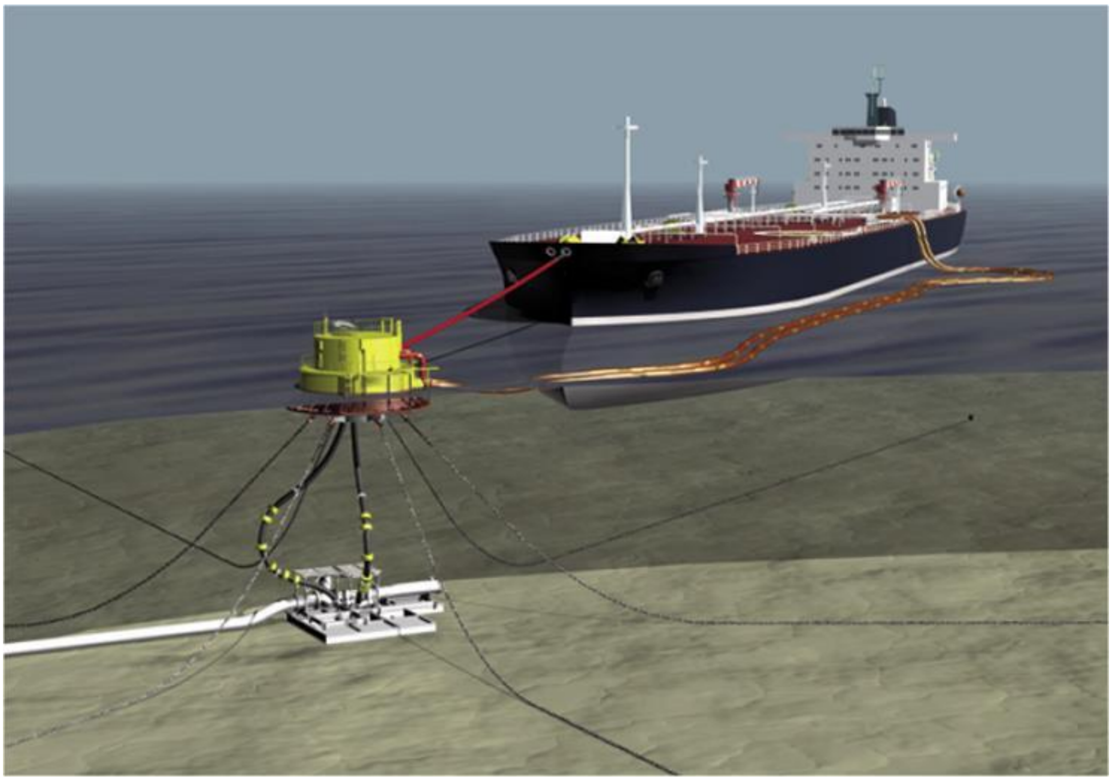


Figure 5.3: Design of a typical CALM buoys concept (Courtesy of Bluewater)

5.1.2 Navigational Considerations and Typical Layouts

This section highlights navigational considerations and constraints, including the required water depth, that have to be considered in order to determine the appropriate CALM buoy location.

5.1.2.1 Navigational Considerations, Berthing Strategies

The CALM buoy system has to be installed in a location that allows the design range of tankers to be moored and operated safely.

For nearshore terminals, the CALM system should be as close as reasonably possible to the shore to minimise subsea pipeline lengths.

For offshore locations in exposed waters (>20 nm), manoeuvring areas should be significantly increased beyond the minimum recommendations due to the environmental conditions found in exposed waters.

For berthing, the ship must have the possibility to manoeuvre under its own power close to the terminal from the most favourable direction and heading depending on the prevailing metocean conditions.

Once moored, the tanker shall be free to move and swing through a 360-degree angle (swinging circle) without risk of collision or contact with any surface or subsea obstacle or other maritime traffic. A station keeping tow may be required on the stern of the vessel to prevent the vessel from contacting the buoy.

The radius of the swinging circle shall be determined by the sum of:

- Radius of the CALM buoy
- Horizontal displacement of the CALM buoy from its theoretical centre when under full mooring load and under maximum operational environmental conditions
- Length of the hawser mooring line
- LOA of the largest tanker
- Towing line and tug lengths if any
- Safety margin

In addition to the swinging circle an extended radius must be considered for manoeuvring. This manoeuvring circle (MMA) must be determined based on the results of a dedicated assessment. For reference, in nearshore and protected waters, the radius of the manoeuvring area (and distance to danger line) is recommended to be at least four times the length of the operating tanker. In offshore exposed waters (>20 nm) or severe metocean conditions the radius of the manoeuvring is to be significantly increased. (See Figure 5.4 showing 'clearance' distance to nearby platform).

Exposed waters include locations where the prevailing environment (wind, waves, current, squalls, microbursts, rotary currents, and shallow water effect) unfavourably influences the mooring manoeuvre.

When possible (reference is made to OCIMF Single Point Mooring Maintenance and Operations Guide – SMOG) adequate manoeuvring room around the SPM should be determined by a risk/consequence assessment that takes into account the:

- Departure procedures
- Tanker breakout and emergency departure procedures
- Operational environmental conditions
- Tanker draught and water depth at each stage of operations
- Detailed input from the local harbour authority and pilots

In addition to the minimum criteria above, some operators will typically consider 1.2 nautical miles as the manoeuvring area or greater to incorporate a safety margin factor into the manoeuvring area radius.

5.1.2.2 Required Water Depth

The required water depth in each 'safety zone' can be determined following recommendations of PIANC MarCom WG 121 (2014). Additional requirements for minimum water depth requirements can be found in the respective Classification Societies' rules.

The different areas are illustrated in Figure 5.4 below:

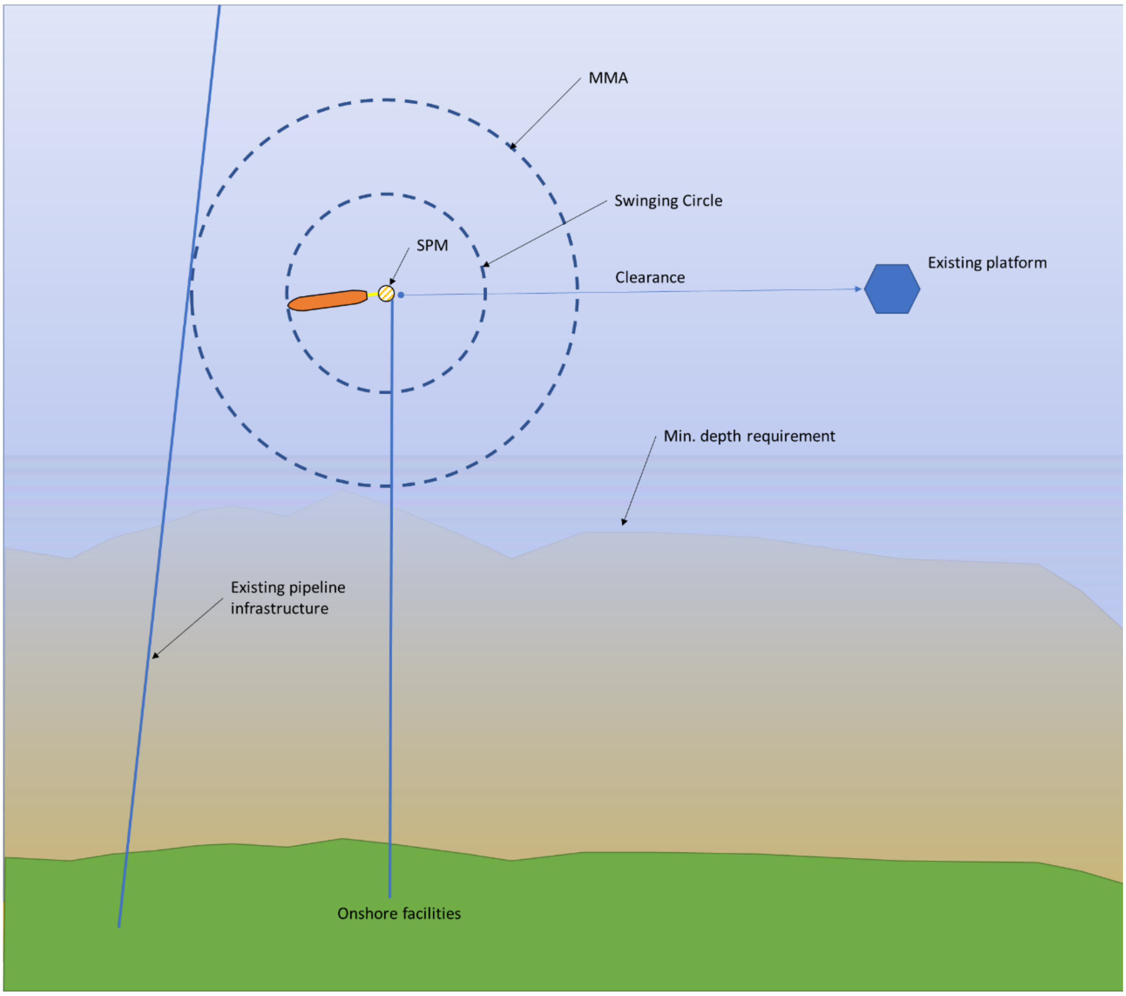


Figure 5.4: SPM manoeuvring area (extracted from OCIMF SMOG)

5.1.3 Buoy Components

5.1.3.1 Hull Characteristics

The CALM buoy has a welded steel floating body. It provides the buoyancy needed to support the mooring and submarine hoses to keep the entire CALM system floating.

Buoy dimensions depend on several aspects but essentially are linked to the number of products to be handled, the available water depth and the design vessel. Typically, the size ranges from 8 to 14 m in diameter and from 3 to 5 m in height.

The buoy body is divided into several internal compartments by watertight bulkheads to provide sufficient buoyancy even in the event of an accident causing damage and flooding to one of the compartments.