Designation: F2766 – 11 (Reapproved 2015)

Standard Test Method for Boat Barriers[1]

This standard is issued under the fixed designation F2766; 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 test method is intended to provide a means of evaluating the performance of Boat Barriers and through that evaluation provide a certification of performance in the form of an ASTM International Impact Rating for Boat Barriers to be used in the design and specification of Boat Barriers. In addition to the Impact Rating, testing under this standard requires the determination and reporting of the maximum deformation of the barrier during testing to further aid in appropriate barrier selection.

1.2 This test method provides a range of small surface motor boat impact condition levels and penetration performance levels to select boat barriers appropriate for use at potentially threatened onshore port facilities, offshore facilities, and floating assets.

1.3 This test method is designed to test and evaluate the stopping capabilities of boat barriers at the point of impact and the moments subsequent to impact of a small surface motor boat.

1.4 This test method is not intended to be used for the testing criteria of floating "lines of demarcation" or similar items or technologies that do not make claims of "boat or small surface motor boat" stopping capabilities.

1.5 Governing agencies may adopt those performance levels in this test method that satisfy their specific needs and assign certification ratings for small surface motor boat stopping barriers based on the tests and test methodologies described in this test method.

1.6 Many test parameters are standardized to arrive at common small surface motor boat types and masses, enhance test realism and replications, and produce uniform rating designations.

1.6.1 Compliance with these rating designations establishes a measure of performance but does not render any boat barrier invulnerable to motor boat penetration. Caution should be exercised in interpreting test findings and projecting results to other hypothetical conditions.

1.7 Product design/certification in this test method only addresses the ability of the barrier to withstand the impact of the test motor boat. It does not represent an endorsement of the product/design or address its operational suitability.

1.8 *Units*—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.

1.9 *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 *SAE Standard:*[2]

SAE J-211/2 Instrumentation for Impact Test—Part 2: Photographic Instrumentation

2.2 *ISO Standard:*[3]

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *Federal Standard:*[4]

46 CFR 24.10-1 Shipping: Chapter 1—Coast Guard, Department of Homeland Security—Part 24: General Provisions—Definitions

3. Terminology

3.1 *Definitions:*

3.1.1 *accredited independent testing laboratory, n*—testing laboratory accredited to perform the referenced testing procedures by a nationally recognized accrediting agency in accordance with ISO 17025 and led by a test director; an accredited independent testing laboratory shall have access to the apparatus, facilities, personnel, and calibrated instruments that

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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[2] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

are necessary to inspect and test the boat barriers; and an accredited independent testing laboratory may not: *(1)* have any financial interest in or otherwise be affiliated with companies or individuals, for which they perform accreditation testing; *(2)* be owned or controlled by the manufacturer of similar equipment or material to be inspected; *(3)* be owned or controlled by a vendor of the equipment or material to be inspected or a vendor of similar equipment or material; *(4)* be owned or controlled by a supplier of materials to the manufacturer; or *(5)* advertise or promote the manufacturer's equipment or material that the laboratory inspects and tests.

3.1.1.1 *Discussion*—Hereinafter, accredited independent testing laboratories are referred to as "the test facility", with "accredited" being understood as prerequisite. Other independent testing agencies actively pursuing accreditation and whose testing protocols are accepted by a federal agency may also conduct tests for a period of one year after performing the first test using this test method.

3.1.2 *line of demarcation, n*—system used to identify restricted waters.

3.1.2.1 *Discussion*—This type of floating system provides little or no boat stopping/delay capacity.

3.1.3 *waterfront boat barrier, n*—a device intended to provide a standoff from protected assets by *(1)* delineating an exclusion zone around the waterfront approach to an asset and *(2)* preventing the entry into the exclusion zone by a waterborne threat impeding the motion of a boat attempting to penetrate a protected area.

3.1.3.1 *Discussion*—The barrier is primarily intended to stop, delay, or destroy hostile high-speed motor boat of 65 ft (19.8 m) or less in length.

3.1.4 *motorboat, n*—means any vessel 65 ft (19.8 m) in length or less, which is equipped with propulsion machinery (including steam).

3.1.4.1 *Discussion*—The length must be measured from end-to-end over the deck, excluding sheer. This term includes a boat equipped with a detachable motor. For the purpose of this document, motorboats are included under the term vessel, unless specifically noted otherwise. The various length categories of motorboats are as follows:

(1) Any motorboat less than 16 ft (4.9 m) in length.

(2) Any motorboat 16 ft (4.9 m) or over and less than 26 ft (7.9 m) in length.

(3) Any motorboat 26 ft (7.9 m) or over and less than 40 ft (12.2 m) in length.

(4) Any motorboat 40 ft (12.2 m) or over and not more than 65 ft (19.8 m) in length.

3.1.5 *vessel, n*—includes every description of watercraft or other artificial contrivance, used or capable of being used as a means of transportation on water.

3.1.5.1 *Discussion*—In addition to motorboats defined in 3.1.4, vessels also include the following:

(1) Motor vessel—any vessel more than 65 ft (19.8 m) in length, which is propelled by machinery other than steam.

(2) Sailboat—a boat designed or intended to use sails as the primary means of propulsion.

(3) Barge—a non-self-propelled vessel.

3.1.6 *length, n*—the straight line horizontal measurement of the overall length from the foremost part of the boat to the aftermost part of the boat, measured from end to end over the deck excluding sheer, and measured parallel to the centerline. Bow sprits, bumpkins, rudders, outboard motor brackets, handles, and other similar fittings, attachments, and extensions are not included in the measurement.

3.1.7 *beam, n*—the maximum width of a vessel from: *(1)* outside of planking to outside of planking on wooden vessels and *(2)* outside of frame to outside of frame on all other vessels.

3.1.8 *draft, n*—the vertical distance from the molded baseline (bottom) of a vessel amidships to the waterline (when vessel is waterborne).

3.1.9 *penetration, n*—hereinafter penetration shall mean the distance from the point of impact between the motor boat and the boat barrier and the point where the velocity of the motor boat has been reduced to zero.

3.1.9.1 *Discussion*—Penetration may also be understood as the maximum deflection of the barrier from its resting position just prior to motor boat impact to the point where the motor boat has been effectively halted. This penetration value is intended to aid the end-user in the estimation of achievable stand-off between the threat vessel and the asset to be protected. Users of this standard should be aware of the impact of barrier elasticity and as-tested versus in-place barrier length(s) on the total deflection/penetration to be expected in the actual application of the barrier. Penetration shall not mean breach or otherwise overwhelming of the barrier which shall constitute failure of the barrier to perform.

3.1.10 *specifying agency, n*—any entity (federal, state, foreign or private) requiring the testing and certification under this ASTM standard of a manufacturer's boat barrier.

3.2 *Acronyms:*

3.2.1 *DoN*—U.S. Department of the Navy

3.2.2 *USCG*—U.S. Coast Guard

3.2.3 *BOR*—Bureau of Reclamation

4. Summary of Test Method

4.1 For a boat barrier to be tested, the following shall be submitted to the specifying agency and the proposed test facility for review: *(1)* a set of complete barrier shop drawings; *(2)* barrier design and layout (as proposed for testing) in plan, elevation, and section; *(3)* barrier mooring/anchorages in detail; and *(4)* a barrier materials list. Upon modification, if required, and acceptance by the agency, the proposed boat barrier test is scheduled, in coordination with an agency technical representative, for testing and evaluation at the accredited facility. Test article construction and test preparations are made in accordance with this test method.

4.2 A certification rating level test, motor boat weight and test speed is selected by the vendor in coordination with the accredited independent testing laboratory. Following receipt of all pretest documentation, the test is conducted at the chosen speed using the defined test. Dynamic test data are recorded using the accredited methods.

4.3 The test director shall determine acceptability of whether testing conditions are within acceptable limits for a valid test. The rating is determined/recommended by the test director at an accredited facility.

5. Significance and Use

5.1 Governmental and private facilities may use "motor boat barriers" with an ASTM International impact rating. Each agency/organization may have their own, or use other, certification lists.

5.2 When dynamic testing is required, procedures in this test method permit performance evaluation of a boat barrier to certify its level of protection against motor boat attack.

5.3 ASTM Intentional Impact Ratings for Boat Barriers shall not be used unless subjected to one or more of the dynamic tests presented herein.

5.4 Small and large boats interact differently with various security devices. Additionally, if occupant risk is of concern, information may be gathered that allows assessment of the likelihood of occupant injury.

6. Threat

6.1 *Threat Overview*—Waterborne hazards come in a great variety of forms and directions. In recent years, there has been worldwide use of watercraft for malicious purposes including smuggling, piracy, covert infiltration, and direct attack. There has been heightened interest in the threat posed by such craft because of the highly visible use of explosive-laden boats by terrorists and insurgents.

6.2 *Threat Characterization:*

6.2.1 There is tremendous range in the size and shape of motor boat that could pose a threat. For this test method, the definition of threat craft will be constrained to keep the scope of the threat within reasonable bounds. Threat craft are those to which the USCG's definition of motorboat applies (46 CFR 24.10-1).

6.2.2 The population of craft to which this definition applies is both numerous and diverse;[5] therefore, additional granularity is required to describe meaningfully the range of plausible threat craft. Some U.S. Government agencies have used craft size distribution statistics as a basis for both characterization and requirements.[6] As stated in 1.4, this test method is limited in scope to boat barrier performance criteria and makes no judgment about what level of performance may be required in a specified situation. Threat characterization is therefore limited to motor boat characterization only.

6.3 *Threat Craft—Physical Characteristics:*

6.3.1 The principle physical attribute of threat craft germane to boat barriers is mass. Specifically for this test method is the total weight of the craft and its contents that can contribute to a barrier penetration defined here as "rigid mass." Unsecured payload, for example, passengers, is unlikely to contribute to the kinetic interaction and is excluded from this measurement. The mass of motorboats varies considerably but those relevant to this test method are very likely to be between 1000–100 000 lbm (454–45 359 kg).

TABLE 1 Threat Speed Zones

Zone	Speed, knots (m/s)
I	0–20 (0–10.3)
II	>20–40 (>10.3–20.6)
III	>40–60 (>20.6–30.9)
IV	>60–80 (>30.9–41.2)
V	>80 (>41.2)

6.3.2 The other primary physical attribute of the threat craft is their maximum speed. The maximum attainable speed for a particular craft is highly dependent upon a number of factors such as engine type and configuration, hull form and state of cleanliness, loading and draft, harbor geography and configuration, sea state, and so forth. The great variety of commercial and custom boat configurations makes it impossible to put an absolute upper bound on boat speed. To account for such variations, the range of possible speeds is divided into five zones in increments of 20 knots (10.3 m/s) each (Table 1). This test method recognizes that, in actual maritime environments, the vast majority of motor boats that can travel at speeds greater than 60 knots (30.9 m/s) will only infrequently encounter operational conditions that will accommodate speeds that high.

6.3.3 The range of physical parameters of primary interest to this test method is shown in Fig. 1. It represents the trade space in which barrier testing will be conducted under this test method (Section 7).

6.3.4 Other physical attributes of test craft relevant to barrier testing (for example, draft and hull configuration) are described in Section 7.

6.4 *Critical Barrier Evaluation Parameter*—The physical parameter that will be used to assess boat barrier performance is kinetic energy. The range of the maximum kinetic energy of motor boats is very large. A small skiff may be able to reach several thousand ft-lbf (joules) of energy (500 lbm at 15 knots is 5000 ft-lbf [227 kg at 7.7 m/s is 6775 J]). Common privately-owned cruisers can readily reach several hundred thousand ft-lbf (joules) (5000 lbm at 30 knots is 200 000 ft-lbf [2268 kg at 15.4 m/s is 271 kJ]). At maximum speed, a high-performance speed boat can reach several million ft-lbf (joules) (10 000 lbm at 75 knots is 2 500 000 ft-lbf [4536 kg at 38.6 m/s is 338 952.5 kJ]). This wide range of possible energies precludes the use of a single level against which to measure barrier performance. The range of levels for use in this test method is listed in Table 2.[7] The intervals provide scaled granularity of kinetic energy over the plausible range of motorboat mass/speed combinations (Fig. 2). The Barrier's Impact Rating, (ASTM International Impact Rating for Boat Barriers), shall be determined by the kinetic energy of the motor boat at the time of impact with the barrier and the

[5] In 2004, there were over 12 million registered motorboats in the United States alone. (USCG)

[6] Because of the ever increasing population of such craft, such distributions have a limited lifetime of relevance. It is essential to revisit and revalidate distributions on a periodic basis if the information is used in any derivative fashion.

[7] These bounds are not specifically tied to the statistical distribution of craft in U.S. waterways and do not imply requirements.

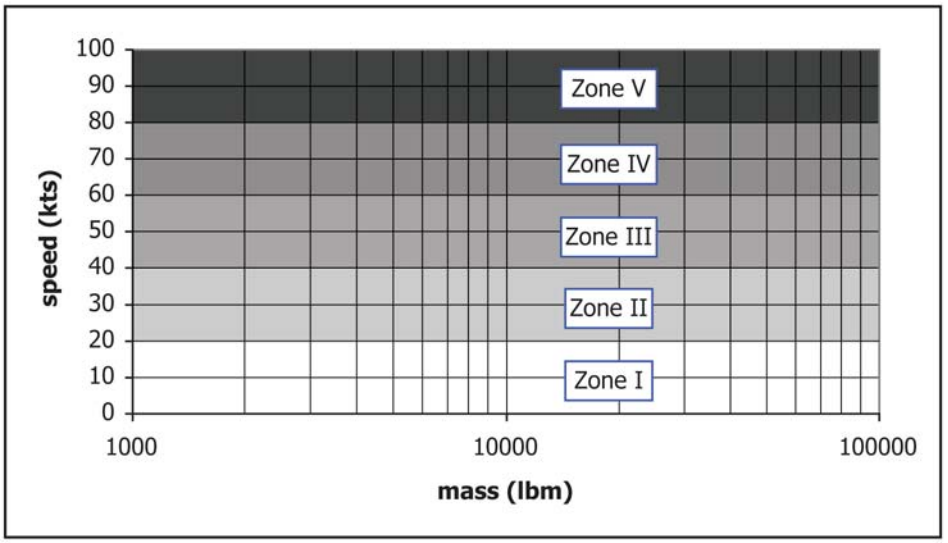

FIG. 1 Threat Craft Physical Parameter Space

TABLE 2 Kinetic Energy Levels

Level	Kinetic Energy	
	ft-lbf	kJ
A	100 000	135.581
B	300 000	406.745
C	600 000	813.491
D	1 200 000	1626.981
E	2 500 000	3389.545
F	5 000 000	6779.090

successful performance of the barrier in halting the forward motion of the motor boat. Impact Rating levels (A thru F) shall be assigned according to kinetic energies shown in Table 2.

6.5 *Illustrative Example:*

6.5.1 To support various physical security initiatives, the USCG's Intelligence Coordination Center generated a table of threat craft.[8] The table cites specific models that are representative of the general categories of craft that operate in U.S. waters. Table 3 provides the baseline masses for the USCG threat categories. They are derived from specific models but are intended to capture the variation in dry weight of the range of boat models and payload such as fuel and miscellaneous gear. Although the threat is not necessarily going to be an explosive craft, embedded within these masses is a positive payload gradient to give credit for larger craft to be able to carry larger (explosive) payloads.[9]

6.5.2 The speeds required of these craft to achieve the kinetic energy levels of Table 2 are listed numerically in Table 4 and illustrated in Fig. 3. The shaded codes correspond to the speed zones illustrated in Fig. 1. Although some of the requisite speeds are clearly unachievable (for example, power boat at 106 knots [54.5 m/s]), the table is intended to illustrate the range of mass/speed combinations that can be evaluated against a selected kinetic energy level.

7. Test Criteria

7.1 *Test Craft:*

7.1.1 Unlike motor vehicles on shore, there is very little standardization in the size, shape, or configuration of motor boats afloat. This is true even for specific craft types such as a yacht or powerboats. Because of this, it is difficult, if not impossible, to characterize test craft with the same specificity as for cars or trucks. However, it is still possible to establish craft selection criteria that give those conducting tests flexibility when searching for and selecting acceptable boats.

7.1.2 Table 5 provides detailed specifications of test craft (as illustrated in Fig. 4). The values selected are intended to favor the selection of craft that have attributes more favorable to kinetic barrier penetration. The motor boat selected for a test should be seaworthy, in good condition, and otherwise unmodified in such a manner as to affect test performance. Engine capability should be within the manufacturer's recommended capability. The hull should be constructed of materials representative of the threat vehicle being tested and documented.

7.1.3 Actual vehicle impact speed shall be within the permissible range shown in Table 1 to receive the rating for the designated condition level at the intended nominal speed. Tests with vehicle impact speed outside this range are not valid for the rating assignment but may be rated by the test director at an appropriate condition level.

7.1.4 Where additional ballasting is required, it can take the form of either solid (for example, sand) or liquid (for example, water). To count as "rigid mass," it shall be secured to the hull in such a manner that it remains rigid upon impact. In addition, any extra ballast shall be positioned such that overall craft parameters stay within the bounds of Table 5.

[8] Smallboat VBIED Threat Chart CG-2410-006-06.

[9] Although it is a critical factor in establishing requirements for barrier use and emplacement, explosive payload is not specifically broken out here because it only contributes inertia to a barrier impact.

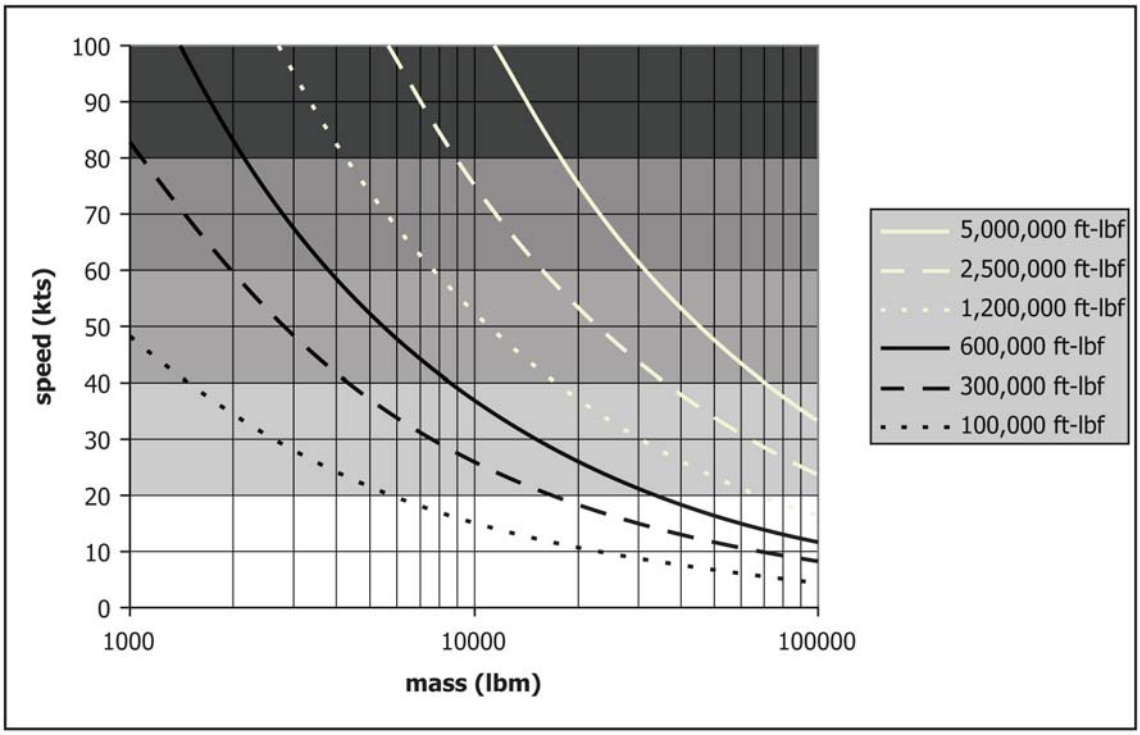

FIG. 2 Kinetic Energy Levels

TABLE 3 Example Threat Craft

Type	Rigid Mass	
	lbm	kg
Rigid hull inflatable boat (RHIB)	2000	907
Power boat	5000	2268
Cruiser	7500	3402
High performance	10 000	4536
Yacht	30 000	13 608
Large yacht	50 000	22 680

8. Apparatus

8.1 Appendix X1 and Appendix X2 describe parameters to be measured before, during, and after collision, including measurement tolerances and techniques.

8.2 Pretest data acquisition shall document the as-built, untested barrier and test motor boat configuration. Documentation includes as-tested specifications and drawings, measurements, and photography.

8.3 During the test, motor boat impact speed and impact point shall be measured. Video documentation shall be made to accurately document the events of the test. Photographic instrumentation specifications shall be in accordance with SAE J-211/2. Minimum high-speed film or video shall be captured at 400 frames per second (fps) or greater.

8.4 Kinematics, barrier displacements, and strains may be important when a barrier needs modification or redesign. When the aforementioned information, or a determination of occupant risk, is necessary, then optional vessel instrumentation may be included. When instrumentation is used, motor boat acceleration shall be measured near center of mass. Electronic instrumentation specifications shall be in accordance with SAE J-211/1. When applicable, occupant risk values are to be computed per the NCHRP Report 350 method of Appendix A Commentary.[10]

8.5 Post test evaluation shall include, maximum barrier deformation, maximum motor boat penetration, and damage of both test article and motor boat shall be documented with measurements, data recordings, and photography. Other parameters peculiar to a barrier may entail additional documentation. For instance, a gate may be shown to be operational after the collision, even though this is not a requirement of this test method.

9. Preparation of Apparatus

9.1 *Test Article:*

9.1.1 Each device, assembly, or structure used in a barrier is to be identified and documented by engineering drawings and specifications.

9.1.1.1 All proprietary information shall be clearly indicated in the document. All such information provided to the agency will be safeguarded and will not be disclosed to unauthorized personnel.

9.1.1.2 Each sheet shall include the barrier title/description, drawing number, and date and shall be submitted in 11 by 17-in. (215 by 280-mm) format. Each drawing shall identify the barrier in exact detail. Assembly drawings shall show the arrangement, locations, and dimensions of all components. All

[10] H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie, "Recommended Procedures for the Safety Performance Evaluation of Highway Features," NCHRP Report 350, Transportation Research Board, National Research Council, Washington, DC, 1993.

TABLE 4 Example Mass/Speed Combinations

	Speeds in knots[A] Kinetic Energy, lbf[B]					
	Mass	100 000	300 000	600 000	1 200 000	2 500 000	5 000 000
RHIB	2000	33.6	58.2	82.3	116.4	168.0	237.6
Power boat	5000	21.3	36.8	52.1	73.6	106.3	150.3
Cruiser	7500	17.4	30.1	42.5	60.1	86.8	122.7
High performance	10 000	15.0	26.0	36.8	52.1	75.1	106.3
Yacht	30 000	8.7	15.0	21.3	30.1	43.4	61.4
Large yacht	50 000	6.7	11.6	16.5	23.3	33.6	47.5

[A] 1 knot = 0.5144 m/s.
[B] 1 lbf = 4.448 N.

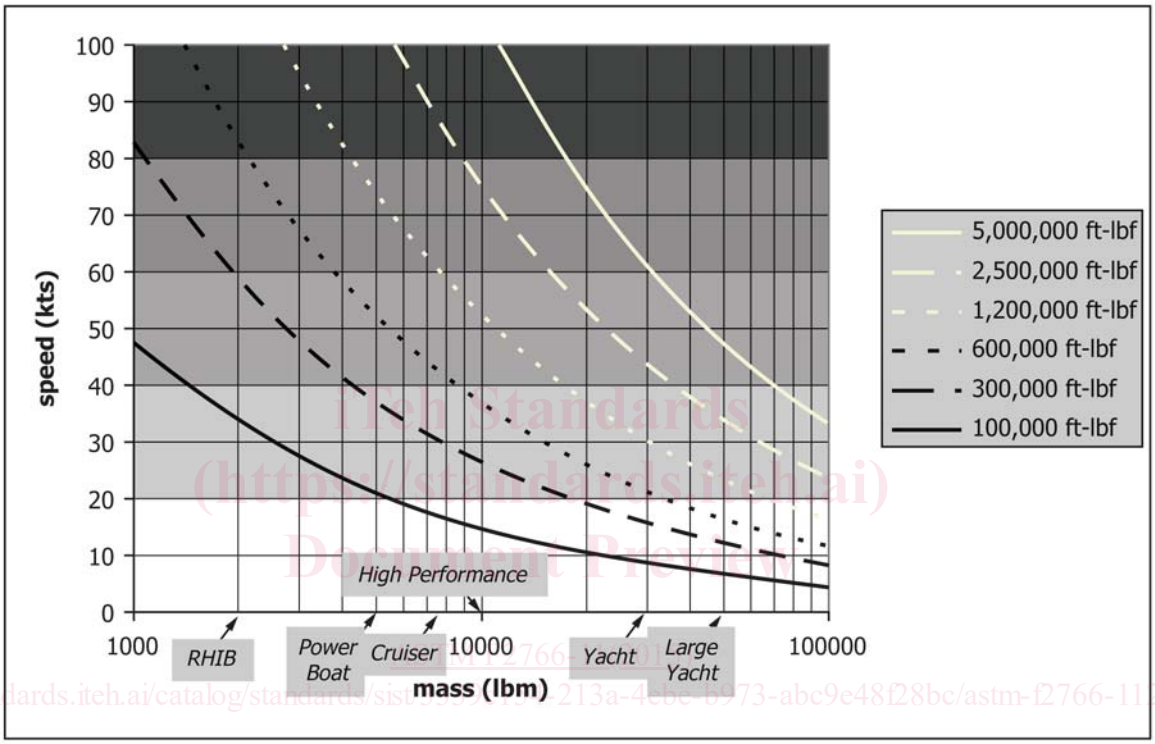

FIG. 3 Example Craft Kinetic Energy

TABLE 5 Test Craft Parameters[A]

Parameter	KE, ft-lbf					
	100k	300k	600k	1200k	2500k	5000k
Speed, knots	15–30	20–40	30–50	30–60	30–60	30–60
Mass, lbs	3000–10 000	4400–17 400	5600–15 400	8000–32 000	16 000–64 000	3200–128 000
Hull Construction Material	Composite	Composite or aluminum	Composite or aluminum	Composite or aluminum	Composite or aluminum	Composite, aluminum, or steel
Drivetrain	Outboard	Outboard	Inboard, outboard	Inboard, outboard	Inboard	Inboard
Draft (static), ft	1–3	1–4	2–5	2–5	3–6	3–6
Rake (entry angle)	0–25°	0–25°	0–30°	0–30°	0–45°	0–45°
Trim (static)	0–2° aft	0–2° aft	0–2° aft	0–2° aft	0–2° aft	0–2° aft
Freeboard (static), ft	< 3	< 3	< 4	<5	< 5	< 6
List/heel	<1°	<1°	<1°	<1°	<1°	<1°
Flare	0–30°	0–30°	0–20°	0–20°	0–15°	0–10°
Waterline length, ft	15–30	20–35	30–45	40–55	45–60	45–60
Beam, ft	6–10	8–15	8–15	8–20	10–20	10–20
Hull form	Shallow vee	Shallow vee	Shallow or deep deep vee	Shallow or deep deep vee	Deep vee	Deep vee

[A] 1 ft-lbf = 1.355 J; 1 knot = 0.5144 m/s; 1 lb = 0.4536 kg; and 1 ft = 0.3048 m.

text and detail on drawings shall be clearly legible without need for magnification.