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Standard Guide for Selection of Booms for Oil-Spill Response[1]

This standard is issued under the fixed designation F2683; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the selection of boom for the containment and recovery of marine oil spills.

1.2 This guide does not address the compatibility of spill-control equipment with spill products. It is the user's responsibility to ensure that any equipment selected is compatible with anticipated products and conditions.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F818 Terminology Relating to Spill Response Booms and Barriers

F1093 Test Methods for Tensile Strength Characteristics of Oil Spill Response Boom

F1523/F1523M Guide for Selection of Booms in Accordance With Water Body Classifications

F2152/F2152M Guide for In-Situ Burning of Spilled Oil: Fire-Resistant Boom

3. Significance and Use

3.1 This guide is intended to aid in the selection of oil spill containment boom for various response conditions. It is not intended to define rigid sets of boom selection standards.

3.2 This guide is intended to be used by persons generally familiar with the practical aspects of oil spill cleanup operations including on-scene response coordinators, planners, oil spill management teams, oil spill removal organizations, and plan evaluators.

3.3 Minimum requirements for boom dimensions, buoyancy, and tensile strength are specified in Guide F1523/F1523M. This guide provides additional qualitative information to aid in boom selection.

3.4 Seven general types of boom systems are described in this standard. Each description includes a summary of the operating principle and a list of selection considerations.

3.5 Definitions relating to boom design, boom types, boom components, boom characteristics, and boom performance can be found in Terminology F818.

3.6 Selection considerations are included to help the user on the selection of a particular boom type or category. Users are cautioned that within each category there may be a wide variation in performance among the various booms.

4. Boom Selection Considerations

4.1 Selecting a boom for a particular application involves examining the boom's likely performance with regards to a range of operational requirements. The following recommendations are a guide to this process with the requirements grouped together according to the operating environment, the slick conditions, and boom performance criteria. Comments on each of these operational requirements, specific to each boom type, are given in Section 6.

4.2 The general statements below describe likely boom performance with regards to individual design elements, and should be used with the understanding that overall performance is affected by a combination of design elements. For example, lower than typical buoyancy may be counteracted by providing increased longitudinal flexibility.

4.3 *Wave and Current Conditions*—In general, booms work best in calm conditions or in a long, gentle swell with no

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

current. Performance is degraded in high waves, in short, choppy or breaking waves, and in strong currents.

4.4 *Roll Response in Currents*—Good roll response is important to effective containment in high currents and waves. Roll response is improved with: sufficient ballast; ballast located low on the skirt; flotation located away from the boom centerline; and tension members located low on the skirt.

4.5 *Heave Response in Waves*—Good heave response will reduce losses due to splashover. Heave response is a function of the buoyancy, boom mass, and the float water plane area. Heave response is improved with increased waterplane area and buoyancy-to-weight ratio.

4.5.1 Heave response is also a function of the longitudinal flexibility of a boom as a wave moves along its length. Boom freeboard and draft are reduced if a boom is too rigid to move with the wave pattern. Water plane area and buoyancy are good measures of heave response if a boom has the flexibility to move with the wave pattern. Good flexibility helps a boom follow the surface of a moving wave. Boom flexibility is generally enhanced by shorter float sections and closer float spacing, providing flex between floats is allowed by the fabric. Good flexibility is also provided by a continuous, but limber flotation material, such as a continuously inflated flotation chamber.

4.5.2 Calm Water booms should have a gross buoyancy-to-weight (BW) ratio of at least 3:1, Protected Water booms 4:1, and Open Water booms 8:1. (See "Recommendations for Selection of Spill Containment Booms," Guide F1523/F1523M.)

4.5.3 In general, booms with buoyancy-to-weight ratios lower than those specified in Guide F1523/F1523M may not be as effective in other than benign conditions (that is, no wind, waves, or currents). Exceptions to the specified minimum BW ratios include booms designed for special applications, such as boom designed for static containment (that is, not towed), fire-resistant boom, and permanent boom. The latter two types of boom typically have low buoyancy-to-weight ratios as a result of their use of heavy, durable materials for fire-resistance and long-term deployment, respectively. These booms may have BW ratios lower than the minimums listed in Guide F1523/F1523M.

4.6 *Freeboard Height and Skirt Depth*—Adequate freeboard is desirable to prevent splashover losses. Excessive freeboard can lead to problems in high winds, with the wind depressing the freeboard and raising the skirt if the appropriate relationships between freeboard, draft, and ballast are not maintained.

4.6.1 Skirt depth is typically half to two-thirds of the total boom height. A deeper skirt does not contain more oil and may be detrimental in high current conditions. In a fast current, water accelerates to move around the bottom of the skirt, which is likely to cause entrainment losses. Generally a skirt should not be deeper than 6 in. (150 mm) in a current greater than 1.5 knots and 3 in. (75 mm) for speeds greater than 3 knots.[3] In shallow water, the skirt should be no greater than ⅓ rd to ⅕ th the depth of the water or the acceleration of the water in the restricted area between the bottom of the skirt and the stream bed may cause entrainment losses.

4.7 *Forces on a Boom:*

4.7.1 Straight-line drag force is tension on a boom caused by towing it from one end. This may limit transit speed of vessels en route to a spill. Tow speed should be adjusted to account for the strength of the towline, strength of the boom tension members, strength of end connectors where the towline is attached, and stability of the boom under tow.

4.7.2 Towing a boom in a catenary configuration (U or J) will generate much higher drag forces than towing in a straight line. Booms are towed in this way at very low speeds, typically (0.5 to 0.75 knots). Tow forces are easily estimated as a function of boom draft, length, gap ratio, and tow or current speed.[4,5]

4.8 *Boom Strength Criteria*—Tensile strength is an important boom criterion and also one of the most difficult to measure accurately and to understand. There are several problems. If a boom is stressed to failure, tension members may not all fail together. This means that the strength of a boom is not necessarily equal to the aggregate strength of its assembled components. Although all tension members contribute to overall strength, boom strength may be determined by its weakest component. For example, boom connectors may fail long before the tension members, so boom strength would be limited to the strength of the weakest component. The only way to accurately determine boom strength is to test a sample to failure. (See Test Methods F1093.)

5. Boom Selection Checklist

5.1 The primary selection criteria are generally draft and freeboard dimensions, strength, and buoyancy-to-weight ratio. Buoyancy-to-weight ratios greater than those listed may result in improved boom performance under certain conditions; however, further research is required before minimum values greater than those shown can be established. As a result, users should be alert to special requirements that would demand higher buoyancy-to-weight ratios than those listed in the guide. The user should be particularly alert when selecting heavy, permanent boom. Many of these products have size and strength appropriate for Protected Water or Open Water, but some have very low buoyancy-to-weight ratios and therefore may not be as effective except in Calm Water.

5.2 Boom flexibility is important for applications in medium swells and short-period waves. Shorter flotation elements generally provide better flexibility. Further, the distance between flotation sections should be less than one half the average wave length to prevent out of phase motions being set up. Good flexibility is also provided by a continuous but flexible flotation material or an inflated flotation chamber.

5.3 External flotation, rigging lines, or other surface features may interrupt the fluid flow along the boom. A boom that has

[3] Hansen, K. and Coe, T., Oil Spill Response in Fast Currents: A Field Guide, *U.S. Coast Guard Report CG-D-01-02*, 2001 .

[4] *World Catalog of Oil Spill Response Products*, 9th Edition, 2008.

[5] Schulze, R. and Potter, S. "Estimating Forces on Oil Spill Containment Booms," *Spill Technology Newsletter*, Vol 27, Jan-Dec 2002, Environment Canada, Ottawa, Ontario.

TABLE 1 Boom Selection Criteria

Boom Type	Typical Applications	General Comments	Buoyancy	Roll Response	Heave Response
Fence	Permanent or long-term deployment; fueling areas, around ships, power plant outfalls, and other calm and protected water applications.	Easy to deploy, resistant to damage, but relatively bulky for storage.	Generally low, varies with design.	Generally low; may be improved by ballast and off-center float area.	Generally low; may be improved by increasing water plane area and B:W ratio.
Curtain, internal foam flotation	Various calm and protected water applications.	Fairly easy to store.	B:W ratios generally in the range of 2 to 8.	Good; helped by flexibility and bottom tension member.	Good; improved by short float sections to increase flexibility.
Curtain, external foam flotation	Industrial, permanent, and other calm and protected water applications.	Durable. Easy to store and deploy; generally more expensive than curtain boom with internal foam.	B:W ratios generally in the range of 2 to 8.	Good; helped by flexible fabric and ballast.	Fair to good; helped by B:W ratio and flexibility.
Self-inflatable curtain	Calm, protected, and open water applications. Generally not used for industrial applications or long-term deployment.	Rapid deployment. Low storage volume. Typically stored on reels.	B:W ratios generally >10. Buoyancy could be lost from puncture or leaking valve.	Good; good flexibility and bottom tension help roll.	Good resulting from high B:W and flexibility.
Pressure-inflatable curtain	Calm, protected, and open water applications. Generally not used for industrial applications or long-term deployment.	Deployment somewhat slower than self-inflatable curtain. Typically stored on reels.	B:W ratios generally >10. Buoyancy could be lost from puncture or leaking valve.	Good due to bottom tension and flexibility.	Good due to high B:W ratio and flexibility.
Fire resistant	Used to contain an oil slick for in situ burning. Conventional booms may be used to direct oil into burn pocket of fire-resistant boom.	Generally designed for one burn application; some can be stored and reused.	B:W ratios generally in the range of 2 to 5; generally low due to use of relatively heavy fire-resistant materials.	Generally poor due to weight and low B:W; depends on boom type.	Generally poor due to weight and low B:W; depends on boom type.
Tidal seal	Used in the intertidal zone, perpendicular or parallel to shore, to prevent oil from moving along shoreline or into intertidal areas.	Used to bridge the gap between land and water.	Only enough to rise with tide; controlled by water ballast.	Generally good; controlled by buoyancy and ballast.	Poor due to low B:W (note: generally not an issue in intertidal applications).

a consistent profile along its length, and that is free of surface irregularities will promote laminar fluid flow along the boom and reduce losses related to eddy currents. A consistent profile is also less prone to collecting debris.

5.4 Materials should be strong enough to resist puncture by debris. With air flotation booms, puncture resistance is a prime consideration.

5.5 Anchor points are recommended at about 50 ft (15 m) intervals.

5.6 Booms should be packaged for ease in transportation. Storage volume is important for storage and handling.

5.7 Booms should be easy to assemble, deploy, and retrieve.

5.8 Handles located along the top of the boom aid in deployment and handling.

5.9 Booms can deteriorate in storage, particularly when exposed to the elements, to extreme temperatures, to extreme humidity, and when handled in extreme temperatures. Selection of appropriate fabrics and good storage practices are important to slow deterioration and extend the life of the boom.

6. Description of Boom Types

6.1 The following describes the operating principles and key selection considerations of seven main types of boom systems. In some cases, subcategories are used to describe

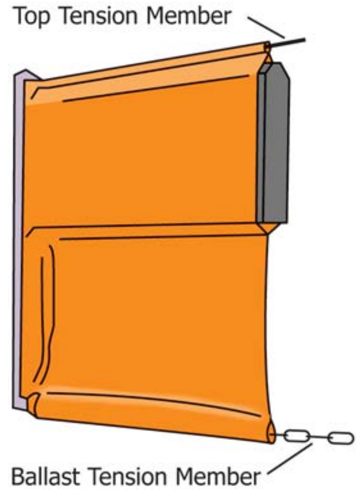

FIG. 1 Fence Boom with Internal Flotation

different configurations of a common operating principle. Selection considerations are summarized in Table 1 at the end of this section.

6.2 *Fence Boom:*

6.2.1 A fence boom is rigid or nearly rigid in the vertical plane, a condition that is achieved either by using vertical stiffeners in flexible boom material or by using heavy fabric that is stiff vertically but free to bend in the horizontal plane to conform to water movement. Fence boom can be further classified according whether the flotation used is inboard (Fig. 1) or external (Fig. 2):

6.2.2 Fence boom with internal flotation generally has a water plane area that is small and concentrated near the centerline of the boom. This narrow, flat flotation makes the boom easier to store, but both roll and heave response are likely to be poor. Wider floats improve wave response, but at the expense of storage. Problems with roll response may be relieved somewhat by ballast weights. High freeboard may compensate for low heave response.

6.2.3 Fence boom with external flotation generally has better roll response and heave response. Some booms of this type are made of heavy fabric that is fairly stiff in the vertical plane, but pliable in the horizontal plane. These boom sections can be easily folded for storing. Floats that can be rotated vertically make the boom more compact for storage. External flotation may have the disadvantage of collecting debris and the projecting floats may make the boom hard to clean. Fence booms with easily removable floats will facilitate decontamination and repair after a spill.

6.3 *Curtain Boom*—Curtain boom typically has a flexible skirt that may be stiffened by rods between sections, connections, or tension members. The boom's stability under tow or in current is aided by the addition of tension members such as cable or ballast chain attached to the connector. Curtain boom is classified according to whether flotation is: (*1*) internal foam, (*2*) external foam, (*3*) self-inflatable, or (*4*) pressure-inflatable.

6.4 *Curtain Boom with Internal Foam Flotation:*

6.4.1 Curtain boom with internal foam flotation (Fig. 3) generally uses a flexible, relatively light PVC or polyurethane-coated fabric to cover flexible foam flotation. The fabric encloses the flotation, and some contain a ballast chain and top cable that serve as strength members. Ballast may also be provided by lead weights instead of chain. The foam flotation may be either cylindrical or rectangular. "Fast current" versions of the boom sometimes have holes near the bottom of the boom skirt. This design feature is intended to reduce the likelihood of entrainment losses, and to reduce the towing or anchoring loads.

6.4.2 The flotation element is generally a solid foam log or a log rolled from sheet foam material. Foam flotation generally comes in short segments to improve heave response and to provide fold points for storage. Granular flotation provides excellent flexibility for heave response, but the granular foam can become saturated with water or lost if the flotation chamber is torn; it is not commonly used as a result. Solid foam avoids these problems, but heave response is not as good and the solid foam may crumble and break with handling. Flexible rolled foam is often used because it provides a moderate amount of flexibility, is very durable, and maintains its buoyancy even if the flotation chamber is flooded. All foams used should be of a closed-cell type and be UV stable.

6.5 *Curtain Boom with External Foam Flotation:*

6.5.1 Curtain boom with external foam flotation (Fig. 4) looks like some fence boom except that the skirt material is flexible. Fence boom with external foam is often made of very heavy, stiff conveyor belt material, and is often used as permanent boom. As new fabrics were developed, it became possible to have a very strong, but light and flexible skirt to which external foam flotation is attached. This product, with the flexible skirt, is classified as curtain boom.

6.5.2 Boom flotation is provided by moulded polyethylene floats. These floats should be completely sealed to prevent water or oil saturation, and filled with closed cell foam for security. This type of boom is not typically used for response work as it is heavy to manage. The belt-type fabrics provide

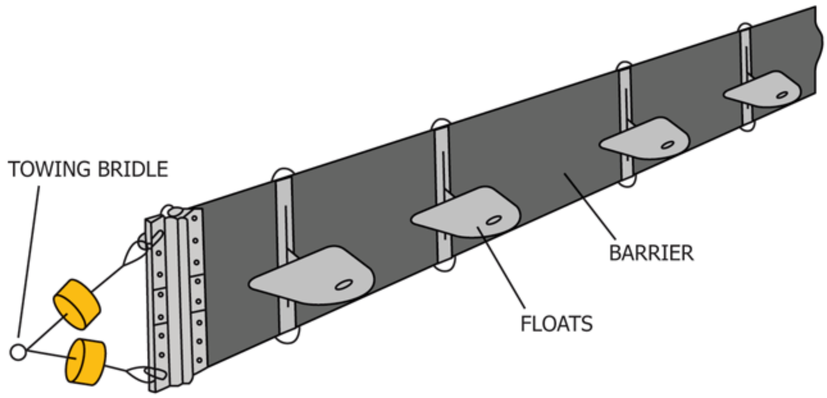

FIG. 2 Fence Boom with External Flotation

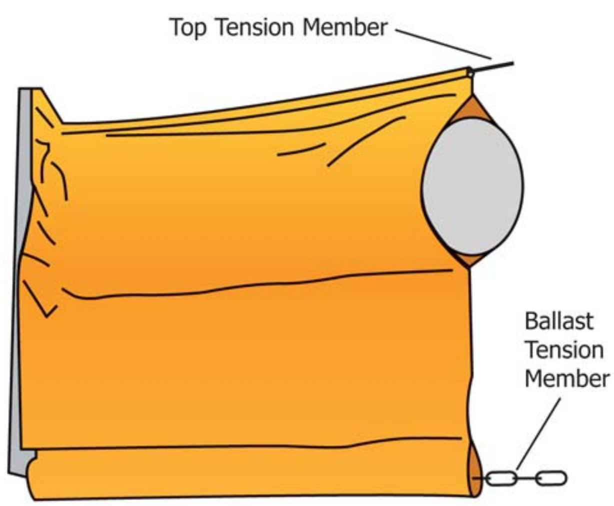

FIG. 3 Curtain Boom with Internal Foam Flotation

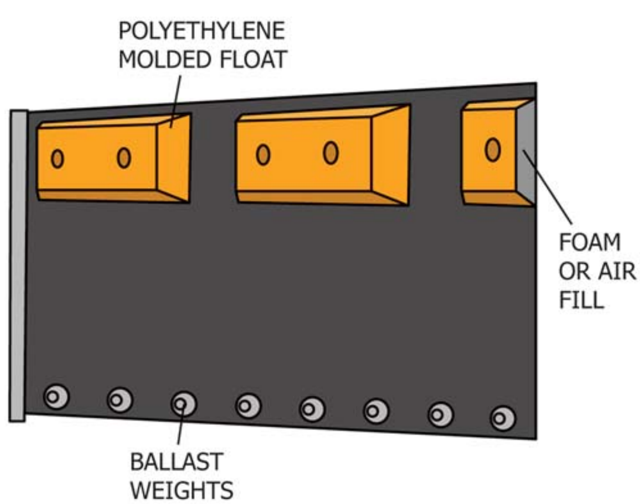

FIG. 4 Curtain Boom with External Foam Flotation

vertical rigidity and tensile strength. Belt materials may be treated with marine growth inhibitors. Sacrificial anodes will prolong the life of metallic components. Ballast is typically provided by corrosion resistant metallic block weights. Chain may be used if properly attached or encased to prevent loss during long-term deployment.

6.6 *Self-Inflatable Curtain Boom*—Self-inflatable curtain boom (Fig. 5) has flotation chambers that are compressed in storage and are inflated by atmospheric air on deployment through one-way intake valves. Self-inflatable curtain booms are generally made of flexible, relatively light PVC or polyurethane coated fabric; collapsible frames, springs, or helical

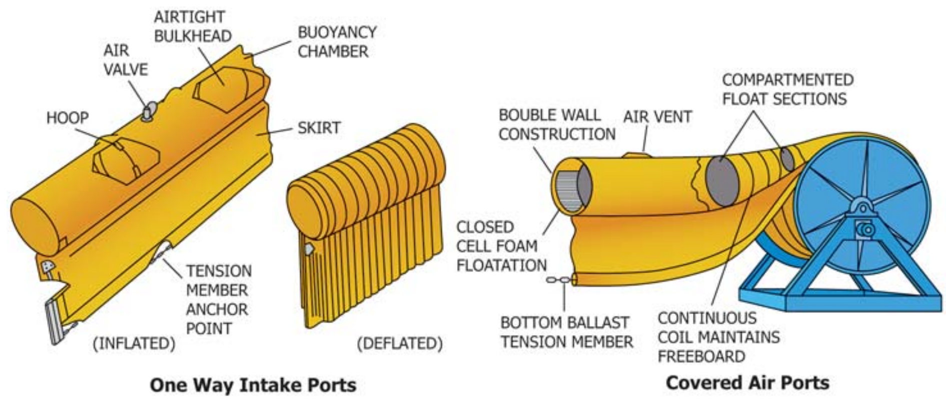

FIG. 5 Typical Self-inflatable Curtain Boom

coils are sometimes used to establish the shape of the air chamber. Their main advantages are: rapid deployment; flexible buoyancy chambers and generally high buoyancy-to-weight ratio provide good heave response; compactible and store in a small volume. Their main disadvantages are: generally have a relatively low tensile strength, may be more vulnerable to damage than other curtain booms; during deployment or if towed too fast, the flotation chambers may fill with water and cause the boom to sink; the helical coils may be compressed so that the buoyancy chamber flattens resulting in a loss of buoyancy.

6.7 *Pressure-Inflatable Curtain Boom:*

6.7.1 Pressure-inflatable curtain boom (Fig. 6) generally has segmented buoyancy chambers that are inflated individually, but may have a continuous buoyancy chamber. Multiple air chambers which are compartmented will prevent a total loss if the air chamber is punctured. Some versions of the continuous buoyancy chamber boom have compartmented sections with check valves and are inflated by an air manifold from an air blower. Depending on the application, pressure-inflatable booms may be made of light PVC or polyurethane coated fabric, or heavy neoprene or nitrile rubber-nylon.

6.7.2 Pressure-inflatable booms main advantages are: high buoyancy-to-weight ratio and good heave response; generally are made of much stronger material than self-inflatable boom; compactible, can be stored in a small volume. Their main disadvantage is that they are deployed more slowly than the self-inflatable boom.

6.8 *Fire-resistant Boom:*

6.8.1 Fire resistant boom is designed to withstand the heat and stress of in-situ burning. A more complete guide to fire resistant boom is provided in Guide F2152/F2152M. Fire resistant boom designs include:

6.8.1.1 Heavy stainless steel fence type booms designed for multiple uses in harsh environments.

6.8.1.2 Smaller metallic reinforced booms with a variety of fire resistant materials designed for single or multiple uses

6.8.1.3 Self inflating boom enclosed in heat resistant fabrics.

6.8.1.4 Modified inflatable booms with active or passive water-cooling jackets to provide heat resistance.

6.8.2 Each design has relative attributes and shortcomings that must be evaluated for the environment and service into which they will be deployed.

6.8.3 The roll response, heave response, and oil containment characteristics of fire resistant booms are generally not as favourable compared with conventional boom, due to the use of relatively heavy fire-resistant materials and generally lower buoyancy.

6.9 *Tidal Seal Boom*—Tidal seal booms (Fig. 7) use air or foam for buoyancy and water for ballast. They float free at high tide and seal to the mud or sand at low tide. When grounded, the heavy water ballast seals the boom to the shoreline and prevents oil from moving along the intertidal zone.

7. Keywords

7.1 booms; containment; oil spill response

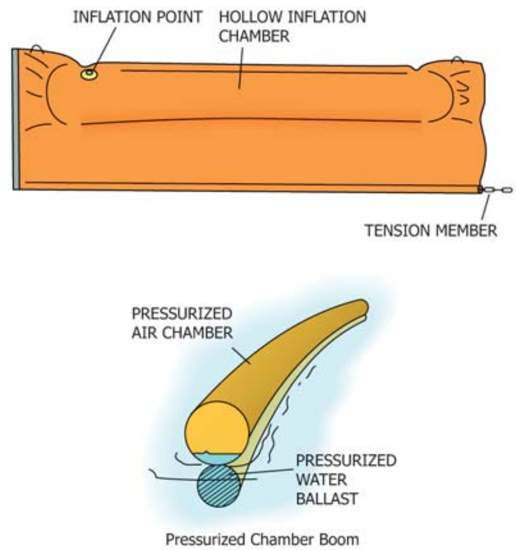

FIG. 6 Pressure-inflatable Curtain Boom

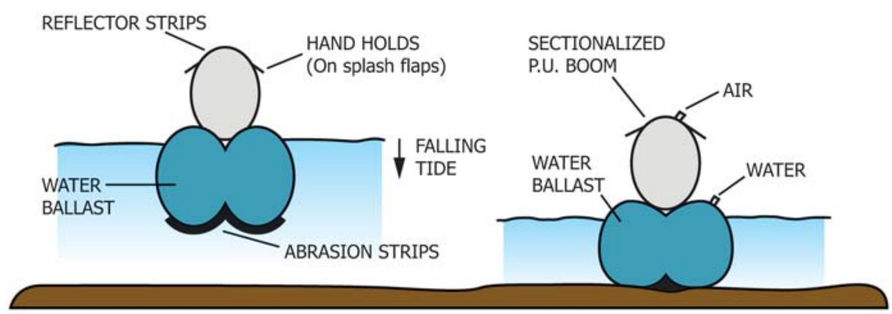

FIG. 7 Typical Tidal Seal Boom