Designation: F2436 – 14

Standard Test Method for Measuring the Performance of Synthetic Rope Rescue Belay Systems Using a Drop Test[1]

This standard is issued under the fixed designation F2436; 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 covers drop test procedures to measure rope rescue belay system performance. It applies only to belay systems consisting of an untensioned rope connecting the load to an anchored belay device. This test method does not address other types of belays, such as self-belays or belays for lead climbing, nor does it test the rescuer's belaying ability.

1.2 This test method may be used to help measure a rescue belay system's performance under controlled drop test conditions, but it will not necessarily provide guidance as to which belay method is most suited to a particular application. Other considerations, such as ease of handling, performance on different types and diameters of rope, portability, versatility, system safety factor, cost, and automatic operation that do not require the positive action of the belayer may influence the selection of a belay system and are not dealt with in this test method. See X1.1.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Additional precautions for this test method are given in 8.1 and 8.2.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1776 Practice for Conditioning and Testing Textiles

F2266 Specification for Masses Used in Testing Rescue Systems and Components

2.2 *Other Document:*

CI 1801-98 Low Stretch and Static Kernmantle Life Safety Rope[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *belay, n*—a secondary system, or the system components, used to arrest the load in the event of a failure in the system.

3.1.2 *belay, v—in rope rescue systems*, to operate an untensioned secondary rope (belay line) so that it may be taken in or let out as the load is raised or lowered, and then hold the load in case of failure of the lifting line (working line) system.

3.1.3 *belay assembly, n*—all elements of the belay system, but not including the belay line and the belay anchor.

3.1.4 *belay assembly extension,* L, (cm), *n*—the increase in length of the belay assembly, due to stretch or other extension, measured from the anchorage to the farthest gripping point of the belay assembly while statically tensioned, post-drop, expressed in centimetres (cm).

3.1.5 *belay device, n*—that element of the belay system providing a moveable connection point to the belay line, which can secure the belay line when necessary.

3.1.6 *belay line, n—in rope rescue systems*, a secondary line, generally untensioned, acting as a back-up to the lifting line as distinguished from the lifting line (working line) that actually raises, lowers, or transports the load.

3.1.7 *belay system, n*—the belay assembly and the belay line, but for the purposes of this test method, not including the belay anchor.

3.1.8 *belay system extension,* L, (cm), *n*—the distance below the zero line (this excludes drop height) reached at the maximum extension during fall arrest, prior to rebound; also known as stopping distance, expressed in centimetres (cm).

3.1.9 *belay system failure, n*—when the test block hits the ground.

[1] This test method is under the jurisdiction of ASTM Committee F32 on Search and Rescue and is the direct responsibility of Subcommittee F32.01 on Equipment, Testing, and Maintenance.

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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.

[3] Available from Cordage Institute, 994 Old Eagle School Rd., Wayne, PA 19087, http://www.ropecord.com.

3.1.10 *drop height,* L, (cm), *n*—the free-fall distance the block falls before the belay system begins to arrest its fall.

3.1.11 *elongation classification, n—in rope rescue systems*, elongation of new rope as measured by CI 1801-98 at 10 % of the manufacturer's rated breaking strength: static <6 % elongation, low-stretch >6 % and <10 % elongation

3.1.12 *extension,* L, *n*—the change in length of a material, device, or system due to a change in an applied force, usually measured at some specified force, force rate, or duration of force, or combination thereof.

3.1.13 *final rope length, [L], (cm), n*—the distance between the inside of the bowline where it contacts the shackle of the test block and the lowest gripping portion of the belay assembly after the test block has rebounded and come to rest.

3.1.14 *lifting line, n*—the line that lifts the test block and from which a quick disconnection is made to drop the test block (working line).

3.1.15 *maximum arrest force, MAF, (N), n*—the peak force measured during the fall arrest.

3.1.16 *pre-grip slippage, L, (cm), n*—rope movement through the belay device before gripping stops movement.

3.1.17 *rope rescue system, n*—a system using fiber ropes to raise, lower, or transport a load.

3.1.18 *zero line, n*—the level of the contact between the inside of the bowline and test block shackle when it is 3 m below the lowest gripping portion of the belay assembly, prior to the drop.

4. Summary of Test Method

4.1 A rigid test block of the correct mass simulates a rescue load. A rope of given length connects the test block to a belay assembly that is in turn connected to a suitably rigid overhead anchor point. The test block is raised a given distance with a separate lifting system and is then released. After the block has free-fallen to its starting point, the belay system (the rope and belay assembly) begins to arrest its fall. Among other things, maximum arrest force and belay system extension are measured. The belay system may or may not be successful in stopping the falling test block.

5. Significance and Use

5.1 The types of rope rescue systems to which this test method apply use a tensioned mainline and untensioned belay line. If a fall occurs because of a mainline system failure or misuse, considerable energy must be absorbed by the belay for a successful arrest. This drop test method simulates a "worst case" condition when systems are operated as designed, and is designed to help evaluate and compare the performance of various rope rescue belay systems under such conditions. (See Note 1.) The successful catching of a load does not imply that the tested system is suitable for any and all belaying. See X1.2.

NOTE 1—Higher forces may be encountered under some circumstances, such as the belay being operated with excessive slack.

6. Interferences

6.1 The method used to release the test block could affect the results by imparting motion to the block, in addition to the straight fall caused by gravity.

6.1.1 Residual magnetism of an electromagnetic release shall be guarded against.

6.1.2 The use of a light cord between the test block and the hoist line, which is cut by a heated nichrome wire or stick mounted knife, is also satisfactory.

6.1.3 Any release buckle, latch, or device that might impart a sideways force to the suspended mass shall not be used.

6.1.4 Any restriction imposed on the test block, such as the use of guide rails to contain and control the block's fall, or the use of a linear motion transducer, shall be constructed and maintained so that the combined effect shall not reduce the velocity of the mass more than 2 % from the velocity of a free falling block of similar mass. Velocity measurements shall be made and recorded at the beginning of each test day when guide rail type test rigs are to be used.

6.2 If the lifting line's system uses a twisted cable, there may be difficulties with the test block turning and twisting the rope. This can be prevented by light "anti-twister" cords running off to the side of the block that are released at the same time as the lifting line connection.

6.3 Inconsistency in the tightening of knots shall be avoided.

7. Apparatus

7.1 The test facility shall be a structure with less than 1 mm of immediate elastic deformation at a force of 50 kN at the anchor point and having a natural frequency above 200 Hz.

7.1.1 Failing this, a distinct cautionary note should be made in all reports generated at the test facility regarding the anchor rigidity or natural frequency.

7.2 The test block shall have an appropriate mass and, if made from a collection of plates, bars, or ingots, shall be joined in a fashion that prevents play or relative movement of parts during the testing. It shall be provided with a shackle for the attachment of the belay line and the lifting line (through the quick-disconnect fitting) from which it hangs in symmetry. The shackle shall have less than 1 mm of immediate elastic deformation at a force of 50 kN.

7.2.1 The mass of the rigid test block shall be Type II (100 kg), Type IV (200 kg), or Type V (280 kg) ± 1 %, including attachment hardware, for the testing of equipment intended for use with various rescue systems, in accordance with Specification F2266. The user should select the most appropriate mass to the intended application. Adequate attachment point, rigidity, and symmetry shall be maintained. The mass used shall be included in the report.

7.3 The belay line shall be tied directly to the test block using a bowline knot. Use of a setup where the rope is tied to a platen (catch plate) upon which the falling test block impacts shall not be permitted.

7.4 The test block lifting system shall be able to position the test block to a tolerance of ±0.5 cm and when stopped, sustain the test block for a 5 min period at a given height with the same tolerance.

7.4.1 The lifting line shall pass not more than 10 cm horizontally in distance from the anchor point for the belay assembly.

7.5 If a pit of loose material such as sand is used, care should be taken so that the test block does not increase its mass by picking up material from the pit after impact.

7.6 For belay assemblies that require an active gripping hand for operation, an artificial hand shall be substituted to prevent staff injuries.

7.6.1 The artificial hand shall be constructed as pictured in Fig. 1.

7.6.2 The artificial hand shall be spring pressure plates that provide a constant belay rope tension. The user shall select the appropriate tension. See X1.3. The tension used shall be included in the report.

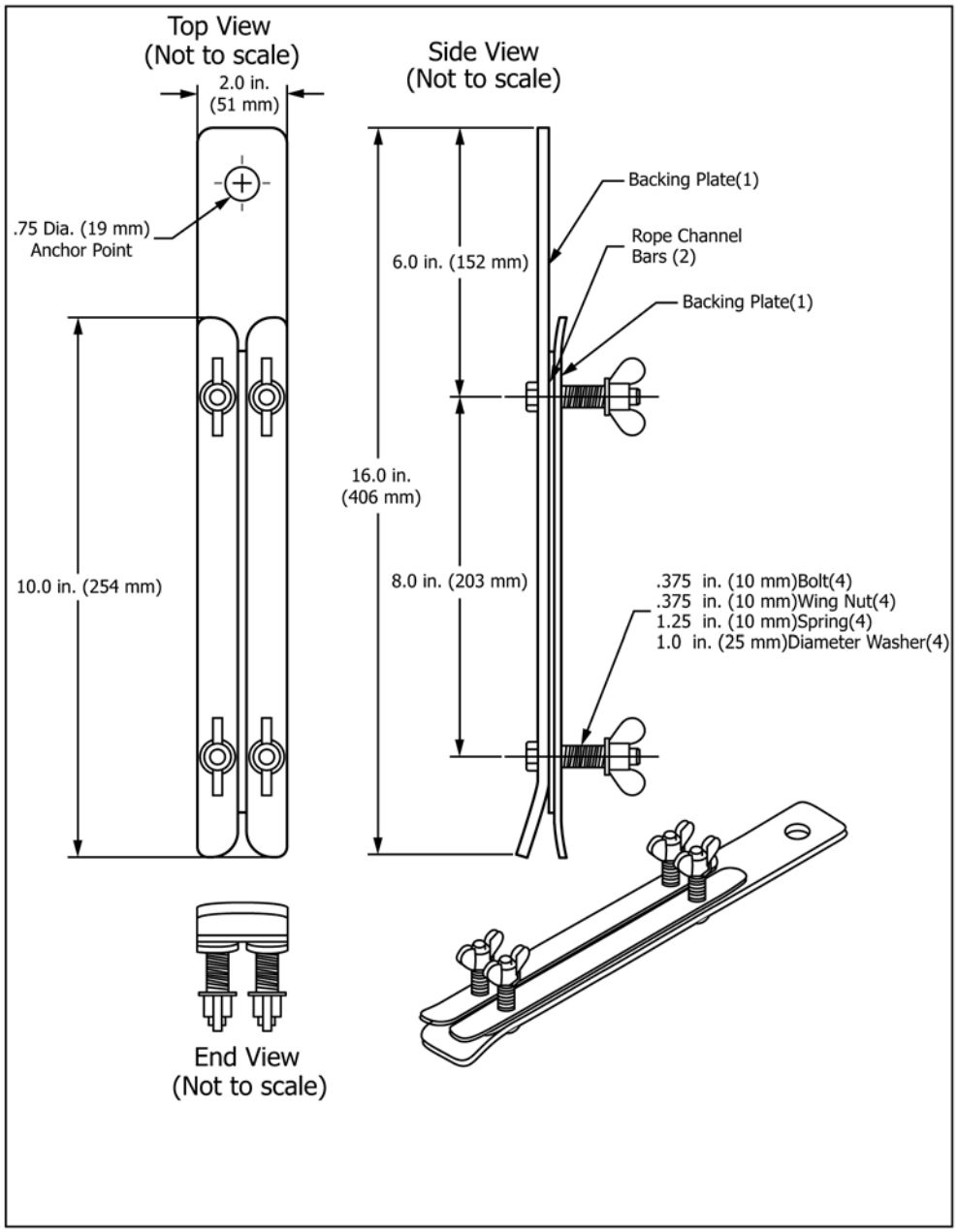

FIG. 1 Artificial Hand

7.6.3 When an artificial hand is used, it is considered to be an integral part of the belay assembly.

7.6.4 Hanging a mass on the belay rope in place of an artificial hand is not permitted.

7.6.5 The point where the rope leaves the artificial hand (when required) shall be within 40 cm of the point where the rope enters the belay assembly. There shall be no slack in the rope between the artificial hand and the belay assembly.

7.6.6 Various anchor points for the artificial hand, each with an immediate elastic deformation of less than 1 mm under the application of a 500 N force, shall be provided so that the position relative to the belay assembly can duplicate the position of function in actual use.

7.7 The test facility shall have a rope flaking area, where additional rope can be loosely flaked out. The test block shall be able to reach the ground without using up this additional rope.

7.7.1 The flaking area shall be a flat horizontal surface on the testing facility with no roughness or irregularities to impede the free flow of the rope.

7.7.2 The rope (belay line) shall be flaked at an angle less than 15° of directly in line with the device's intended manner of use for braking, and the flaking area shall be positioned to provide 1 m (±10 cm) of unsupported rope between the flaking area and the belay device being tested.

7.8 The maximum arrest force (MAF) shall be measured by a system, which is accurate to ±1 % of the MAF, free from artifact, and whose calibration is traceable to a recognized source. It is preferable that the recording device also be able to generate a force/time curve.

7.8.1 MAF measurements are obtained by sampling of an electronic load cell or other suitable device. Its physical characteristics and all associated electronics shall allow sampling at a minimum of 2000 times per second. The minimum resonant frequency of the load cell shall be 4 kHz.

7.9 To determine the belay extension, the lowest point during the drop shall be read by using a suitable device capable of measuring to an accuracy of ±1 cm. Care shall be exercised that extension measuring system causes no significant cushioning or retarding effect on the test block. The total velocity difference from a free falling mass and a mass with or without guide rails and an extension measuring system shall be less than 2 %. The system used shall be clearly described and illustrated in the report.

8. Safety Hazards

8.1 *Precautions*—This test method involves a falling mass, moving rope, numerous possible pinch points, and the potential for flying debris if a component fails during a drop test. Avoid contact with any of the test materials or the apparatus during operation and provide shielding for workers. Place hazard warning signs in a conspicuous place. The development of safety procedures, both general and specific to the particular test facility, is strongly recommended.

8.2 Precautions should also be taken to protect any instrumentation, such as force transducers, electrical leads, distance measurement devices, and so forth, from possible damage from rope snapback or flying debris in the event of a failed component during a drop test.

9. Sampling

9.1 If the belay assembly is intended for use on various diameters of ropes, tests shall be done on both the largest and smallest and, if the range exceeds 2 mm, on representative diameters in between. If the belay assembly is intended for use with various brands and designs of ropes, each rope brand and construction should be tested. (See Note 2.)

NOTE 2—Different rope brands of same diameter can have unexpected differences in performance, apparently, due to fairly small differences in rope construction. It should be clearly stated which rope brands, sizes and constructions were tested and the condition they were in at the start of testing.

10. Conditioning

10.1 While different conditions of temperature and humidity may affect impact forces and other test results, conditioning of ropes is not feasible for most testing. If conditioning is feasible, standard conditions of Practice D1776 shall be used and be recorded in test results.

10.2 If conditioning is not an option, temperature and humidity during the tests shall be those under which equipment would normally be used. These conditions shall be noted in your test report.

10.2.1 Storage conditions prior to the tests shall be those under which equipment would normally be stored prior to use. These conditions shall be noted in the test report.

10.3 A different piece of dry, new rope shall be used for each test.

10.3.1 Altering rope conditions (used, wet, muddy, icy, and so forth) will result in belay performance differences. The user of this test method may wish to use this method to test different rope conditions with a belay device; if so, the condition of the rope shall be noted in the test report.

11. Procedure

11.1 Procedural details will vary with the facility. Any deviations from the items listed in this section shall be included in the report.

11.2 All rope, cord, and webbing samples shall be cut and the ends finished by methods that preserve the integrity of construction, such as hot-cutting. All pre-drop measurements shall be made twice to ±0.5 cm while under 10 N of tension. Pertinent dimensions, masses, and so forth of each component of the system to be tested shall be recorded.

11.3 The rope (belay line) is tied to the test block with a regular bowline with the tail of the knot inside the loop. The loop of the bowline is made as small as possible around the attachment point, and then the knot is hand tightened.

11.4 A tension of 10 N is applied to the rope, oriented vertically, at a location approximately 325 cm from where the rope is attached to the test block; the remaining portion of the rope cannot interfere with the tension applied. The rope is marked 300 cm from the contact point between the test block and the bowline.

11.5 The belay system is rigged, checked for correctness, and pertinent measurements taken. These rigging details and measured parameters are undefined by this test method and are dictated by the system used. Defining, measuring, and recording them ensures that the system described in the report matches what was rigged.

11.6 Position the test block so that there is 300 ± 0.5 cm between the bowline-test block contact and the most distal point of the gripping portion of the belay assembly.

11.7 Ensure that the belay device has adequate ability to grip the rope. Use a mechanical hand for positive-grip required belay devices. With the hoisting system (lifting line), lower the test block onto the belay system. Record any rope settling-in or slip, or both, after 30 s.

11.8 To ensure the belay device gripping mechanism can activate when the test block is dropped, hoist the test block and reposition it with 300 cm between the test block and the most distal point of the gripping portion of the belay assembly. Record pertinent measurements (belay assembly length, dimensions, and so forth). Suddenly release the test block from the hoisting system. Record pertinent measurements (pre-grip slippage, settle-in and slip distances, belay assembly length, any rope degradation, and so forth).

11.9 Subsequent tests shall use a different section of rope for each test.

11.10 Attach a new rope as per 11.3 – 11.6

11.11 To measure the belay device's ability to arrest the falling test block, raise the test block 100 ± 0.5 cm above the zero line (the position where there is 300 cm between the most distal gripping portion of the belay assembly and the bowline test block contact), and ensure that the 300 cm rope marking is positioned at the most distal gripping portion of the belay assembly. Record pertinent measurements, and remove any unwanted motion of the test block. Conduct a thorough safety check.

11.12 The test block is released.

11.13 Record force, belay system extension, belay assembly length, final rope length, slippage, rope and belay condition, and so forth.

11.14 Repeat no less than four more times as per 11.9 – 11.13.

11.14.1 If a failure occurs in any of these drops, decrease the drop height in 25 cm increments until a minimum of five drops, using new materials, are obtained where the belay system was successful in arresting the test block.

11.15 If the drops in 11.14 are all successful, with new sections of rope, increase the drop height in increments of 25 cm from 100 cm, until belay system failure is observed.

11.16 Decrease the drop height by 25 cm, and repeat four more drop tests, using new rope each time.

11.16.1 If a failure occurs in any of the drops, then continue to decrease the drop height in 25 cm increments until a minimum of five drops, using new materials, are obtained where the belay system was successful in arresting the test block.

11.17 All pre- and post-drop measurements made shall be to the nearest 0.5 cm and shall be done twice; all post-drop measurements shall be made within 1 min directly following the drop.

11.18 The standard length of rope used in the test method shall be 300 ± 2 cm between the inside of the bowline where it contacts the shackle of the test block and the lowest gripping portion of the belay assembly.

11.19 *Tensile Strength of Rope*—A section of new rope from the same production run as the test rope and the section of rope where the belay device was used during the drop test shall be tested per CI 1801-98, Section 8.2—Minimum Breaking Strength. Any change in strength between the new rope and the drop test rope shall be reported.

12. Report

12.1 The report shall include the following general information for the test series:

12.1.1 Date of testing.

12.1.2 Location of testing.

12.1.3 Test facility—rigidity.

12.1.4 Force measurement device, calibration date.

12.1.5 Weather conditions, temperature, and relative humidity at start of testing.

12.1.6 Testing staff—names and duties.

12.1.7 Rope used for testing—manufacturer, model, construction, elongation classification, diameter, manufacture date, pre-test storage (conditioned per Practice D1776 or container, temperature, and humidity), and tensile strength of rope from the same lot used for testing and the tensile strength of the rope where the belay device was used during the drop test for each belay device tested.

12.1.7.1 If practical, a series of five baseline rope tests should be performed on each type and production lot of rope per 9.1 with both ends of the sample rope tied off. The MAF and rope extension shall be recorded and reported for each type of rope used in the test series.

12.2 The report shall include the following information for each test:

12.2.1 Test number.

12.2.2 Time, temperature, and relative humidity at time of test.

12.2.3 Belay device tested (include all components that make up the belay assembly).

12.2.4 Test block mass (kg).

12.2.5 Rope sample length (cm) (between the bowline-test block contact and the most distal point of the gripping portion of the belay assembly).

12.2.6 Drop height (cm).

12.2.7 Belay assembly length (cm) (pre-test at 10 N).

12.2.8 Artificial hand used; Force setting (N).

12.2.9 Flaking area—shall be noted as to the position in relationship to where the rope enters the belay device being tested.

12.2.10 Rope settling-in or pre-grip slippage after 30 s with test block hanging on belay system (cm).

12.2.11 Belay assembly length (cm) (after static test block hang).

12.3 The report shall include the following post-drop information for each test:

12.3.1 Belay system failure.

12.3.2 Belay assembly extension (cm).

12.3.3 Pre-grip slippage (cm).

12.3.4 Final rope length (cm).

12.3.5 Belay system extension (cm) (pre-rebound).

12.3.6 Maximum arrest force (N) (Note if a force/time curve was generated or additional observations).

12.3.7 Damage to rope or belay assembly, or both, revealed by visual inspection.

12.3.7.1 When reporting the effect of the belay device being tested or the procedure on the belay line or cords in contact with it (for example, prusik hitches), or both, the terms chafe, coat, fuse, glaze, melt, rip, scuff, settle in, slip, stick, tear, and weld shall be used based on standard dictionary definitions of these terms.

12.3.7.2 The terms damaged, failed, or broke shall be used in the report only with qualifications expressing the exact condition of the parts referred to.

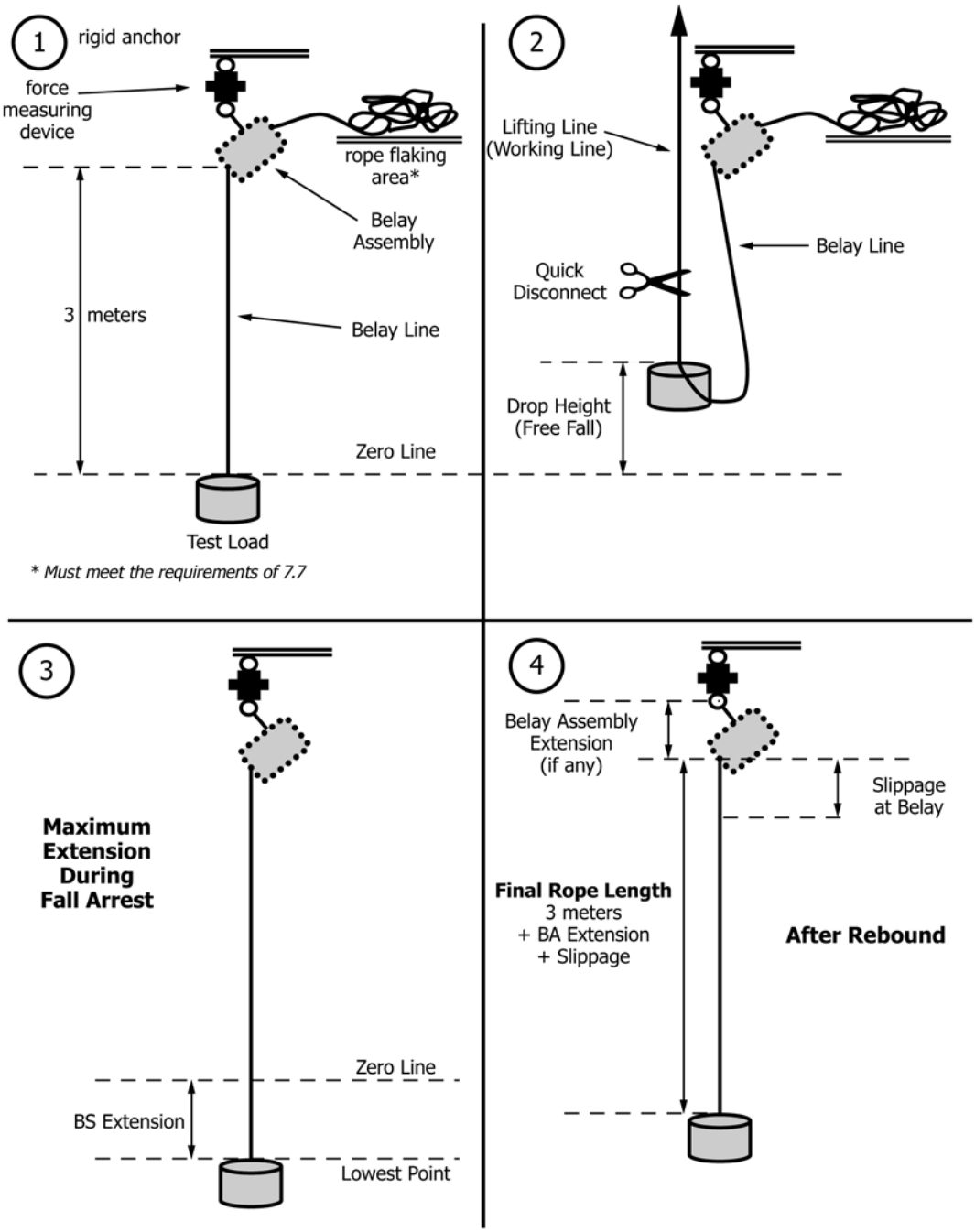

FIG. 2 Drop Test for Rope Rescue Belays

12.4 *Test Report Summary:*

12.4.1 The belay system extension (stopping distance) on each of the 5 (or more) 1 m drops for each belay device tested; the range of measurements and the expected degree of accuracy (±).

12.4.2 The belay assembly extension on the 5 (or more) 1 m drops for each belay device tested; the range of the measurements and the expected degree of accuracy (±).

12.4.3 The maximum drop height, which is a multiple of 25 cm, for which each belay system was always successful (5 tests minimum) in arresting the test block.

12.4.4 The MAF on the 5 (or more) 1 m drops for each belay device tested; the range of the measurements and the expected degree of accuracy (±).

12.4.5 The report shall contain the statement: "Remember that these test results are for a particular belay system and that no prediction is made regarding use of individual components outside of this particular system."

12.4.6 The report shall state that the tests were done as directed in Test Method F2436, or if they were not, the extent and reason for the deviation shall be noted.

12.4.7 Tests that exceed the capability of the belay system shall be reported and the place where the rope broke or where and how the belay assembly failed shall be noted along with photos.

12.4.8 Supplementary observations not foreseen in this test method shall also be reported.

13. Precision and Bias

13.1 *Precision*—Sufficient data has not yet been produced using this test method to determine the precision of this procedure. The publication of this test method is intended, in part, to facilitate uniform testing and reporting of data. Validation of this methodology may be achieved through screening this testing.

13.2 *Bias*—The true value of belay performance can be defined only in terms of a specific test method. Within this limitation, this test method has no known bias and is generally accepted as a referee method.

14. Keywords

14.1 belay; drop test; performance

APPENDIX

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 Though primarily designed for testing belay systems, this test method can also be used to evaluate other elements of the rescue system such as ratchets, releasing hitches, shock absorbers, spiders, stretchers, and so forth that can also be subjected to impact forces under accident situations. Changes made to this test method to accommodate such items shall be clearly indicated in the test report.

X1.2 This test method may produce valuable information when used to run tests with multiple drops on the same rope, to vary the rope length, or to attach loads intended to simulate a specific rescue system (for example, a loaded litter). With a variation of this test method, it is possible to introduce an edge for the rope to contact during the fall. In this case, the maximum arrest force measurement must be made at the test block. These deviations from this test method shall be clearly indicated in the test report.

X1.3 The appropriate tension shall be the minimum gripping ability of the person or persons that will be operating the belay device. This can be determined by a user-defined test method, or by using published data such as Gripping Ability on Rope in Motion[4], a study conducted by Kirk & Katie Mauthner. This study determined that the minimum gripping ability of a single gloved hand on a rope in motion was 46 N (10.3 lbf). The user would need to refer to the study to determine if this test method fits their situation.

[4] Available from Rigging for Rescue, P.O. Box 745, 324 5th St., Ouray, CO 81427, http://www.riggingforrescue.com.