UL 1197

STANDARD FOR SAFETY

Immersion Suits

UL Standard for Safety for Immersion Suits, UL 1197

Third Edition, Dated April 20, 2007

Summary of Topics

This revision to UL 1197 dated September 23, 2021 is issued to remove the ANSI designation from the titlepage, as ANSI has been withdrawn from the standard.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

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UL 1197

Standard for Immersion Suits

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April 20, 2007

This UL Standard for Safety consists of the Third Edition including revisions through September 23, 2021.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover immersion suits intended for United States Coast Guard (USCG) approval under 46 CFR 160.171.

1.2 The suits covered by these requirements are intended to reduce the occurrence of shock to the wearer upon entering cold water and retard the onset of hypothermia (reduce the rate of body heat loss during periods of immersion in water). Immersion suits are required by the USCG to provide thermal protection properties in accordance with USCG regulations [see Thermal Protection Test, Section 22 in this standard and 46 CFR 160.171-17(d)].

1.3 These requirements cover immersion suits that incorporate auxiliary, inflatable means to provide buoyancy as well as suits that rely only on inherently buoyant material to provide the required flotation characteristics.

2 Units of Measurement

2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

3 Undated References

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

4 Components

4.1 Except as indicated in 4.2, a component of a product covered by this standard shall comply with the requirements for the Standard for Components for Personal Flotation Devices, UL 1191, and when the United States Coast Guard has specific requirements for the components, it shall comply with those requirements first.

4.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

4.3 A component shall be used in accordance with its rating established for the intended conditions of use.

4.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

5 Glossary

5.1 For the purpose of this standard the following definitions apply.

5.2 FOAM – Closed-cell, flexible, foamed polymeric material.

5.3 FREEBOARD – A distance measured perpendicularly from the surface of the water to the lowest point where the wearer's respiration is impeded. The freeboard of a test subject wearing an immersion suit is measured with the subject in the attitude of static balance in which respiration is not impeded.

5.4 RETROREFLECTIVE MATERIAL – A material that reflects light so that the paths of the light rays are parallel to the incident rays.

5.5 STRUCTURAL SEAM – A seam that serves a functional purpose in the end product as distinguished from a decorative function.

6 Materials

6.1 Metal hardware shall:

a) Be AISI Type 410 stainless steel; or

b) Have at least equivalent resistance to corrosion when subject to the Corrosion Resistance Test, Section 32.

6.2 Metals shall be used in combinations that are galvanically compatible.

6.3 The primary (inherent) buoyancy of an immersion suit shall be provided by foam. Loose or granular materials shall not be relied upon to provide buoyancy; however, inflatable compartments intended to provide auxiliary buoyancy are not prohibited. See Stability and Retroreflective Material Tests, Section 18.

6.4 Adhesive shall be an all-purpose, waterproof type intended for use with the materials being bonded.

CONSTRUCTION

7 General

7.1 An oral inflation mechanism shall not be able to be locked in the open or closed position.

8 Sizing and Arrangement

8.1 General

8.1.1 An immersion suit shall be constructed to cover the entire area of a wearer's body, except the area of the nose and eyes are not required to be covered. The construction shall not permit a water spray to enter a wearer's mouth directly.

8.1.2 An adult size immersion suit shall be constructed to fit persons ranging from:

a) 110 to 330 pounds (50 to 150 kg) in weight; and

b) 59 to 75 inches (1.5 to 1.9 m) in height.

8.1.3 A child size immersion suit shall be constructed to fit persons ranging from:

a) 44 to 110 pounds (20 to 50 kg) in weight; and

b) 39 to 59 inches (1.0 to 1.5 m) in height.

8.1.4 An oversize-adult immersion suit shall be constructed to fit persons too large for the adult size immersion suit.

8.1.5 An immersion suit shall be constructed to facilitate donning by an untrained person and shall be as comfortable and nonrestrictive of motion and vision as practicable, consistent with its intended purpose. See Sections 12 – 16.

8.1.6 An immersion suit shall be accompanied by a storage case or similar protection, which shall be formed of either:

a) Vinyl-coated fabric; or

b) Material that provides equivalent protection to the suit when stored.

Also, see Storage-Temperature Ambient Tests, Section 23, and Flame Exposure Tests, Section 27.

8.1.7 The primary color of the exterior surface of each suit shall be vivid reddish orange (color number 34 of National Bureau of Standards Publication 440).

8.2 Gloves and feet

8.2.1 An immersion suit shall be provided with integral or removable gloves. When the gloves are removable:

a) Each sleeve of the suit shall terminate in a wristlet seal that complies with the requirements in the Impact Test, Section 21,

b) Each sleeve shall provide means for the attachment of a glove when being worn, and

c) Means shall be provided for the securement of the gloves when not being worn, such as by a tether or lanyard or pockets provided on the sleeves, to avoid a loss.

8.2.2 A removable glove shall be designed so that only a small amount of water is capable of entering the glove during use.

8.2.3 An immersion suit shall be provided with integral feet having either:

a) Hard soles; or

b) Room to accommodate work shoes.

The sole or bottom of each foot shall be natural or synthetic rubber that is ribbed or bossed to provide skid resistance.

8.2.4 The construction of a suit shall restrict air from being entrapped in the leg area. See Water and Air Penetration Test, Section 20.

8.3 Retroreflective material and light

8.3.1 An immersion suit shall be provided with Type I retroreflective fabric or tape that is USCG Approved under 46 CFR 164.018 located so that at least 31 square inches (200 cm^2) of the material shall be visible on the front of a wearer when in water. See 18.1 and 18.3.

8.3.2 An immersion suit shall be arranged to provide means for attachment of a survivor locating light on a front shoulder area by a method that shall not adversely affect the in-water performance characteristics

of the suit. When the suit accommodates a specific light model, the suit shall be marked accordingly or reference shall be made to the instructions. See 40.4.

8.4 Retrieval

8.4.1 A belt of a lifting harness is to be constructed of any material, except leather, that complies with the requirements in the Retrieval Harness Strength Test, Section 35.

8.4.2 All hardware, except rivets, shall be of drop-forged or pressed steel provided with a corrosion resistant finish that complies with the Corrosion Resistance Test, Section 32.

Exception: The period for exposure during the Corrosion Resistance Test is to be 50 hours when a determination is made that 50 hours is representative of the conditions of intended use.

8.4.3 A D-ring or a snap hook shall have a tensile strength of at least 1500 pounds (680 kg) and shall comply with Retrieval Harness Strength Test, Section 35.

8.4.4 A body strap shall be not less than nominal 1-3/4 inch (44.5 mm) webbing.

8.4.5 A retrieval harness shall be provided with a retrieval ring with an inner diameter of not less than 2-1/4 inch (57 mm).

9 Assembly

9.1 Hardware shall be:

a) Of a type and arrangement that facilitates operation; and

b) Attached in a manner that reduces the risk of improper operation.

9.2 Stitching used to form a structural seam shall be a lock type and shall comply with the requirements of Federal Standard No. 751a for one of the following designations:

a) Class 300 lockstitch; or

b) Class 700 single-thread lockstitch.

Other stitches, which are not lockstitch, are not prohibited for use in reinforcing a glued seam when the seam has the required strength after the nonstandard stitch is removed. Also, see Seam Strength Test, Section 29 and Air Retention Test, Section 34.

9.3 For an immersion suit provided with an auxiliary means of buoyancy, each joint in the oral inflation tube shall be joined by means of a clamping device. A flange connection between the tube and the inflatable chamber shall be reinforced so that the flange is secured between the material that forms the chamber and the reinforcement.

PERFORMANCE

GENERAL

10 Required Tests

10.1 For an adult size immersion suit, representative samples of the suit are to be subjected to each of the tests described in Sections 11 – 25, 27, 28, and 33 – 35. Material specimens are required for the tests described in Sections 26, 29 – 32, and 36.

10.2 Only the tests described in 18.1 – 18.3 and Sections 25 and 28 are required for a child size immersion suit, and only the test described in Section 25 is required for an oversize-adult size immersion suit [based on prior USCG approval of the suit in the adult size – see 46 CFR 160.171-7(c)]. However, additional tests are required when construction differences between these sizes and the adult size suit affect other performance characteristics.

FLOTATION AND MOBILITY TESTS

11 General

11.1 Samples

11.1.1 For the tests described in Sections 12 – 22, the number of samples of an immersion suit to be used and the number of tests to which a particular sample is to be subjected is not specified; except that, for the Impact Test, Section 21, the same sample is to be worn by a subject in each of the subject's six jumps (a particular sample is not required to be used by more than one subject). Additionally, the same sample used for the Impact Test, Section 21, is to be used for the Thermal Protection Test, Section 22.

11.2 Subjects

11.2.1 Selection

11.2.1.1 For an adult size immersion suit, the tests described in Sections 12 – 22 are to be conducted using ten human subjects, seven of which are to be male and three female. The heaviest male and female subject shall weigh at least 254 pounds (115 kg) and the lightest male and female subject shall weigh not more than 121 pounds (55 kg). The subjects are to be representative of the range of anatomic builds (ectomorphic, endomorphic, and mesomorphic) and the sizes for which the suit is intended.

11.2.1.2 For a child size immersion suit, the tests described in 18.1 – 18.3 are to be conducted using six human subjects, whose sexes are not specified. The heaviest subject is to weigh at least 22 pounds (10 kg) more than the lightest subject. The subjects are to be representative of the range of anatomic builds and the sizes for which the suit is intended.

11.2.1.3 Each subject is to be unfamiliar with the particular immersion suit being tested.

11.2.1.4 A youth test participant may be used to satisfy specific anthropomorphic characteristics for weight, chest size, or girth of an adult-size device. When testing an adult-size device, when the youth is less than 13 years of age, his or her test results are able to be excluded for Donning Test, Section 12, or Hand Dexterity Test, Section 14 due to the participant's inherent limitations in dexterity, strength, and maturity. For an adult-size device, where the results for a youth test participant are excluded, a substitute test participant shall be used for the excluded test. The substitute participant shall have anthropomorphic characteristics within the candidate devices specified range, that are similar to, and not necessarily identical to the excluded participant.

11.2.2 Attire

11.2.2.1 For the tests, each subject is to wear the following:

a) Underwear (short sleeved, short legged);

b) Shirt (long sleeved);

c) Trousers (not woolen);

d) Woolen or equivalent synthetic socks; and

e) Rubber-soled work shoes.

12 Donning Test

12.1 Complete donning of an immersion suit, including the gloves and other accessories, and removal from the package shall be accomplished in 2 minutes or less by at least nine of the ten subjects when the suit is tested as described in 12.2 and 12.3.

12.2 Each subject is to be allowed to examine the suit and read the instructions provided by the manufacturer in accordance with 40.1 for 60 seconds. At the end of this period, the subject is to remove the suit from its storage case and attempt to don the suit as rapidly as possible. When the subject does not remove the suit from the storage case and don the suit completely within 2 minutes, the subject is to remove the suit, reread the instructions for an additional 60 seconds, and again attempt to don the suit. The subject is to be given a demonstration of correct donning at this point.

12.3 A subject is not to use the aid of a chair or lean on a support during a donning attempt; however, the subject is not prohibited from sitting on the floor. No subject is to view the examination or donning attempts by another subject prior to the subject's own donning attempt.

13 Field of Vision Tests

13.1 Horizontal field tests

13.1.1 An immersion suit shall not restrict a subject's vision throughout the horizontal arc of 60 degrees to either side of the straight-ahead line of sight with the subject's head turned to any angle up to 30 degrees to either side of straight ahead, as determined by the tests described in 13.1.2 and 13.1.3.

13.1.2 Each subject is to don the suit, stand upright, and face straight ahead. An observer is to assume a position at least 3 feet (0.9 m) from the subject and along the line at an angle of 60 degrees to the subject's straight-ahead line of sight. The observer is to walk past the front of the subject to a position on the line 60 degrees to the opposite side of the subject's straight-ahead line of sight. The suit shall not obstruct the observer's view of the subject's closest eye at any point along the path traveled.

13.1.3 With the subject facing straight ahead, an observer is to assume a position at least 3 feet (0.9 m) from and to the side of the subject and on a line 90 degrees to the subject's straight-ahead line of sight. The subject is to turn the head to look straight along a line 30 degrees towards the observer. This procedure then is to be repeated on the opposite side of the subject. The suit shall not obstruct the observer's view of the subject's closest eye on either side with the subject's head turned the full 30 degrees.

13.2 Vertical field test

13.2.1 An immersion suit shall not restrict or obstruct a subject's ability to view a spot directly:

a) Above the subject; and

b) On or between the subject's feet;

when the subject attempts to look at these spots through the combination of head and eye movement only while wearing the suit and standing upright.

14 Hand Dexterity Test

14.1 Following a subject's immersion in water at 5°C (41°F) for one hour, an immersion suit shall permit at least eight of ten subjects to pick up and write with a 3/8 inch diameter (9.5 mm), cylindrical wooden pencil, with the subjects wearing the complete suit (including gloves) and the pencil initially placed on a flat, hard-surfaced table. Each subject is to use only one hand for the attempt, and then attempt to lift the pencil off the table, position it, and write with it. A physician is to be present during the test.

Exception: This test is capable of being conducted in conjunction with the Thermal Protection Test, Section 22, in which five of six test subjects shall comply with the requirement.

15 Walking Test

15.1 While wearing the immersion suit, a subject shall not slip or increase the average travel time over two attempts of the course specified in 15.2 to more than 125 percent of the average time taken on the two attempts while not wearing the suit.

15.2 A 100 foot (30 m) long walking course is to be laid out on a smooth linoleum floor, the finish of which allows water to lie on it in a sheet rather than in beads. The course is not to have any abrupt changes in direction. Each subject is to be timed walking the course at a normal pace, with the floor dry. The subject then is to be timed walking the course at a normal pace, with the suit donned and the course wet. The subject is to rest until no longer fatigued prior to the second traversal of the course.

16 Climbing Test

16.1 The average time required for a subject to climb a ladder while wearing an immersion suit shall not be more than 125 percent of the average time required without wearing the suit when tested as described in 16.2.

16.2 A rigid vertical ladder extending at least 17 feet (5.2 m) above a level floor is to be used for this test. The ladder shall have a rung width of 14 – 19 inches (355 – 483 mm), and a height between each rung of 10 – 15 inches (254 – 381 mm).

Figure 16.1

Climbing test
Figure deleted

16.3 The average time required for a subject to climb a ladder while wearing an immersion suit shall not be more than 125 percent of the average time required without wearing the suit when tested as described in 16.2.

17 Swimming and Water Emergence Test

17.1 At least two-thirds of the qualified test subjects, specified in 17.3, shall be able to swim the distance specified in 17.3 and 17.4 and emerge from the water onto a liferaft within 30 seconds while wearing the immersion suit.

17.2 The liferaft is to be USCG Approved under 46 CFR 160.051 and shall not have a boarding ramp.

17.3 In order to qualify for the test, each subject is to don a USCG Approved Type I PFD and is to enter the water and swim at least 25 meters (27 yards). The subject then is to attempt to emerge from the water onto the liferaft:

a) Using only the hands placed on top of the liferaft; and

b) Without contacting the sides or bottom of the pool.

Those subjects that are able to emerge onto the liferaft in 30 seconds or less are to be used for the test specified in 17.4. When fewer than five of the ten original subjects are unable to qualify, substitute subjects shall be used.

17.4 Each qualified subject is to don the suit. The subject then is to enter the water and swim at least 25 meters (27 yards). Any auxiliary means of buoyancy provided on the suit is not to be used. After swimming and while still in the water, the subject is to attempt to emerge from the water onto the liferaft:

a) Using only the hands placed on top of the liferaft; and

b) Without contacting the sides or bottom of the pool.

18 Stability and Retroreflective Material Tests

18.1 When tested as described in 18.3, an immersion suit (including any auxiliary means of buoyancy) shall comply with the following (also, see 18.2):

a) The suit shall provide a stable floating position in which the face plane angle is between 30 and 80 degrees above the horizontal. The face plane angle is the angle, relative to the surface of the water, of the plane formed by the most forward part of the forehead and chin of a wearer floating in the attitude of static balance in which respiration is least impeded;

b) No subject shall have a freeboard less than 120 mm (4-3/4 inches); and

c) For each subject in any stable floating position, at least 200 cm^2 (31 $inches^2$) of retroreflective material shall be visible above the water to an observer.

18.2 When the suit relies on an auxiliary means of buoyancy for compliance with the requirements in 18.1, each subject shall be floated in a stable position providing a freeboard of not less than 50 mm (2 inches) without the use of the auxiliary means when tested as described in 18.3.

18.3 Each subject is to don the suit and enter the water. Auxiliary means of buoyancy are not to be used. The subject then is to assume a face-up position and allow the body to completely relax. Observations are to be made of the floating position. The amount of retroreflective material visible above the water, and the head angle and freeboard of the subject are to be measured. When the suit is provided with an auxiliary means of buoyancy, this procedure is to be repeated using the means.

18.4 The subject is then to assume any other stable floating position, such as face down, and the amount of outer reflective material visible above the water is to be measured.

19 Righting Test

19.1 When tested as described in 19.2, an immersion suit shall either:

a) Turn a subject to a position in the water where the subject's face is clear of the water within 5 seconds; or

b) Permit the subject to turn face up under the subject's own power in 5 seconds or less.

19.2 While in the water with the suit on and using no auxiliary means of buoyancy, each subject is to take a deep breath, assume a face-down position, and slowly exhale. The time required for the suit to turn the subject so that the subject's face is clear of the water is to be measured. When this time is more than 5 seconds, the subject is to again assume a face-down position and the time required for the subject to turn face up under the subject's own power is to be measured. When the suit is provided with an auxiliary means of buoyancy, this procedure is to be repeated using each combination possible.

20 Water and Air Penetration Test

20.1 When tested as described in 20.2, an immersion suit shall not entrap:

a) Air in the leg area; or

b) More than 500 grams (17.6 ounces) of water.

In addition, after one hour of flotation, the weight of the subject in the suit at the end of the flotation period shall not exceed the weight of the subject at the beginning of the flotation period by more than 200 grams (7 ounces).

20.2 Each subject is to be weighed while wearing a prewetted suit. Auxiliary means of buoyancy are not to be used. The subject is then to jump into the water from a height that results in the subject being completely immersed. After the water entry, the subject is to swim or tread water for 1 minute. At the end of the one minute period, the subject is to emerge from the water and be weighed in the wetted suit within 10 seconds. The procedure is then repeated with the subject entering the water head first. When air accumulates in the legs as the subject enters, head first, it must be expelled automatically. The weight of the subject in the wetted suit following both immersions shall not exceed the weight of the subject in the dry suit by more than 500 grams (17.6 ounces). Each subject then is to re-enter the water without being completely immersed and is to float for a period of one hour. The weight of the subject in the suit at the end of the test shall not exceed the weight of the subject in the suit at the beginning of the period of flotation by more than 200 grams (7 ounces). This weight is to be determined within 10 seconds from emergence from the pool.

21 Impact Test

21.1 When tested as described in 21.2, an immersion suit shall:

a) Permit each subject to assume a stable, face-up position without assistance after each jump; and

b) Not tear, incur separation at any seam, or exhibit any other characteristics to an extent that impairs the intended performance of the suit.

The same suit used for the Thermal Protection Test, Section 22, is to be used for this test.

21.2 Each subject is to jump, feet first, into the water six times from a platform that is 15 feet (4.5 m) above the surface of the water. Auxiliary means of buoyancy are not to be used.

22 Thermal Protection Test

22.1 General

22.1.1 When an immersion suit is tested as described in 22.2.1 – 22.7.1, the average rectal temperature drop for the group of test subjects shall not be more than 2°C (3.6°F). The average rectal, finger, toe, and lumbar skin temperatures extrapolation is not prohibited for the group of test subjects shall not be less than 5°C (41°F).

22.2 Test subjects

22.2.1 Male subjects of the body size, shape, and composition limits in accordance with the Heath-Carter anthropometric method are to be used for this test (i.e., endomorphy 3.5 ±1.0; mesomorphy 4.0 ±1.5; ectomorphy 3.5 ±1.0). Each subject is to be familiarized with the test procedure before starting the test. Each subject is to have had a normal night's sleep the night before the test, a well-balanced meal 1 to 5 hours before the test, and no alcoholic beverages for 24 hours before the test. In addition to the suit, each subject is to wear the attire specified in 11.2.2.1.

22.3 Test equipment

22.3.1 The test is to be conducted in calm water at a temperature between 0 and 2°C (32 and 36°F). The air temperature 1 foot (300 mm) above the water surface is to be between minus 10 and 20°C (14 and 68°F). Each subject is to be hooked up to an electrocardiograph, a thermistor or thermocouple in the rectum placed 150 mm (6 inches) beyond the anus, a thermistor or thermocouple on the lumbar region, a thermistor or thermocouple on the tip of the index finger, and a thermistor or thermocouple on the tip of the big toe. Each thermistor or thermocouple is to have an accuracy of 0.1°C (0.18°F). The suits used for this test are to be the same ones used for the Impact Test, Section 21.

22.4 Test procedure

22.4.1 A physician is to be present during this test. Before donning the suit, each subject is to rest quietly in a room at a temperature between 10 and 25°C (50 and 77°F) for 15 minutes. The rectal temperature is to be recorded as the initial rectal temperature. The subject is to don a suit as rapidly as possible without damaging the instrumentation and is then to immediately enter the water. The subject is to assume a face-up, stable floating position. No auxiliary means of buoyancy is to be used during this test. The subject is to remain in the water engaging in activity that maintains the heart rate between 50 and 140 beats per minute for the first hour, and between 50 to 120 beats per minute during the remainder of the test, except that no attempt is to be made to control heart rate when the subject is shivering. Each thermistor or thermocouple reading is to be recorded at least every 10 minutes.

22.5 Completion of testing

22.5.1 Testing of a subject is to end 6 hours after entering the water, unless terminated sooner in accordance with 22.4.1.

22.6 Termination of test

22.6.1 Testing of a subject is to be terminated before 6 hours when any of the following occurs:

a) The physician determines that the subject is not fit to continue.

b) The subject requests termination due to discomfort or illness.

c) The subject's rectal temperature drops more than 2°C (3.6°F) below the initial rectal temperature, unless the physician determines that the subject is fit to continue.

d) The average skin temperature of the hand, foot, or lumbar region falls below 10°C (50°F), unless the physician determines that the subject is fit to continue.

22.7 Test results

22.7.1 The test results are to be prepared as follows:

a) The total rectal temperature drop during the test period and the average finger, toe, and lumbar region temperature at the end of the test are to be determined for each subject in the test, except subjects who did not complete testing for a reason stated in 22.6.1 (a) or (b). These temperatures and temperature drops are then to be averaged. The average lumbar, toe, and finger temperature shall not be less than 5°C (41°F). Data from at least four subjects is to be used in making these temperature calculations.

b) Rates of toe, finger, lumbar region, and rectal temperature drop for each subject who did not complete testing for a reason stated in 22.6.1 (c) or (d) are to be determined using the highest temperature measured and the temperature measured immediately before testing was terminated. These rates are to be used to extrapolate to 6 hours the estimated rectal, finger, and toe temperature at the end of that time. These estimated temperatures are to be used in computing the average temperatures for the group of test subjects.

MECHANICAL CHARACTERISTICS TESTS

23 Storage-Temperature Ambient Tests

23.1 An immersion suit and the storage case shall not be damaged, as evidenced by shrinking, cracking, swelling, dissolution, or any other change in mechanical properties to an extent that shall affect the intended performance when conditioned for ten cycles as described in 23.2 –23.4 and when tested as described in 23.5.

23.2 Two samples of the suit are to be tested. The two samples are to be alternately subjected to the conditioning specified in 23.3, then to the conditioning specified in 23.4. The samples are to be stored as intended in the storage case that accompanies the suit during the conditioning.

23.3 The samples are to be placed in a chamber maintained at 65 ±2°C (149 ±4°F) for 8 hours. The samples are to be removed from the warm chamber that same day and left exposed under ambient room conditions until the next day.

23.4 The samples are to be placed in a chamber maintained at minus 30 ±2°C (minus 22 ±4°F) for 8 hours. The samples are to be removed from the cold chamber that same day and left exposed under ambient room condition until the next day.

23.5 At the conclusion of the final cycle of cold chamber and while still in the cold chamber, two test subjects (who successfully completed the Donning Test, Section 12, and who are to be attired in protective clothing) are to unpack and don the immersion suits.

24 Specific Buoyancy and Buoyancy Loss Factor Determinations

24.1 General

24.1.1 The properties of buoyant material used in immersion suits are to be investigated for buoyancy properties in accordance with the requirements in this section. See Table 24.1. The Buoyant Loss Factor (E_i) is to be used to determine compliance with the Buoyancy Test described in 25.1. The calculated specific buoyancy, while not a requirement, is recorded for manufacturing purposes and to determine the relative buoyant property of the investigated material to other buoyant materials.

24.1.2 At least 30 samples are required for the tests and conditioning specified in 24.1.3 – 24.4.4.1. The buoyant material samples and methods for measurement of volume and buoyancy are to be as described in 24.1.3 – 24.3.1, except that the samples are to be tested in the thickness provided.

24.1.3 Except where otherwise noted, samples of a material are to measure 12 by 12 inches (305 by 305 mm) by the thickness being investigated. The condition of the material is to be representative of that intended for the end-product (for example, with or without skin).

Table 24.1
Investigation of foam for immersion suits

Property to be investigated	Minimum number of samples
Specific buoyancy[a]	30
Buoyancy loss	
After water soak	10[b]
After heat conditioning	10[b]
After compression	10[b]

[a] This property shall be investigated for each nominal thickness in which the material is used, except that, for material used in thicknesses greater than 1 inch (25.4 mm), a plot of property values versus thickness, based upon at least three thicknesses (thinnest, midrange, and thickest) of 1 inch and greater, may be used to obtain values for intermediate thicknesses.

[b] The samples are to be the same samples used for the specific buoyancy determination.

24.2 Volume measurement

24.2.1 The volume of a sample is to be determined by any convenient method. However, when referee measurements are required, the following method is to be used:

a) A rigid-rectangular container with vertical sides and to which an inclined manometer is connected is to be filled with enough distilled water to enable total submersion of the sample. The volume of the submerged portion of the device used to submerge the sample (such as a metallic T-frame with impaling points) is to be calculated either mathematically or by displacement.

b) The initial water level, l_o, is to be determined by reading a point on the meniscus on the graduated scale on the glass tube of the inclined manometer. Following the conditioning specified in 24.4.2.1, the sample is to be submerged by slowly lowering the submersion frame and sample. The sample is not to come in contact with the sides of the tank. When the water in the rectangular container becomes calm, the final water level, l_f, is to be determined by reading the same point of the meniscus (as in the initial reading) on the graduated scale.

c) The volume of the sample is to be calculated using the following equation:

$$V_i = C(I_f - I_o) - V_f$$

in which:

V_i is the volume of the sample in cubic inches (cm^3).

C is the cross sectional area of the container in square inches (cm^2).

I_f is the final water level reading in inches (cm).

I_o is the initial water level reading in inches (cm).

V_f is the volume of the submerged portion of the immersing frame in cubic inches (cm^3).

24.3 Buoyancy measurement method

24.3.1 The buoyancy of a sample is to be determined as follows:

a) A test tank is to be filled with fresh water at a temperature of 20 ±3°C (68 ±5°F) and a weighted wire basket or grate is to be suspended over the tank. The means of suspension is to be such that the basket is capable of being weighed to the nearest gram while completely submerged under the water.

b) The basket is to be submerged so that the top of the basket is 2 ±1/4 inches (51 ±6 mm) below the surface of the water, and then is to be weighed.

c) The sample is to be placed in the basket and the combination is to be completely submerged. The basket then is to be adjusted so that its top is at the position specified in Item B and the combination of basket and sample is to be weighed.

d) The buoyancy of the sample is to be calculated according to the following equation:

$$B = 2.205 \times 10^{-3}(W_b - W)$$

in which:

B is the buoyancy of the sample in pounds;

W_b is the weight of the basket in grams, determined in accordance with (a); and

W is the weight of the combination of basket and sample in grams, determined in accordance with (c).

24.4 Buoyancy measurements

24.4.1 Initial buoyancy

24.4.1.1 All samples are to be individually stored on racks for 120 hours at 23 ±2°C (73 ±4°F). The buoyancy of each sample (B_i) then is to be measured in accordance with 24.3.1.

24.4.2 Water soak

24.4.2.1 Ten of the samples are to be positioned so that the top surface of each sample is submerged 2 inches (51 mm) for 24 hours in fresh water at 20 ±3°C (68 ±5°F). The buoyancy of each sample (B_f) then is to be determined in accordance with 24.3.1.

24.4.3 Heat conditioning

24.4.3.1 Ten different samples are to be conditioned for 168 hours in an air circulating oven at 60 ±2°C (140 ±4°F). A spacing of at least 1 inch (25 mm) is to be maintained between the samples. The buoyancy of each sample (B_s) then is to be determined in accordance with 24.3.1.

24.4.4 Compression application

24.4.4.1 The ten remaining samples are to be placed on a flat, rigid surface with one of the 12- by 12-inch (305- by 305-mm) surfaces facing down. A 100 pound-mass (45.4 kg) load then is to be uniformly applied for 2 hours to the top of the sample. The ambient temperature is to be 23 ±2°C (73 ±4°F) during the compression. The buoyancy of each sample (B_f) then is to be determined in accordance with 24.3.1.

24.5 Specific buoyancy (B_s) calculation

24.5.1 The specific buoyancy (B_s) of the foam is to be calculated in accordance with the following equation:

$$B_s = \frac{\sum_{i=1}^{N}}{N} B_{si}$$

in which:

B_s is the specific buoyancy of the material in lbs/ft^3 (kg/m^3 × 0.0623),

B_{si} is the specific buoyancy of an individual sample, determined by the formula:

$$\frac{B_i}{V_i}$$

in which:

B_i is the initial buoyancy of an individual sample, determined in accordance with 24.4.1.1,

V_i is the volume of an individual sample, determined in accordance with 24.2.1, and

N is the number of samples used.

24.6 Buoyancy loss factor (E_i) calculation

24.6.1 The buoyancy loss factor is to be the greater of the three values calculated from the following equation, first using the results of the samples subjected to the water soak specified in 24.4.2.1, then using the results from the samples subjected to the heat aging specified in 24.4.3.1 and then using the results from the samples subjected to the compression application specified in 24.4.4.1. The factor is to be rounded up to the nearest whole number.

$$Factor\ (E_i) = 100 \sum_{i=1}^{N} \frac{B_i - B_f}{B_i}$$

in which:

B_f is the final buoyancy of an individual sample,

B_i is the initial buoyancy of an individual sample,

N is the number of samples subjected to the applicable conditioning.

25 Buoyancy Test

25.1 When tested as described in 25.2 – 25.6:

a) The adjusted buoyancy (B_a) of an immersion suit, determined in accordance with 25.7, shall not be less than:

1) 22 pounds-force (100 N) for an adult size; and

2) 11 pounds-force (50 N) for a child size.

b) The measured buoyancy (B_m) of an immersion suit shall not be reduced by more than 5 percent after 24 hours submersion in fresh water.

25.2 This test is to be conducted on a sample of the complete suit, or on component parts (i.e. not glued or sewn) of a complete suit in a test tank of water that is capable of being secured against change of water level or disturbance of the sample. Entrapped air, or air enclosed in folds of the cloth, is to be removed from the sample immediately following immersion. An auxiliary means of buoyancy is not to be used.

25.3 A test basket made of wire mesh or equivalent material and of a size capable of holding the sample without unduly compressing the material is to be ballasted with weight such that the basket and sample are completely submerged.

25.4 The submerged ballasted basket, without the sample, is to be suspended from a scale or load cell calibrated to an accuracy of at least ± 1 ounce (± 28.3 g), and the weight of the submerged basket determined.

25.5 The sample is to be submerged, filled with water, folded, and placed in the ballasted basket so that its upper surface is 2 inches (50.8 mm) below the water surface. The basket is to be tilted slightly in each of four perpendicular directions, for 5 minutes in each position. A 1 inch (25.4 mm) diameter doll rod is to be used to manipulate the samples to remove all entrapped air. Then, the samples are to be maintained in the submerged position for 24 hours. The weight of the submerged ballasted basket with the sample inside is to be determined.

25.6 The buoyancy of the complete suit (B_m) is to be calculated by the method described in 24.3.1(d). The result is to be corrected to establish the buoyancy at an atmospheric pressure of 29.92 inches Hg (101 kPa) and a water temperature of 68°F (20°C).

25.7 The adjusted buoyancy of the suit (B_a) then is to be calculated according to the following formula:

$$B_a = B_m \sum_{i=1}^{N} P_i \left[1 - \frac{E_i}{100}\right]$$

in which:

B_a is the adjusted buoyancy of the suit;

B_m is the measured buoyancy of the suit, calculated in accordance with 25.6,

P_i is the fraction of buoyancy provided by the material to the total buoyancy of the suit as determined by the formula B_i/B_m (See 24.3.1),

E_i is the buoyancy loss factor for the material, determined in accordance with 24.6.1.

26 Thermal Insulation – Identification

26.1 General

26.1.1 Following the Thermal Protection Test, Section 22, three samples of the material of the suit, for each thickness provided, are to be tested in accordance with 26.2.1 – 26.3.3. The time it takes for the water temperature in the test cylinder to drop from 45 to 33°C (113 to 91°F) is to be recorded and shall be used for reference purposes.

26.2 Test equipment

26.2.1 For this test, the following apparatus and samples are required:

a) A sealed aluminum test cylinder that:

1) Shall hold at least 1.6 liters (0.42 gallon) of water; and

2) Permits the removal of all entrapped air.

See Figure 26.1.

b) Three thermocouples that are accurate to within ±0.1°C (±0.18°F) and that are arranged to measure the temperature of the water in the test cylinder at three different water levels.

c) Three samples of the insulation material being tested taken from three separate locations of the suit, each of a size capable of encapsulating the cylinder and thermocouple leads. See Figure 26.1. The surface covering (surface treatment) and number of layers of material tested are to be the same as those of the material used in the suit. When the material used in the suit varies in thickness or number of layers, each thickness or layer of the material is to be tested.

d) A clamping arrangement (adhesive) to form a watertight seal around the edges of the sample with the test cylinder inside.

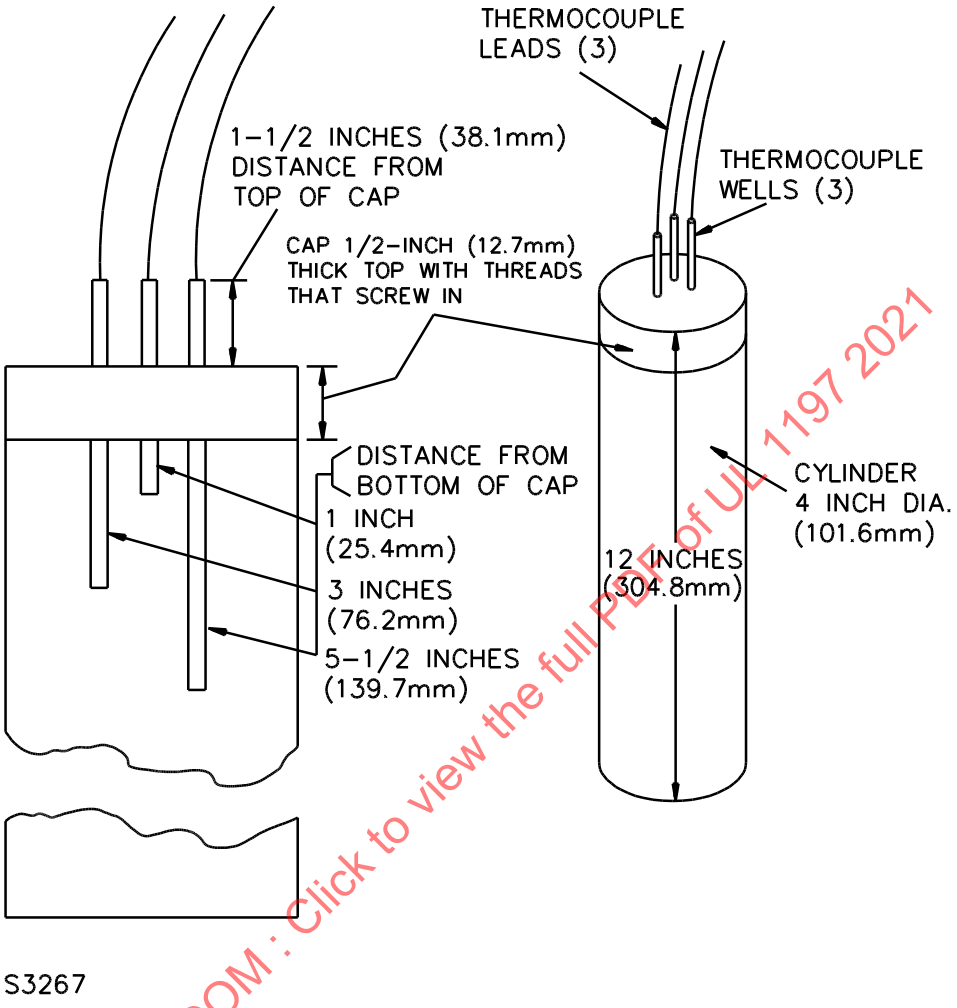
e) A container of water at least 3 feet (0.9 m) wide and 3 feet long and deep enough to permit the entire assembly of the test cylinder and sample to be held at least 1 meter (39 inches) below the surface of the water.

f) A means to control the temperature of the water in the container at a value between 0 and 1°C (32 and 33.8°F).

g) A thermocouple that is accurate to within ±0.1°C (0.18°F) and that is arranged to measure the temperature of the water in the container at the depth at which the test cylinder and samples are held.

Figure 26.1

Test cylinder



26.3 Test procedure

26.3.1 Each sample of insulation material is to be fitted, in turn, around the test cylinder so that there are no air gaps.

26.3.2 The temperature of the water in the test cylinder is to be raised, by any convenient means that does not damage the sample, to 45°C (113°F) or higher. The assembly then is to be placed in the container and submerged so that:

a) The highest point of the assembly is 1 m (39 inches) below the surface of the water; and

b) No part of the assembly touches the bottom or sides of the container.

The temperature of the water in the container is to be between 0 and 1°C (32 and 33.8°F), and is to be maintained within this range throughout the submersion.

26.3.3 When temperature stratification occurs inside the test cylinder, then after each 2 minute period of submersion, the assembly is to be shaken and then inverted from its previous position while submerged. Any other convenient means so as to preclude temperature stratification is to be used for this test.

27 Flame Exposure Tests

27.1 Suit exposure

27.1.1 An immersion suit shall withstand a 2 second immersion to flame as described in 27.1.2 – 27.2.1 without sustaining burning or continued melting after removal from the flame.

27.1.2 The bottom of a 12 by 18 by 2-1/2 inch test pan is to be filled with water to a depth of 1/2 inch (12 mm). A 1-1/2 inch (40 mm) deep layer of heptane then is to be floated on top of the water in the pan. The pan is to be placed in a draft free area and the heptane is to be ignited and allowed to burn freely for 30 seconds.

27.1.3 A sample of the suit is to be held from its top by the holding arrangement and is to be passed through the flames, with the lowest portion of the suit 9-1/2 inches (240 mm) above the surface of the burning heptane. The suit is to be passed through the flames at a rate that exposes the suit for 2 seconds. The 2 second period is to begin when the flames first contact the forward portion of the suit and is to end with the suit being removed from the flames.

27.1.4 When the suit shows evidence of damage other than scorched surfaces after the flame immersion, it is to be subjected to the tests specified in 18.3 (Stability and Retroreflective Material Tests using one subject only), Thermal Protection Test, Section 22, and the Buoyancy Test, Section 25 (the suit is only to be submerged for 2 hours). The suit shall comply with the requirements in 18.1, 18.2, 22.1.1, and 25.1.

27.2 Storage case exposure

27.2.1 When tested as described in 27.2.2, the storage case shall not burn through at any point and the stored immersion suit shall not show visible evidence of damage.

27.2.2 The test procedure is to be as described in 27.1.2 and 27.1.3; except that a sample of the suit stored in a sample of the storage case that accompanies the suit is to be tested, and the suit/case combination is to be held from its top by the holding arrangement and passed through the flames so that the lowest point on the case is 9-1/2 inches (240 mm) above the surface of the burning heptane. The 2