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Standard Guide for Determining the Buoyancy to Weight Ratio of Oil Spill Containment Boom[1]

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ε1 NOTE—Editorial changes were made to Sections 3, 6, 7, and 9 in June 2012.

1. Scope

1.1 This guide describes a practical method for determining the buoyancy to weight (B/W) ratio of oil spill containment booms.

1.2 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F818 Terminology Relating to Spill Response Barriers
F1523 Guide for Selection of Booms in Accordance With Water Body Classifications

3. Terminology

3.1 *boom section*—length of boom between two end connectors. **F818**

3.2 *boom segment*—repetitive identical portion of the boom section. **F818**

3.3 *buoyancy to weight ratio*—gross buoyancy divided by boom weight. **F818**

3.4 *gross buoyancy*—weight of fresh water displaced by a boom totally submerged.

3.5 *reserve buoyancy*—gross buoyancy minus boom weight. **F818**

4. Significance and Use

4.1 This guide describes a method of determining the buoyancy to weight ratio of spill response booms. The principle is based on Archimedes Law, which states that a body either wholly or partially immersed in a fluid will experience an upward force equal and opposite to the weight of the fluid displaced by it.

4.2 Unless otherwise specified, when used in this guide, the term *buoyancy to weight ratio (B/W ratio)* refers to the gross buoyancy to weight ratio. Buoyancy is an indicator of a spill response boom's ability to follow the water surface when exposed to current forces, fouling due to microbial growth (which adds weight), and wave conditions. Surface conditions other than quiescent will have an adverse effect on collection or containment performance. When waves are present, conformance to the surface is essential to prevent losses. Minimum buoyancy to weight ratios for oil spill containment booms are specified in Guide F1523 for various environmental conditions.

4.3 This guide provides the methodology necessary to determine the buoyancy to weight ratio using a fluid displacement method. This method is typically applied to booms having relatively low B/W ratios (in the range of 2:1 to 10:1). Booms with greater buoyancies may also be tested in this manner. It is acceptable to use calculation methods to estimate boom displacement for booms with buoyancies greater than 10:1, where the potential error in doing so would have a less significant effect on performance.

4.4 When evaluating the B/W ratio of a spill response boom, consideration must be given to the inherent properties of the boom that may affect the net B/W ratio while in use. These considerations include, but are not limited to, absorption of fluids into flotation materials, membranes that are abraded during normal use, and entry of water into components of the boom.

4.5 The entry of water into boom components is of particular concern with booms that contain their flotation element within an additional membrane. (This is the case for many booms that use rolled-foam flotation and relatively lightweight material for the boom membrane.) It is also important for booms that have pockets that enclose cable or chain tension members or ballast. When new, the membrane enclosure may contain air that would result in increased buoyancy. In normal use, the membrane material may be easily abraded such that it

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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.

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would no longer contain air, and water would be allowed in at abrasion locations. For such booms, the membrane enclosure shall not be considered as part of the flotation of the boom, and the membrane shall be intentionally punctured to allow water to enter during the test procedure.

5. Summary of Test Method

5.1 *Displacement Method*—Buoyancy to weight ratio is estimated using two key values, the dry weight of the boom and the gross buoyancy of the boom. Weight of the boom is measured directly. The gross buoyancy is equal to the weight of fresh water displaced by a boom totally submerged. Gross buoyancy is measured by submerging the boom, measuring the volume of water that is displaced, and calculating the weight of the displaced water.

6. Equipment Requirements

6.1 This method requires a scale to measure the dry weight of the boom, an open-top tank sufficient in volume and footprint area to physically hold the boom section or segment, a means of submerging the test section, a fresh water supply, and a method of accurately measuring the volume of water that is delivered to the tank. A recommended method of restraining the boom's buoyant force is to use a fabricated grid of dimensional lumber or steel that fits inside the tank surface area. The grid would be positioned above the boom such that it holds the boom underwater when the tank is filled.

6.2 The preferred method of determining the displacement of the boom is to use a complete boom section including end connectors, tension members and ballast, and so forth. Depending on the size of the boom, it may be more practical to measure only a portion of the boom (several segments, for example) and to scale the results. It is helpful, but not essential, that the tank have a consistent cross-sectional area. Prior to use, the tank shall be leveled and a datum established from which to obtain relative measurements.

6.3 For accurate results, the surface area of the tank shall not greatly exceed the area that the boom occupies within the tank. A recommended rule-of-thumb for this is that the surface area of the tank be no greater than twice the area occupied by the boom or boom segments being tested.

7. Test Method

7.1 The following is a summary of the methodology for measuring buoyancy-to-weight ratio. The methodology is intentionally generalized to allow the user to employ alternative test apparatus that may be readily available.

7.2 Obtain the dry weight of the boom to be tested (section, segments, and/or components) and record the weight.

7.3 Inspect the boom for areas that may trap air during the test. These include: ballast chain pocket, layers of fabric sown together, and voids at hinges, connectors, and flotation chambers. A means of allowing water to fill these air pockets must be provided for accurate results.

7.4 Place the boom within the (empty) tank, orienting it in a close to upright position as it would be deployed for use. When placing the boom in the tank, care shall be taken to not introduce folds in the boom skirt that could trap air, and orienting the boom in a close to upright position is recommended to aid in this.

7.5 Place the submerging grid (or other device to restrain the boom below water) in position. There shall be enough space for the boom to float freely as the tank is filled.

7.6 Fill the tank with water and allow sufficient time for trapped air to escape. Filling the tank to submerge the boom shall take no less than one hour, during which time the flotation element and the skirt shall be moved around to facilitate the release of trapped air. (Note that this must be done periodically, and will be difficult or impossible once the boom is submerged and its buoyant force is holding the boom against the restraining grid.)

7.7 Once the boom and the restraining grid have been submerged, record the volume of water that has been delivered and mark the water level from the datum.

7.8 Remove the boom from the tank and empty the tank. With the boom removed and the restraining grid back in place, fill the tank again to the same water level. Record the volume of water that is delivered to achieve this. The difference between this and the measurement in 7.7 will be the displacement of the boom.

8. Accuracy

8.1 Given the use of the data, a reasonable goal in this test would be to achieve an accuracy of the buoyancy-to-weight ratio of less than ±10 %. With an accurate and recently calibrated load cell, the tester should be able to determine the weight of the boom to within less than ±1 %. Therefore, the main test requirement is to measure the buoyancy of the boom to an accuracy of less than ±10 %.

8.2 The required accuracy has implications for equipment selection, particularly the test tank. Assuming that the water level can only be measured to an accuracy of ±1 mm (or approximately 1⁄16 in.), the tester can estimate the corresponding accuracy of the measured water volume. This shall be compared with the estimated volume measurement of the boom (see 7.8) to ensure that it is within the required ±10 %.

8.3 Accurately measuring the water level is critical to an accurate estimation of the boom's displacement. One method is to scribe a datum mark at an appropriate height, and use the datum as the "fill" mark. Alternatively, a scaled ruler can be mounted at an appropriate location. In both cases, it is essential that the test tank be undisturbed through the test period so that successive tests, and duplicate test runs to establish accuracy, can be performed using the same datum. Whatever the measurement method used, the tester shall confirm through duplicate tests that the selected method achieves the required accuracy.

8.4 Totalizing flow meters are available with a stated accuracy of ±2 %, and can be installed on the water supply (to the tank) to provide an accurate estimate of the total volume of water delivered to the tank. Duplicate tests shall be performed to confirm the required accuracy.

9. Potential Sources of Error

9.1 The following items are the most likely sources of potential error, other than error due to imprecise measurement techniques. The tester shall be aware of and take appropriate precautions for each of these items.

9.2 The most likely source of error is related to the potential trapping of air between flotation chambers or within folded-over portions of the skirt or sail. Trapped air would lead to an increase in apparent buoyancy. As noted above, the boom must be observed periodically as the tank is filled, and the boom must be manually agitated to ensure that trapped air is freed from the boom. This means that the filling process shall be done over a period of no less than one or two hours to allow ample time for inspection and agitation of the boom.

9.3 If the tank used for the displacement measurement has removable or hinged doors, leakage from the tank may be of concern. If leakage cannot be stopped or controlled it may be possible to collect any such leakage and its volume taken into account in the displacement measurement.

9.4 If the boom being tested has been used previously, its weight may be affected by water trapped within the boom or by the presence of marine growth.

9.5 If the boom being tested is less than a full section, the weight and displacement of the connectors shall be adjusted proportionately.

10. Calculation Methods

10.1 Calculation methods for estimating boom displacement are acceptable for booms with buoyancies greater than 10:1, where the potential error in doing so would have a less significant effect on boom performance. Calculation methods are also acceptable for booms that are self-inflating, and booms that have a continuous buoyancy chamber, where it would be difficult to measure by the above displacement method.

10.2 Calculations are made to estimate the displaced volume of each of the components of a boom section. As with the displacement method, components that may not contribute to buoyancy during normal use shall not be included, specifically, membranes containing solid flotation that may lose their buoyant effect when abraded during normal usage.

10.3 When calculating displacement volumes, care must be taken to account for reductions in cross-section of the flotation element. For example, flotation chambers may be tapered, greatly reduced, or eliminated at the end of each segment or section, and this shall be accounted for in the displacement calculation.

10.4 Calculations will lead to a total displacement volume, which is then multiplied by the density of fresh water to result in total buoyancy in pounds. Total buoyancy is then divided by gross dry weight to produce the buoyancy-to-weight ratio.

11. Keywords

11.1 boom; buoyancy; oil spill control equipment; oil spill response; spill containment

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