


HELICOPTER PASSENGER TRANSPORTATION SUIT SYSTEMS

Prepared by the
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HELICOPTER PASSENGER TRANSPORTATION SUIT SYSTEMS

FOREWORD

CAN/CGSB-65.16 *Maritime Abandonment Immersion Suit Systems* and CAN/CGSB-65.17 *Helicopter Passenger Transportation Suit Systems* provide the potential for dual-role approval of immersion suit systems in certain use situations.

1. SCOPE

1.1 This standard applies to immersion suit systems that:

- reduce thermal shock upon entry into cold water;
- delay the onset of hypothermia during immersion in cold water;
- provide acceptable flotation and minimize the risk of drowning;
- and
- do not impair the wearer's ability to evacuate from a ditched helicopter.

1.2 The testing and evaluation of a product against this standard may require the use of materials and/or equipment that could be hazardous. This document does not purport to address all the safety aspects associated with its use. Anyone using this standard has the responsibility to consult the appropriate authorities and to establish appropriate health and safety practices in conjunction with any existing applicable regulatory requirements prior to its use.

1.3 Appendix A includes guidelines for insulation of the suit exterior fabric.

1.4 Appendix B includes the requirements and test procedures for waterproof zippers.

2. REFERENCED PUBLICATIONS

2.1 The following publications are referenced in this standard:

2.1.1 Canadian General Standards Board (CGSB)

CAN/CGSB-4.2 — Textile Test Methods:

No. 9.2 — Breaking Strength of Fabrics — Grab Method (Constant time-to-break Principle)

No. 12.1 — Tearing Strength — Single-Rip Method

No. 26.1 — Water Resistance — Static Head Penetration Test

No. 32.2 — Breaking Strength of Seams in Woven Fabrics

62-GP-12 — Marking Material, Retroreflective, Enclosed Lens, Flexible Type.

2.1.2 American Society for Testing and Materials (ASTM)

B 21M — Standard Specification for Naval Brass Rod, Bar, and Shapes (Metric)

B 117 — Standard Practice for Operating Salt Spray (Fog) Apparatus

C 177 — Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate-Apparatus

C 5 18 — Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

D 2062 — Standard Test Methods for Operability of Zippers

- 2.1.3 Shoe and Allied Trade Research Association (SATRA)
PM 34 — Resistance to Water Penetration — Maeser Test.
- 2.1.4 Underwriters Laboratories Inc. (UL)
UL 1191 — Components for Personal Flotation Devices.
- 2.1.5 U.S. Department of Transportation, Federal Aviation Administration
Technical Standard Order (TSO) C 13 Life Preservers
Technical Standard Order (TSO) C 85 Survivor Locator Lights.
- 2.2 A reference to a regulation is always to the latest issue. A dated reference is to the issue specified. An undated reference is to the latest issue unless otherwise specified by the authority applying this method. The sources are given in the Notes section.

3. DEFINITIONS

- 3.1 The following definitions apply in this standard:

Escape Buoyancy (Flottabilité (avant gonflement))

The total buoyancy of the system on the wearer, including the inherent buoyancy of the components and entrapped air, but without the inflatable buoyancy element deployed.

Exterior Fabric (Tissu extérieur)

For the purpose of this standard this refers to the principal outer fabric of the suit, either in the form of a single or composite fabric. Where relevant, i.e., abrasion, water penetration, tests refer to the outer surfaces of the fabric.

Flotation Buoyancy (Flottabilité (après gonflement))

The total buoyancy available to the wearer from all elements of the suit system, excluding entrapped air.

Helicopter Passenger Transportation Suit System (Combinaison pour passager d'hélicoptère)

A suit that is designed to reduce the loss of body heat of a person immersed in cold water and to provide buoyancy and flotation as specified by this standard.

Immersed Clo (Clo en état d'immersion)

The insulation measurement taken when a suit is subjected to the effect of hydrostatic compression is called an immersed clo value. One clo equals $0.155^{\circ}\text{C}\cdot\text{m}^2\cdot\text{W}^{-1}$.

Inflatable Buoyancy Element (Élément de flottaison gonflable)

An auxiliary buoyancy element that requires gas inflation as a means of buoyancy.

Test Clothing (Vêtement d'essai)

A long-sleeved cotton shirt, denim trousers, underwear (briefs) and medium-weight dress socks for wear by the subject and by the manikin during the testing procedures.

4. CLASSIFICATION

- 4.1 Suit system sizes shall be classified by the maximum girth and height of the intended wearer.
- 4.2 This standard also allows for suits to be sized to individual wearers.

5. GENERAL REQUIREMENTS

- 5.1 The buoyancy shall not be provided by loose or granular materials.
- 5.2 The suit system shall be designed so that when fully donned, it covers the entire body, except that the face may be exposed.
- 5.3 The exterior fabric shall be resistant to puncture, tearing and abrasion. All other fabrics shall be tested for durability.
- 5.4 The suit system shall not be adversely affected by sea water, perspiration and petroleum products.

- 5.5 The suit system shall be resistant to rot, corrosion and sunlight,
- 5.6 The suit system shall be designed to minimize snagging during emergency egress from a ditched helicopter or when boarding a life raft.
- 5.7 The suit system closures shall be capable of being easily secured.

6. DETAILED REQUIREMENTS

6.1 Construction Details

- 6.1.1 **Body Strength** — The suit system shall be designed and constructed so that it is not damaged when tested for impact (par. 8.1.3.9) durability (par. 8.1.3.10) and body strength (par. 8.1.8). When tested for impact and durability, the suit system must not tear, separate at any seam or sustain any damage that would render it unsafe to use. When tested for body strength no part of the suit may tear or break. The suit system shall not be damaged in any way that would allow water to enter (dry suit system only) or that would affect the performance of the suit.
- 6.1.2 **Seam Integrity** — If the suit system is not a dry suit concept, par. 6.1.2.2 does not apply.
- 6.1.2.1 **Seam Strength** — With the exception of the inflatable buoyancy element (par. 6.2.2.2), each different type of seam in the exterior fabric of the suit system shall have a minimum seam strength of 300 N when tested in accordance with CANICGSB-4.2 No. 32.2.
- 6.1.2.2 **Water Penetration (Seams)** — When tested in accordance with par. 8.1.13, each different type of seam in the exterior fabric of the suit system shall not exhibit leakage before 8000 cycles. Seams that are not crucial to the water integrity of the suit system shall be excluded.
- 6.1.3 **Water Penetration (Fabric)** — When tested in accordance with par. 8.1.13, the exterior fabric (dry suit system only) shall not exhibit leakage before 10 000 cycles.
- 6.1.4 **Closures and Seals** — Each closure, seal and zipper shall be durable and constructed to be donned with ease and secured while fulfilling all other requirements specified in this standard. If the suit system (dry suit system only) comprises elements that may be detached by the wearer, the general water integrity of the suit system shall be maintained when any such element is detached.
- 6.1.4.1 **Zippers** — The zippers shall be capable of being operated with gloved hands. The zippers for the dry suit system shall be tested in accordance with the test procedures in Appendix B and shall meet the requirements also specified in Appendix B.
- 6.1.5 **Additional Fittings** — The size and design of additional suit fittings and their attachment to the suit system shall allow easy use of the fittings. The fittings shall be attached in such a way that they are visually and physically accessible and operable. They shall not attain a position that either degrades the function of the fittings or reduces the wearer's ability to escape or survive.
- 6.1.5.1 **Corrosion Resistance of Metal Parts** — Each metal part of the suit system shall be:
- fabricated from either naval brass in accordance with ASTM B 21M, or metal having equivalent or superior corrosion characteristics when tested for corrosion resistance as described in par. 8.1.10; and
 - compatible galvanically with any other metals with which it may be in contact.
- 6.1.6 **Colour of Suit System Exterior** — The primary colour of the exterior surface of the suit system shall be an international orange/yellow or an equivalent high visibility colour acceptable to the approval authority.
- 6.1.7 **Hand and Arm Construction** — Gloves or mittens may be either integral with the suit system or removable and attached to the suit system. Under both circumstances, the wearer shall retain sufficient dexterity to pass the tests described in par. 8.1.3.5 and the wearer's escape or survival ability shall not be hindered or reduced. If the hand is exposable, the watertight integrity of the suit system (dry suit system only) shall be maintained.

- 6.1.8 Leg Construction** — The suit system shall have the following leg construction:
- a. A foot with a hard sole or enough room for a work shoe to be worn inside. The sole area of the foot shall be natural or synthetic rubber that is ribbed or embossed for skid resistance. The sole shall prevent the wearer from slipping when the suit system is tested as described in par. 8.1.3.4.
 - b. The suit system shall be designed so that when the subject enters the water head first, the suit system shall not prevent the subject from attaining a head-up floating position within a period of not more than 5 s when tested as described in par. 8.1.3.11. This may include the use of leg straps but will not allow the use of neoprene flap valves. All subjects must pass this test. The suit system shall be considered acceptable if all subjects are able to perform both tasks.
- 6.1.9 Wearer Vision and Mobility** — The suit system shall be capable of being worn over test clothing and shall not restrict the wearer's vision or mobility as described below.
- 6.1.9.1 Field of Vision** — Two requirements are necessary for establishing a field of vision. One requirement is to determine the field of vision on land with the subject wearing a suit system in a seated position with the inflatable buoyancy element uninflated. The other requirement is to determine the field of vision in the water with the suit system on, inflatable buoyancy element fully inflated and the subject in a relaxed floating position. The field of vision on land and in the water shall be tested as described in par. 8.1.3.3. All subjects must pass these tests. The suit system shall be considered acceptable if all subjects are able to perform both tasks.
- a. **Field of Vision on Land** — With the subject in a seated position, head perpendicular to the shoulder plane, with the suit system fully secured and the inflatable buoyancy element uninflated, the average single field of lateral vision must be at least 120°. With the subject's head rotated 30° to the left of the perpendicular of the shoulder plane and then 30° to the right, the average single field of lateral vision must also be at least 120°.
 - b. **Field of Vision in the Water** — With the subject floating in a relaxed position in the water with suit system fully secured and the inflatable buoyancy element fully inflated, the subject's field of vision shall be:
 - i. lateral, unrestricted 120° arc of vision from left to right, water level to water level
 - ii. vertical, forward through an arc of 60° and backwards through an arc of 15°
 - iii. horizontal, an arc of 30° starting at right angles to the body and sweeping down towards the feet, parallel to the water surface.
- 6.1.9.2 Mobility and Hand Dexterity** — The suit system size and design shall not unduly restrict the wearer's mobility and dexterity as judged by the tests in par. 8.1.3.5.
- 6.1.10 Retroreflective Material** — Retroreflective material, meeting the requirements of CGSB standard 62-GP-12, shall be placed on the suit system so that at least 200 cm² is visible above the water level when tested as described in par. 8.1.3.6, of which at least 100 cm² shall be on the hood. In addition, a 5 cm wide band of retroreflective material shall be placed around each forearm of the suit system.
- 6.1.11 Breaking Strength** — With the exception of the inflatable buoyancy element (par. 6.2.2.2), the principal exterior fabric shall have a minimum breaking strength of 300 N when tested in accordance with CAN/CGSB-4.2 No. 9.2.
- 6.1.12 Tearing Strength** — With the exception of the inflatable buoyancy element (par. 6.2.2.2), the principal exterior fabric shall have a minimum tearing strength of 25 N when tested in accordance with CAN/CGSB-4.2 No. 12.1.
- 6.1.13 Abrasion Resistance** — When tested in accordance with ASTM D 3886, the minimum number of cycles to hole formation on the outer surface of the principal exterior fabric (hole formation on the first layer of a composite fabric) shall be 500 cycles.
- 6.1.14 Vertical Positioning** — Each subject shall be able to attain a vertical position while wearing the suit system when tested in accordance with par. 8.1.4.

- 6.1.15 **Buddy Line** — The suit system shall be equipped with a buddy line which shall be stowed in such a way that it is visually and physically accessible and operable. The line shall not be less than 1 m and not more than 2 m in length when deployed. The line shall be attached to the suit system in such a way that, if torn from the system, damage does not degrade the suit system's performance. When the buddy line system is attached to the system, it shall have a minimum breaking strength of 1350 N.
- 6.1.16 **Personal Locator Light** — Each suit system shall be fitted with a personal locator light meeting the minimum standard of TSO-C 85.
- 6.1.17 **Personal Whistle** — Each suit system shall be fitted with a whistle acceptable to the approval authority. The whistle shall be located in such a way that it is visually and physically accessible and operational by the wearer when in the water with the inflatable buoyancy element inflated.
- 6.2 **Performance Requirements**
- 6.2.1 **Maximum Escape Buoyancy** — The maximum escape buoyancy of the suit system as determined by testing procedures outlined in par. 8.1.5.1 shall not be more than 175 N.
- 6.2.2 **Minimum Flotation Buoyancy**
- 6.2.2.1 The minimum flotation buoyancy of the suit system shall not be less than 156 N when tested in accordance with par. 8.1.5.2.
- 6.2.2.2 The inflatable buoyancy element shall be capable of inflation by mechanical means requiring a single deliberate action by the wearer to initiate inflation. It shall also be equipped with a means of oral inflation. The materials and components from which the inflatable buoyancy element is constructed shall meet the requirements of TSO-C 13 unless otherwise stated.
- 6.2.2.3 The design and construction of the inflatable buoyancy element shall be such that the following performance requirements are achieved:
- a. Required for approval only:
- Burst Pressure — The cell shall burst at a pressure not less than six times the design working pressure or a gauge pressure of 69 kPa when tested in accordance with par. 8.1.5.2 a.
- b. Required for approval and for every produced item:
- Proof Pressure — No damage to the unit shall be evident when tested in accordance with par. 8.1.5.2 b.
- Leak Test — The pressure shall not be less than 75% of the initial test pressure when tested in accordance with par. 8.1.5.2 b.
- 6.2.3 **Floating Characteristics** — When tested as described in par. 8.1.3.7, the suit system shall provide a stable floating position, with a face plane angle between 30 and 80° to the horizontal, in which the subject is face-up with the mouth and nose at least 120 mm above the surface of the water. This shall be achieved for at least eight out of the eleven subjects.
- 6.2.4 **Righting** — The suit system shall turn the wearer from a face-down position to a face-up position within 5 s or allow the wearer without assistance to turn himself or herself from a face-down position to a face-up position within 5 s. If a suit system has auxiliary buoyancy, the suit system shall be designed to meet these requirements when the auxiliary means of buoyancy is used as well as when it is not used. The righting tests are carried out as described in par. 8.1.3.8.
- 6.2.5 **Thermal Protection** — Two options for measuring thermal protection are given. For dry suit systems, the leak tests as described in par. 8.1.6.1 shall be conducted to determine the amount of water that will be introduced into the suit system for the thermal tests.
- 6.2.5.1 **Using Thermal Manikin** — When tested in accordance with par. 8.1.6.2, the mean level of thermal insulation over the body as provided by the suit system which includes test clothing (described in Section 3) must not be less than $0.116^{\circ}\text{C}\cdot\text{m}^2\cdot\text{W}^{-1}$ (0.75 immersed Clo). Using this test method, the hands shall have a minimum thermal Protection value of $0.6\text{ K}\cdot\text{m}^2\cdot\text{W}^{-1}$ (0.5 immersed Clo).

- 6.2.5.2 **Using Human Subjects** — The suit system shall provide thermal protection such that the average body core (rectal) temperature of persons wearing the suit system for 6 h in calm circulating water that is between 0 and 2°C shall not drop more than 2°C and the finger, toe or buttock temperature of the wearers shall never drop below 5°C, and never below 8°C, for more than 15 min for an entire immersion. Providing the suit system protecting the hands and feet (i. e., gloves and sockets) meets a minimum requirements of 0.5 immersed Clo, it is permissible for the test house to provide additional insulation to the hands and feet, to prevent the occurrence of none-freezing cold injury in the test subjects through hand and foot temperature reductions below these limits. The clo value of gloves can be measured according to the test method in Appendix A.
- 6.2.6 **Flame Resistance** — The suit system shall be designed to be useable after 2 s contact with a gasoline fire, when tested as described in par. 8.1.11.
- 6.2.7 **Temperature Cycling (Storage)** — The suit system shall not be damaged by storage at any temperature between -40 and 65°C, when tested as described in par. 8.1.12.
- 6.2.8 **Oil Resistance** — When tested in accordance with par. 8.1.14, the samples shall not exhibit any damage such as cracking, swelling, dissolution, or change in mechanical properties, and the seams shall have a breaking strength of not less than 150 N. As well, the samples of the exterior material and seams of dry suit system shall not exhibit any leakage.

7. INSTRUCTIONS FOR USE

- 7.1 The suit system shall have written or pictorial instructions for its donning and use. However, instructions for the use of the inflatable buoyancy element shall be primarily pictorial with a minimum use of words. The proper donning procedure and other operational instructions on the use of the suit shall be simple and obvious. If written instructions are provided, they shall be in both official languages.
- 7.2 These instructions shall be readily available to the wearer in the helicopter.
- 7.3 Instructions on the operation of the inflatable buoyancy element shall be readable in the water in low level illumination.
- 7.4 The manufacturer shall provide written instructions for the care and maintenance of the suit system and any relevant information concerning the operation of accessories specific to the suit system.

8. DESIGN APPROVAL — TESTING

8.1 Approval Testing of Suit Systems

CAUTION: During each of the in-water tests prescribed in this section, a person ready to render assistance when needed should be near each subject in the water.

- 8.1.1 **General** — Each suit system shall be tested for design approval as described in this section.
- 8.1.1.1 **Test Anomalies** — Throughout the testing program, certain results may vary significantly from the collected data set. Such results must be recognized and validated by the testing agency. Where this variation is determined to be a suit system design/performance factor, the results shall remain as part of the data set. Where this variation is determined to be an anomaly caused by test subject activities which are outside the scope of the specific test objective, the test may be repeated or the results deleted from the data set. This decision must be made in consultation and agreement with a representative of the approval authority.
- 8.1.2 **Test Samples** — Each test prescribed in this section shall be performed using as many samples of the suit system as are needed to make an efficient use of the test subjects and test equipment, except that in the Impact Test in par. 8.1.3.9, an individual subject shall use the same suit system for the entire test. If the exterior fabric is a composite fabric, it shall be tested as a composite fabric unless otherwise stated.

8.1.3 **Wearer Vision, Mobility and Flotation Tests** — The wearer vision, mobility and flotation capabilities of each suit system shall be tested under the following conditions and procedures:

8.1.3.1 **Test Subjects** — The subjects used in the tests shall be seven males and four females selected to represent the approximate percentile range of heights for the ninety-fifth to the fifth percentiles for both males and females. The test subject selection criteria will be as follows:

Gender	Body height cm	Body mass kg	Number of subjects
Males	184 or greater	90 or greater	2
	170 to 176	68 to 78	3
	162 or less	55 or less	2
Females	170 or greater	65 or greater	2
	157 to 163	52 to 62	1
	150 or less	48 or less	1

8.1.3.2 **Donning Time** — Each subject is removed from the view of the other subjects and allowed time to examine the suit system and the manufacturer’s instructions for donning and using the suit system. At the end of this period, the subject shall attempt to don the suit system as rapidly as possible without the aid of a chair or any support to lean on; however, the subject may sit on the floor. If the subject does not don the suit system completely, including gloves or mittens and any other accessories as necessary to achieve the thermal protection (par. 6.2.5), within 2 min, the subject removes the suit system, examines the ‘instructions for 1 min and again attempts to don the suit system. At least ten of the eleven subjects shall be able to don the suit system completely within 2 min in at least one of the two attempts. Inflation of the buoyancy element is not required.

8.1.3.3 **Field of Vision** — The suit system’s field of vision shall be tested as follows:

a. **Field of Vision on Land** — Each subject not wearing a suit system shall be seated with the chin resting firmly on a support and shall look straight ahead. A person carrying a lighted flashlight pointed at the subject’s head, shall stand behind the seated subject and walk clockwise and then counterclockwise around the circumference of a circle of which the seated subject’s head is at the centre and whose radius is 5 m. It shall be established from the results of carrying out this test that the seated subject, moving the eyes, if necessary, can observe the lighted flashlight on each side at an angle of at least 60° from the perpendicular of the shoulder plane.

The test shall then be repeated with each subject having fully donned the suit system with the inflatable buoyancy element uninflated for each of the following positions:

- i. head perpendicular to the shoulder plane
- ii. head rotated 30° to the left of the perpendicular of the shoulder plane
- iii. head rotated 30° to the right of the perpendicular of the shoulder plane.

b. **Field of Vision in the Water** — The field of vision shall be measured in the lateral, vertical and horizontal planes with the suit system fully donned and inflatable buoyancy element fully inflated. The Bohemier Perimeter Scope (Figure 1) or equivalent shall be used to measure field of vision. This device has studs to stabilize the subject’s head and a 2 cm plastic pipe bent into a semi-circle measuring 2 m in diameter. Marks are placed on the ring at 15 cm intervals using a selection of coloured tapes. Measure the field of vision of each person in the normal flotation angle with head fixed and eyes allowed to move, in the lateral (Figure 2a), horizontal (Figure 2b) and vertical (Figure 2c) planes.

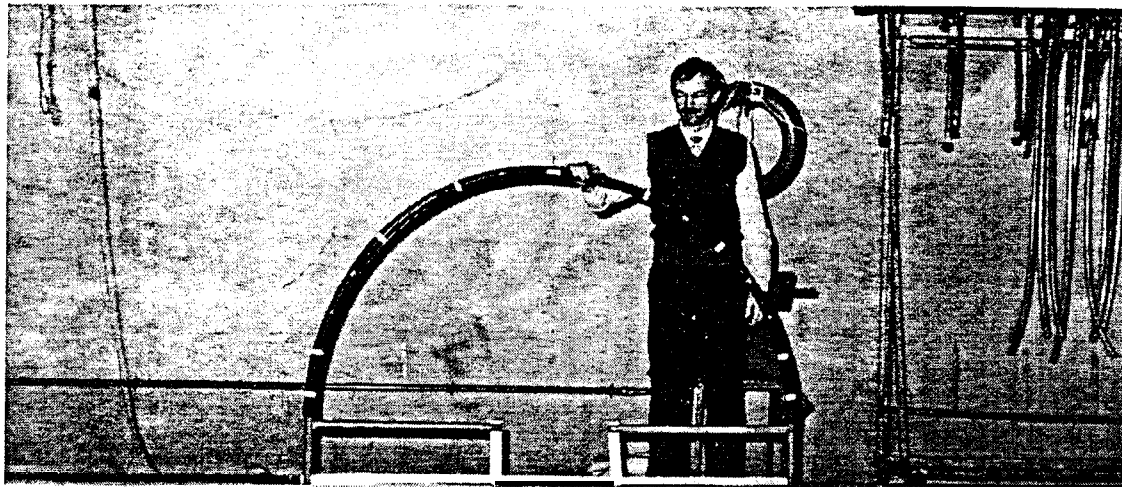


FIGURE 1
Bohemier Perimeter Scope

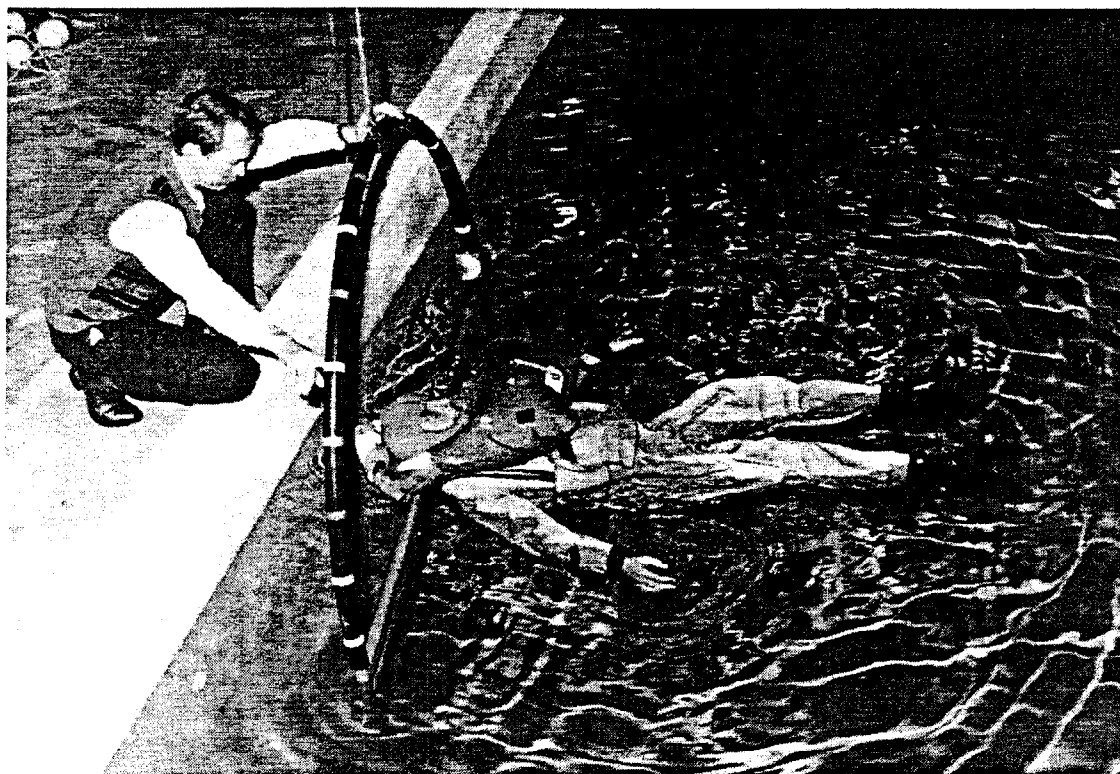


FIGURE 2a
Field of Vision in the Water — Lateral Plane

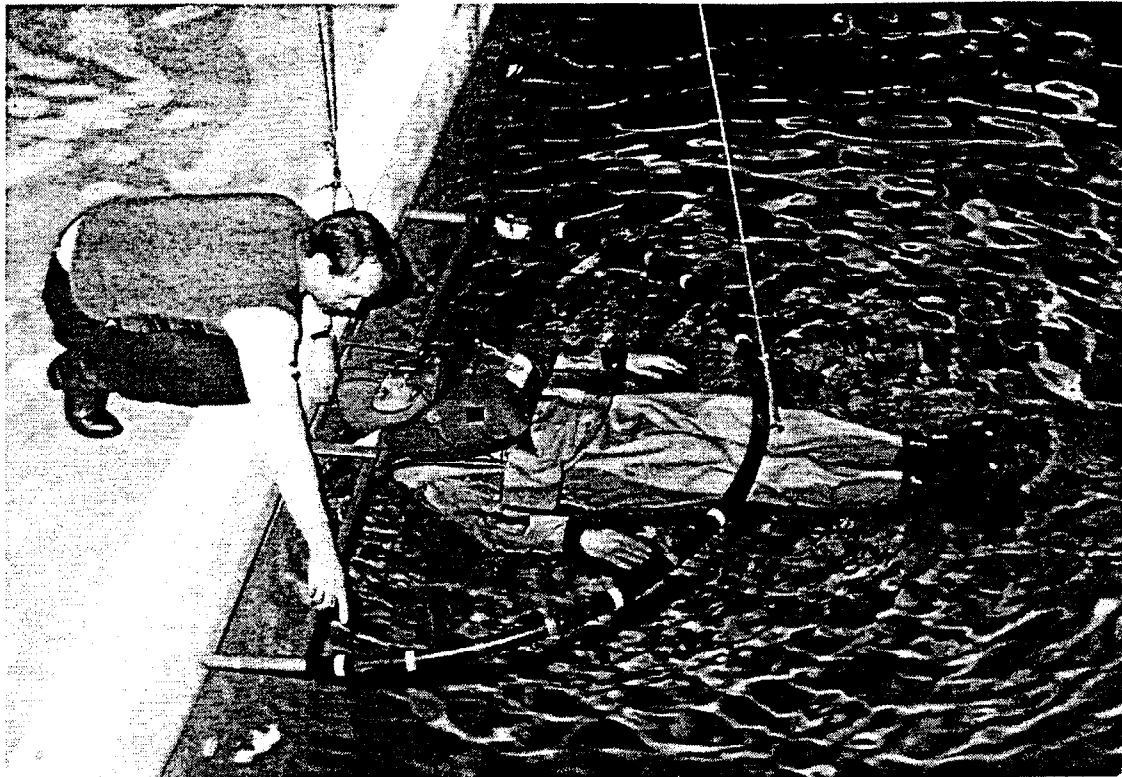
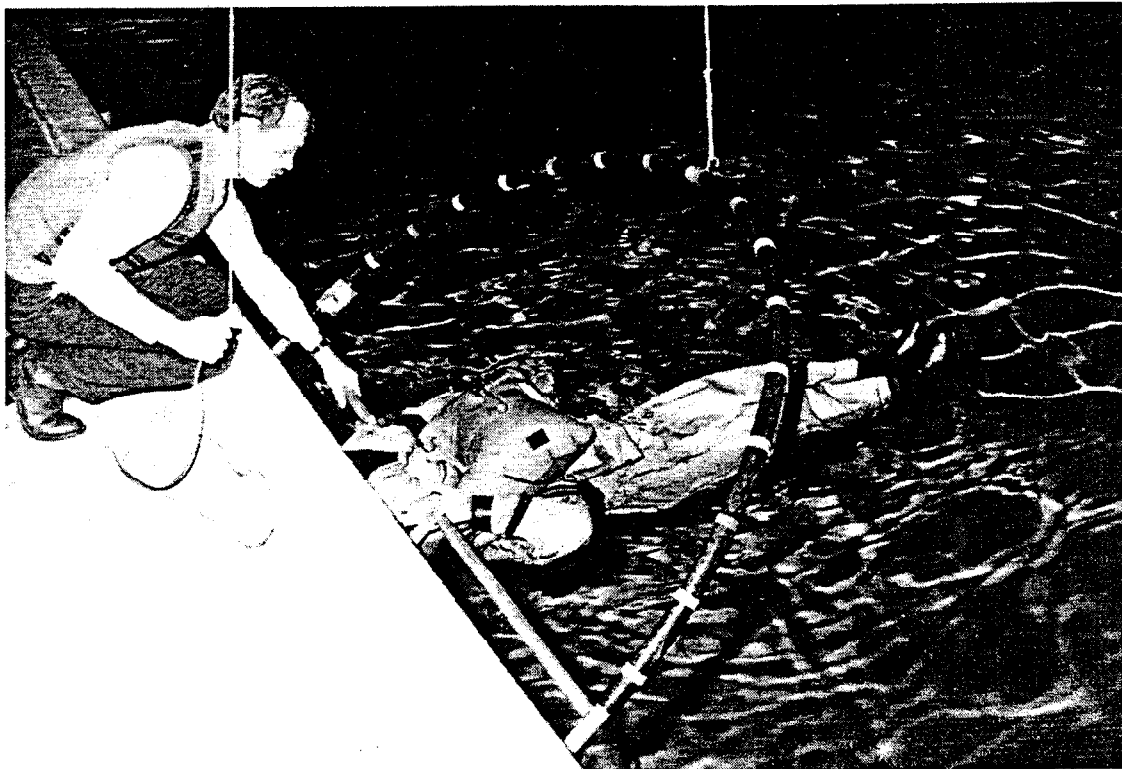
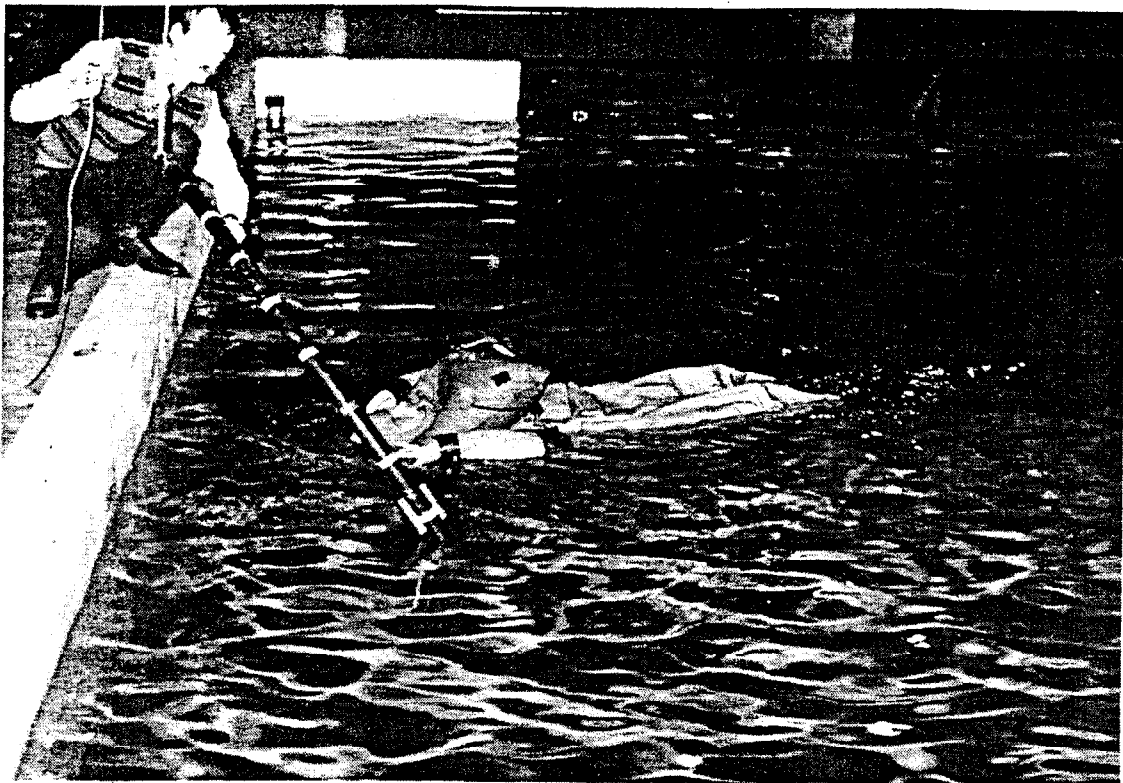


FIGURE 2b
Field of Vision in the Water — Horizontal Plane



(i) Forward

FIGURE 2c
Field of Vision in the Water — Vertical Plane



(ii) Backwards

FIGURE 2c
Field of Vision in the Water — Vertical Plane

8.1.3.4 *Skid Resistance* — Each subject, wearing only the test clothing and rubber-soled footwear, shall walk a distance of 30 m on a smooth wet surface such as tile or painted concrete. The smooth wet surface shall be $23 \pm 5^{\circ}\text{C}$. There shall be at least one turn of at least 90° in the 30 m course. This distance shall be walked twice and the times recorded. The walk is repeated with the suit system fully donned. The average time while wearing the fully donned suit system must not exceed by more than 25% the average time when not wearing the suit system. Rest periods between each transit of the course are permitted.

8.1.3.5 *Mobility and Hand Dexterity* — This is assessed in four parts, (a. to d.) if the suit system has a detachable hood and/or gloves; and three parts, (a. to c.) if the suit system lacks one or both of these detachable components.

- a. A vertical ladder, with rungs 300 mm apart, extending a suitable distance above a level floor shall be used for the first part of this test. Each subject while not wearing the suit system is timed twice climbing the ladder so the feet are at a height of 3 m above the floor. (The subject shall climb the ladder quickly but without jeopardising safety.) The subject shall then don the suit system and is again timed twice climbing to the same height. The subject is given adequate rest periods between trials to avoid fatigue. The average time for each subject to climb the ladder wearing the suit system must not exceed the subject's average time to climb the ladder without the suit by more than 25%.
- b. The life raft used for this test shall be a non-reversible dual chamber. Department of Transport-approved ten to fourteen-person capacity life raft with a boarding ladder which is free-floating on the water. Following a brief, simple demonstration on how to right a life raft, the subjects shall be able to right and climb into the life raft. Each subject shall enter the water at a temperature of not less than 18°C , without the suit system, but with a SOLAS-approved life jacket donned, and swim or tread water for approximately 2 min. The subject shall then be able to right the life raft and climb into it via the boarding ladder with no other boarding aids in a maximum of 3 min. Only subjects that qualify from this task shall be used in the subsequent test. A minimum of eight subjects must qualify for this test.

The test is then repeated with the qualifying subjects as follows:

The subject shall enter the water with the suit system fully secured and deploy the inflatable buoyancy element. The subject may adjust the suit system. The subject is then required to right an inverted life raft and climb into

the life raft via the boarding ladder, with no other boarding aids. The suit system shall be considered acceptable if the task is performed by each subject in less than 6 min.

- c. Once in the life raft, the subject, with the gloves on, is required to cut a painter using a standard raft knife. The subject shall unroll five turns of 2 cm black plastic insulating tape from a 4 cm wood dowel to simulate preparing a hand flare for use. The first 2 cm of tape shall be folded back on itself to form a 1 cm starter tab, simulating a tab on a hand flare.
- d. Where a suit system has a detachable hood and/or gloves, the subject, while floating in the water, shall be able to don both in less than 3 min.

8.1.3.6 *Retroreflective Material* — The inflatable buoyancy element shall be fully inflated for this test. Measure the area of the exposed retroreflective material on the suit system prior to entering the water and above the water level during the flotation characteristics test described in par. 8.1.3.7.

8.1.3.7 *Stability and Floating Characteristics* — Each subject, while wearing a suit system, shall enter the water gently, activate the inflatable buoyancy element and adopt a face-up position with the legs together and the arms at the sides. After a period of 5 min it shall be established that the subject is stable in that position by depressing each shoulder in turn to ensure that the subject returns to the face-up position and does not invert.

With the subject in a relaxed position, measure the freeboard to the mouth and nose, perpendicularly from the surface of the water.

Measure the angle, relative to the surface of the water, of the plane formed by the most forward part of the forehead and chin of the subject floating in the attitude of static balance in which respiration is least likely to be impeded. For each subject determine the stable position and the face plane angle.

8.1.3.8 *Righting* — Each subject, while wearing the suit system in the water fully secured and the inflatable buoyancy element fully inflated, takes a deep breath, assumes a face-down position, allows the body to become limp, and slowly expels air. The suit system shall cause the subject to turn face up within 5 s; or if the suit system does not turn the subject within 5 s, the subject shall be able to turn face up under his/her own power within an additional 5 s. The procedure is repeated using the auxiliary means of buoyancy if one is provided.

8.1.3.9 *Impact* — While wearing the suit system with the inflatable buoyancy element uninflated, each subject shall jump feet first into the water three times from a minimum height of 3 m above the water surface. Then, with the inflatable buoyancy element inflated, each subject shall repeat the same jump three times from the same height while holding the buoyancy element in accordance with the manufacturers' instructions. Each subject shall be able to assume a face-up stable position without assistance after each jump.

8.1.3.10 *Durability* — One suit system shall be fully donned and doffed six times prior to testing in accordance with par. 8.1.6.

8.1.3.11 *Head First Entry* — The subject, while wearing the suit system, shall enter the water head *first* from a height of 1 m above the water surface and shall attain a head-up floating position within 5 s of entry into the water.

8.1.4 *Vertical Positioning*

8.1.4.1 Each subject, while wearing the suit system with minimal buoyancy, shall enter the water and demonstrate the ability to maintain a vertical position in the water without assistance for 2 min.

8.1.4.2 If the subject's legs rise to the water surface, the subject must be able to immediately resume the vertical position without assistance and if the subject's legs rise to the water surface more than once, the subject shall be disqualified from the remainder of this test. Ten subjects must qualify for this test.

8.1.4.3 Those subjects who qualify from the above test shall be allowed adequate rest and will then don the suit system and enter the water. The subject will then attempt to assume and maintain a vertical position without assistance for 1 min. Again, if the legs rise to the water surface, the subject must be able to immediately resume the vertical position without assistance. If the subject's legs rise to the water surface more than once during the 1 min, this will constitute a failure. The suit system shall be considered acceptable if seven or more subjects are able to perform the task.

8.1.5 *Buoyancy*

8.1.5.1 *Maximum Escape Buoyancy* — The measurements of the maximum escape buoyancy shall be determined as follows:

Test Subjects — The subjects used in this test shall be as described in par. 8.1.3.1.

Test Equipment — The following equipment is required for this test:

- a. A suspended scale/load cell with a capacity of 250 kg and an accuracy of M.2 kg.
- b. A digital readout that measures mass in kilograms to an accuracy of M.2 kg.
- c. A pen recorder that will record both mass in kilograms and mass against time.
- d. An 80 kg steel chair with suspension system and seat belt to be used to lower the subject into the water. The overall configuration and dimensions shall be as indicated in Figures 3a, 3b, 3c and 3d.

Test Procedure — The subject, while wearing only a bathing suit, shall be strapped into the buoyancy chair and on command be totally submerged. The subject shall remain still in an upright position for 10 s. After a reading of the subject's natural buoyancy is recorded, the subject is rapidly withdrawn from the water. The subject shall don the suit system with the detachable components in a stowed position. The subject shall then expel excess air by manually releasing any convenient seal, while assuming a crouch position for 10 s. Strap the subject in the seat with the lap belt just comfortably tight. Following the suspension over the water and call for ditching, the subject shall assume a crash position with the hands grasping the underneath of the thighs just behind the knees and the chest and head pulled down as close to the knees as possible. On total immersion the subject shall maintain this position for 5 s. (It is recommended the subject count out to themselves "one thousand and one," "one thousand and two", etc. to make this easier.) After 5 s, the subject shall sit right back in the chair to represent the post-crash situation of re-orientation prior to escape. This position shall be maintained for a further 10 s to complete the 15 s immersed buoyancy recording. Once the 15 s reading is recorded, the subject is rapidly withdrawn from the water. The natural body buoyancy of each subject shall be subtracted from the 15 s readings, and the average of three readings for each subject will be taken to allow for inconsistencies in seat position, lap strap tightness and whether the subject has taken a full inspiration or not. Record the buoyancy in newtons.

8.1.5.2 *Inflatable Buoyancy Element*

a. The following tests are required for type testing only:

Burst Pressure — Inflate the buoyancy element at a rate sufficient to increase the gauge pressure by approximately 7 kPa every 2 s to destruction. Record the pressure at burst.

Buoyancy — Inflate the buoyancy element at the design working pressure. Determine the buoyancy according to the following procedure.

Test Equipment — The following equipment is required for this test:

- A mesh basket that is large enough to hold an inflatable buoyancy element and that is weighted sufficiently to overcome the buoyancy of the buoyancy element when placed in the basket.
- A tank of fresh water that is large enough to contain the basket submerged with its top edge 50 mm below the surface of the water.
- A scale or load cell that has an accuracy of 0.15 N and that is arranged to support and determine the mass of the basket in the tank.

Test Procedure — Submerge the basket so that its top edge is 50 mm below the surface of the water. Determine the mass of the submerged basket. Submerge the inflatable buoyancy element in the submerged basket. Tilt the basket 45° from the vertical for 5 min in each of four different directions to allow all entrapped air to escape. Suspend the basket with the inflatable buoyancy element in the water with the top edge of the basket 50 mm below the surface of the water. Determine the mass of the submerged basket and inflatable buoyancy element immediately. Determine the original measured buoyancy of the buoyancy element by subtracting the mass of the basket plus buoyancy element from the mass of the basket. Correct the buoyancy to an atmospheric pressure of 760 mm mercury and water temperature of 20°C. Calculate the buoyancy in newtons.

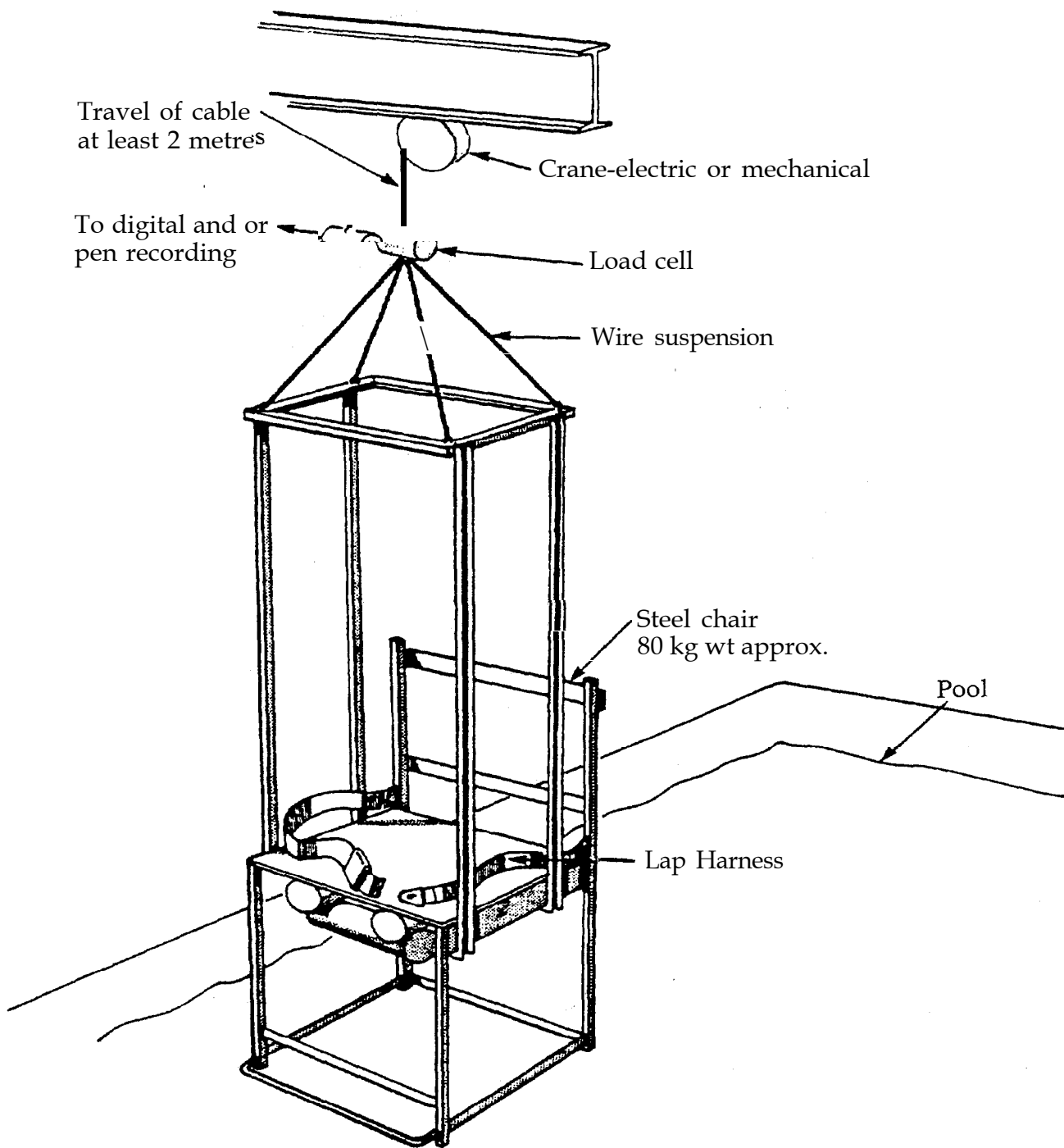


FIGURE 3a
Immersion Suit Buoyancy Measuring System

All dimensions are in millimetres

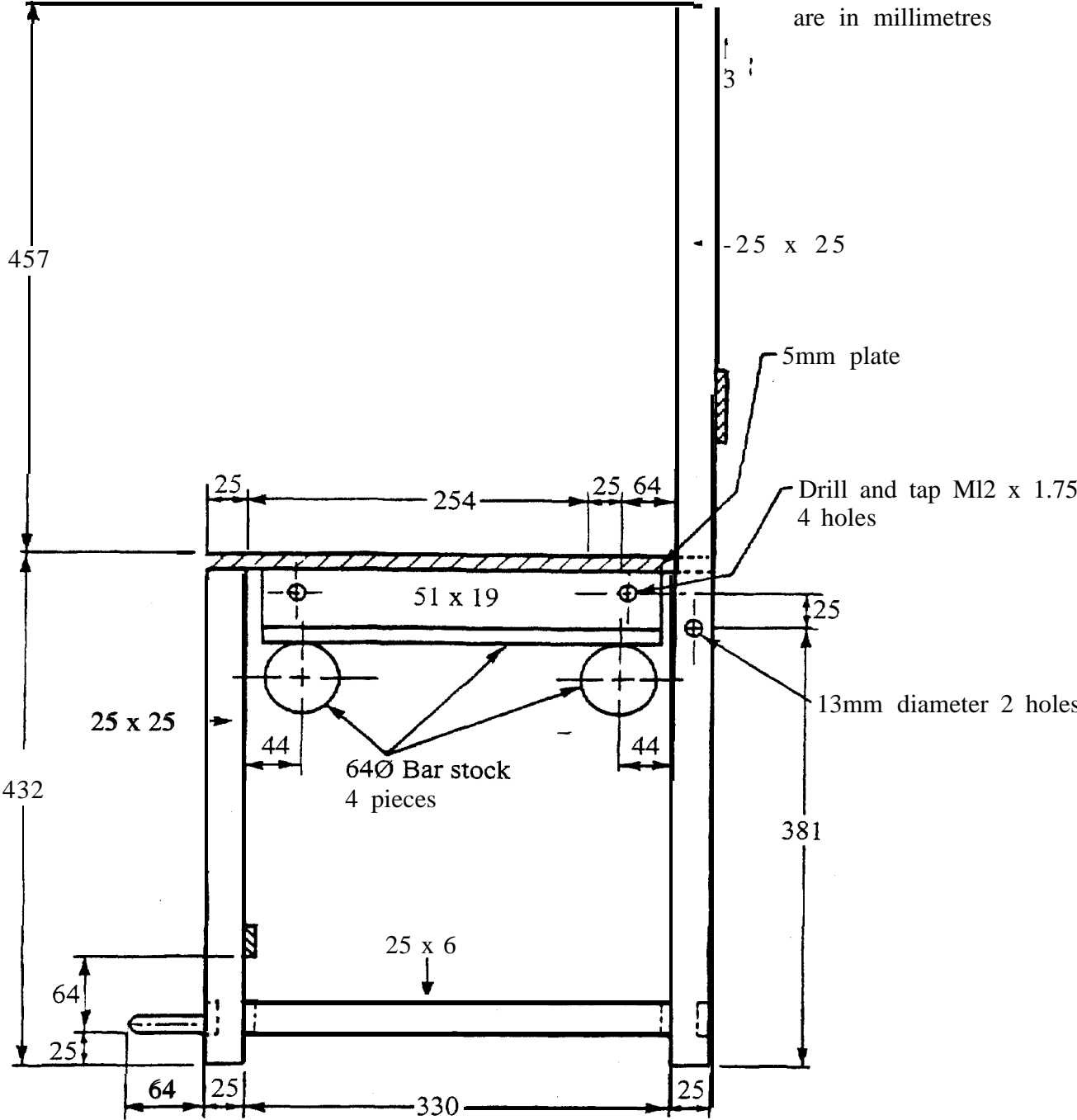


FIGURE 3b
Buoyancy Measuring Device — Side View

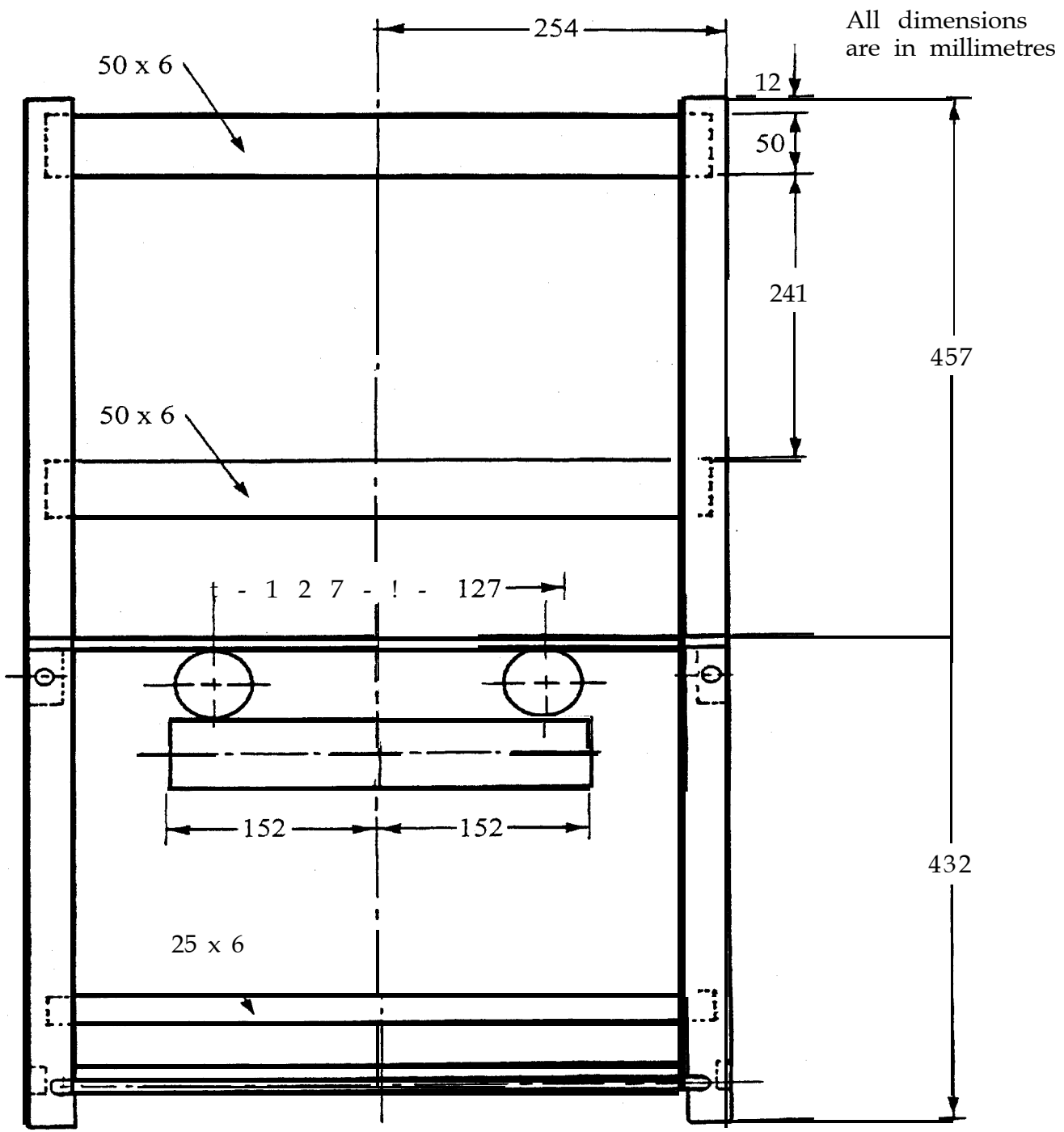


FIGURE 3c
Buoyancy Measuring Device — Front View

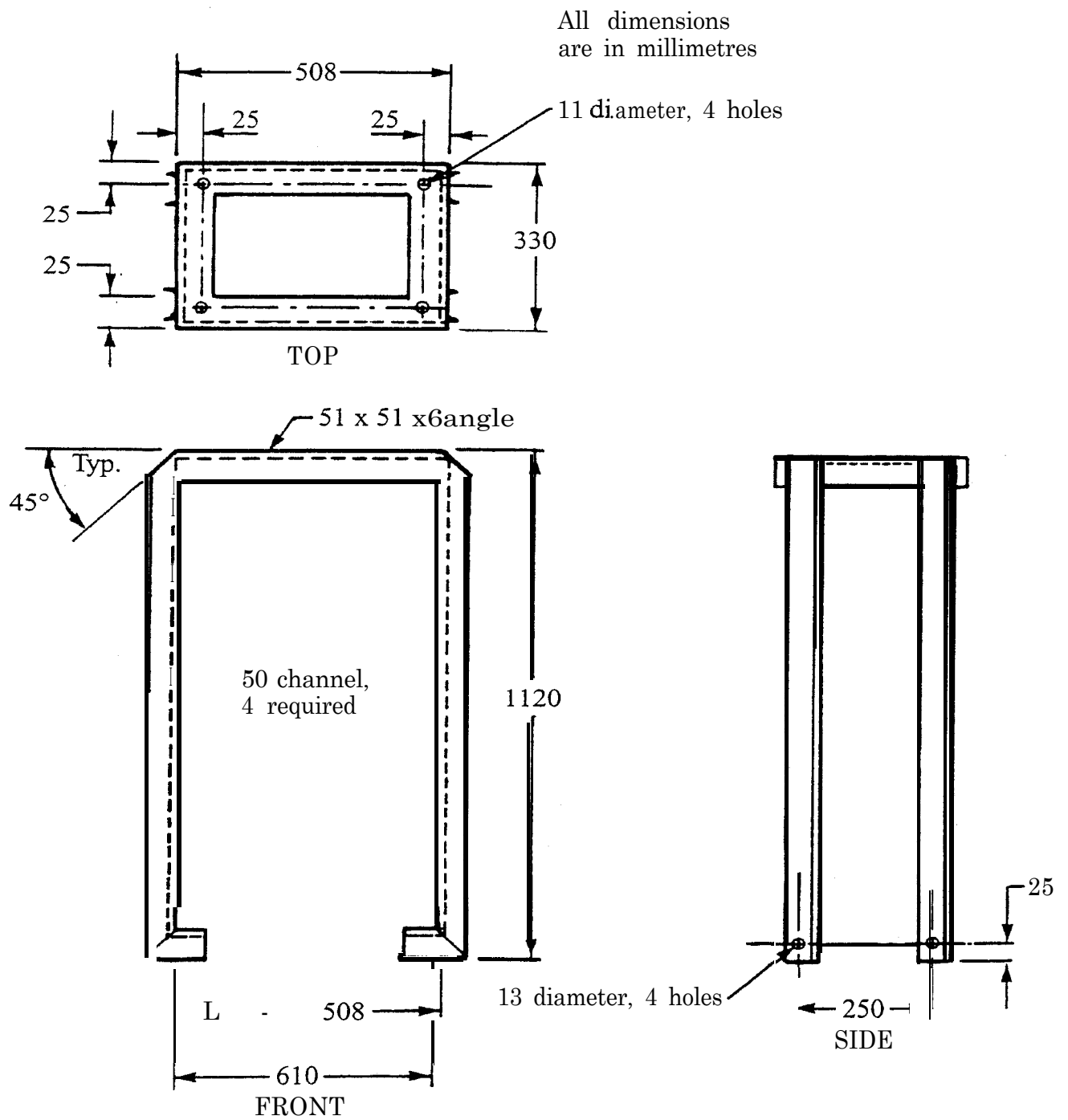


FIGURE 3d
Buoyancy Measuring Device — Top Assembly

- b. The following tests are required for each produced item:

Proof Pressure — Inflate the buoyancy element to a pressure three times the design working pressure for 5 min.

Leak Test — Subsequent to proof pressure testing inflate the buoyancy element to a pressure 1.25 times its design working pressure and hang for 12 h.

8.1.6 Thermal Protection Using a Thermal Manikin — In order to determine compliance with the requirements in par. 6.2.5.1, the thermal protection capability of a suit system shall be tested under the following conditions and procedures:

8.1.6.1 Water Ingress — This section pertains to dry suit system concepts only. Test subjects shall be *as* described in par. 8.1.3.1. Prior to testing, determine the saturation time of the suit system material by conducting a series of tests using two subjects, following the procedures in a. and b., increasing the saturation time by 2 min for each test until the saturation mass does not show a significant increase. That time shall be the established saturation time for this test.

- a. Water Ingress During Jump Into Water — Each subject, with the suit system fully donned, but all detachable components removed (e.g. hood, gloves, buoyancy element), shall climb into the water and remain in the vertical position with the water at neck level for the established saturation time to pre-wet the suit system. Each subject shall then climb out, dunk his/her head in water up to the neck to soak the hair, stand for 1 min to permit excess water to run off the exterior of the suit system and shall then be weighed. Means shall be provided so that any further run-off is included in the weighing. Observe and record any water leakage into the suit.

Each subject, with the suit system fully donned including detachable components, shall then jump into the water from a height of not less than 3 m, sufficient to permit total immersion. The jump shall be carried out in a feet first position and with feet together. Arms should be crossed over the chest using one hand to protect the nose and mouth and the other to hold down the suit and inflatable buoyancy element. The subject shall then remain still in the water for at least 1 min before being manoeuvred into a position at the pool side where it is possible to climb out with the minimum of effort. Immediately after the subject has left the water, detachable components shall be removed. The subject shall stand for 1 min to permit excess water to run off the exterior of the suit system, and then be weighed again in such a manner that any further run-off is included in the weighing. The weighing machine shall be capable of measuring 250 kg with an accuracy of ± 0.025 kg.

On completion of the water ingress jump test each suit system shall be removed and a record made of the location of any observed leaks and damp patches and the total amount of water leakage into the suit system.

- b. Water Ingress During Swimming (Leak Test) — The test shall take place in a swimming pool with a water temperature of not less than 18°C. Each subject, with the suit system fully donned, but all detachable components removed, shall climb into the water and remain in the vertical position with the water at neck level for the established saturation time to pre-wet the suit system. Each subject shall then climb out, stand for 1 min to permit excess water to run off the exterior of the suit system and shall then be weighed again in such a manner that any further run-off is included in the weighing.

A minimum of three subjects shall participate in the test together in order to achieve adequate wave motion in the pool. At the start of the test, each subject, with the suit system fully donned including detachable components, shall enter the water via a suitable step-ladder, inflate the additional buoyancy element and proceed to swim on his/her back, in line abreast with a maximum distance of 2 m between subjects and at an approximate speed of 18 m/min for 60 min. Subjects shall use their arms and legs for swimming throughout. At the end of the tests the distance covered shall be recorded and must lie between 1000 and 1200 m. On completion of the test each subject shall leave the water, and the detachable components shall be removed immediately. Each subject shall stand for 1 min to permit excess water to run off the exterior of the suit system and shall then be weighed.

- c. Calculate the amount of water, W, to be introduced at the start of the insulation measurement from:

$$W = W_1 + 3 L$$

where:

W = amount of water to be introduced, in grams

W₁ = water ingress, in grams, average for eleven subjects, measured at jump test

L = water ingress, in grams, average for eleven subjects, measured at 60 min swim test

Note: W₁ and L should be taken as one standard deviation above the mean for the eleven subjects tested.

Where water ingress has been recorded specific to each detachable component, the greatest ingress value recorded from the tests described in section a. or b. above shall be introduced, specific to the component it was recorded from.

8.1.6.2 Thermal Protection

- a. The thermal protection provided by a suit system shall be assessed by measurement of the effective insulation of the whole suit system and associated test clothing (described in Section 3) placed on a thermal manikin and immersed in turbulent water with a wave height of 40 cm so that the thermal manikin is in a natural floating position as determined in par. 8.1.6.2 b.

A thermal manikin shall be constructed so that it:

- i. has a surface area and shape similar to that of a fiftieth percentile man;
 - ii. can be dressed in representative test clothing;
 - iii. is capable of being heated to and controlled at a programmable, uniform temperature;
 - iv. can control and measure temperatures and power inputs and calculate, record and present the parameters;
 - v. can be immersed to the neck in water without causing failure in the electrical system if water leaks inside the outer clothing.
- b. Flotation Position — A subject (wearing the test clothing described in Section 3) of approximately the same mass and height of the manikin shall don the suit system, inflate all auxiliary buoyancy elements (if any) and enter the water. The subject shall assume a face-up, stable position in calm water. With the subject in a relaxed position, measure the freeboard to the mouth, abdomen and toes, perpendicularly from the surface of the water.
 - c. Test Procedure — Dress the thermal manikin in preweighed test clothing as described in Section 3 and then with the test suit system. Where a suit system is provided with an inflatable buoyancy element, this buoyancy element shall be inflated during the tests. Before placing the suit system on the thermal manikin, preweigh all items worn beneath the suit system including the suit system lining where provided. Immediately before closure of the main suit system zipper, introduce water into the test clothing (dry suit system only) in areas representative of those recorded during the water ingress tests and in amounts, W, calculated from the results of the water ingress tests in par. 8.1.6.1.

After closing the entry zipper and ensuring that all other seals are fully closed and waterproof, lower the thermal manikin into the water until the freeboard to the mouth, abdomen and toes equals the amounts measured in par. 8.1.6.2 b. This position may be achieved by using a frame on which the manikin is mounted.

The target temperature of the thermal manikin and the water temperature are set at levels appropriate to the particular thermal manikin in use. However, the minimum gradient shall not be less than 3°C between the thermal manikin and the water. Provision shall be made for inducing turbulence in the vicinity of the thermal manikin. The temperature(s) of the thermal manikin, the water and the power input(s) shall be measured continuously and recorded as means for each successive period not to exceed 15 min. Once the target temperature is achieved, the thermal manikin shall remain immersed for the time period determined by DCIEM¹ calibration acceptance testing. This ensures reliable data and consistent test results. Insulation is calculated, in the case of a single section thermal manikin, from the measured temperature gradient, the power input (i.e., heat loss) and the known surface area of the thermal manikin. In the case of a thermal manikin consisting of multiple sections, the mean overall insulation is calculated by area, weighting the insulation found in each section. After the thermal manikin is removed from the water, the clothes and lining shall be reweighed to check whether there has been leakage during the test. If leakage has occurred the measurement of insulation will be lower than it should be, and the test may have to be repeated.

¹ The Defence and Civil Institute of Environmental Medicine (DCIEM) can be contacted at 1133 Sheppard Avenue West, Downsview, Ontario, Canada M3M 3B9.

8.1.7 Thermal Protection Using Human Subjects — In order to determine compliance with the requirements of par. 6.2.5.2, the thermal protection capability of a suit system shall be tested under the following conditions and procedures:

8.1.7.1 **Test Subjects** — At least four male and four female subjects must be used for this test. Each subject shall be familiarized with the test procedure prior to the start of the test. Each subject must be between 160 and 185 cm tall and must not be more than 10% overweight or underweight for his height and physical type as determined by a physician or physiologist or from published physiological data. Each subject shall have had a normal night's sleep the night before the test, a well-balanced meal 1 to 5 h before the test, and no alcoholic beverages for 24 h prior to the test. In addition to the suit system, each subject shall wear the test clothing described in Section.3.

8.1.7.2 **Test Equipment** — The test shall be conducted in calm circulating water with a temperature between 0 and 2°C. The air temperature 300 mm above the water surface shall be between -10°C and -20°C. Each subject shall be instrumented with an electrocardiograph, a thermistor or thermocouple in the rectum placed 150 mm beyond the anus, a thermistor or the thermocouple on the tip of the index finger, and a thermistor or thermocouple on the tip of the great toe. Each thermistor or thermocouple shall have an accuracy of 0.1°C.

8.1.7.3 **Test Procedure** — A physician shall be present during this test. Before donning the suit system, each subject rests quietly in a room with a temperature between 10 and 25°C for 15 min. The rectal temperature is then recorded as the initial rectal temperature. If the suit system is a dry suit concept, the quantity of water determined in par. 8.1.6.1 shall then be added to the suit system. The subject dons the suit system as rapidly as possible without damaging the instrumentation, and immediately enters the water. The subject assumes a face-up, stable floating position. No auxiliary means of buoyancy may be used during this test. The subject remains in the water, engaging in activity that maintains the heart rate between 50 and 140 beats per minute for the first hour, and 50 to 120 beats per minute thereafter, except that no attempt is made to control heart rate if the subject is shivering. Each temperature is recorded at least every 10 min. The test continues for 6 h from the time the subject first enters the water, unless it is terminated sooner.

8.1.7.4 **Termination of Test** — If any of the following occurs, the test of the subject must be terminated:

- a. The physician determines that the subject should not continue.
- b. The subject requests termination due to discomfort or illness.
- c. The subject's rectal temperature drops more than 2°C below the initial rectal temperature, unless the physician determines that the subject may continue without danger.
- d. The subject's finger, toe or buttock temperature drops below 8°C for more than 15 min and never below 5°C.

8.1.8 **Body Strength** — The body strength of the suit system shall be tested under the following conditions and procedures:

8.1.8.1 **Test Equipment** — The test apparatus shown in Figure 4 shall be used in this test. This apparatus consists of:

- a. Two rigid cylinders, each 125 mm in diameter, with an eye or ring at each end.
- b. A weight that when combined with the mass of the lower cylinder, comprises a total applied mass of 135 kg.
- c. Ropes or cables of sufficient length to allow the suit to be suspended as shown in Figure 4.

8.1.8.2 **Test Procedure** — A hole 25 mm in diameter is to be punched through each side of the suit, at the waist, to permit the passage of the slings. Immerse the suit system in water for at least 5 min, then remove the suit system from the water and immediately arrange it on the test apparatus, using each closure as it would be used by a person wearing the suit system. Apply the 135 kg mass for 5 min.

Note: Tearing at these locations during the test shall not be considered grounds for rejection of the suit.

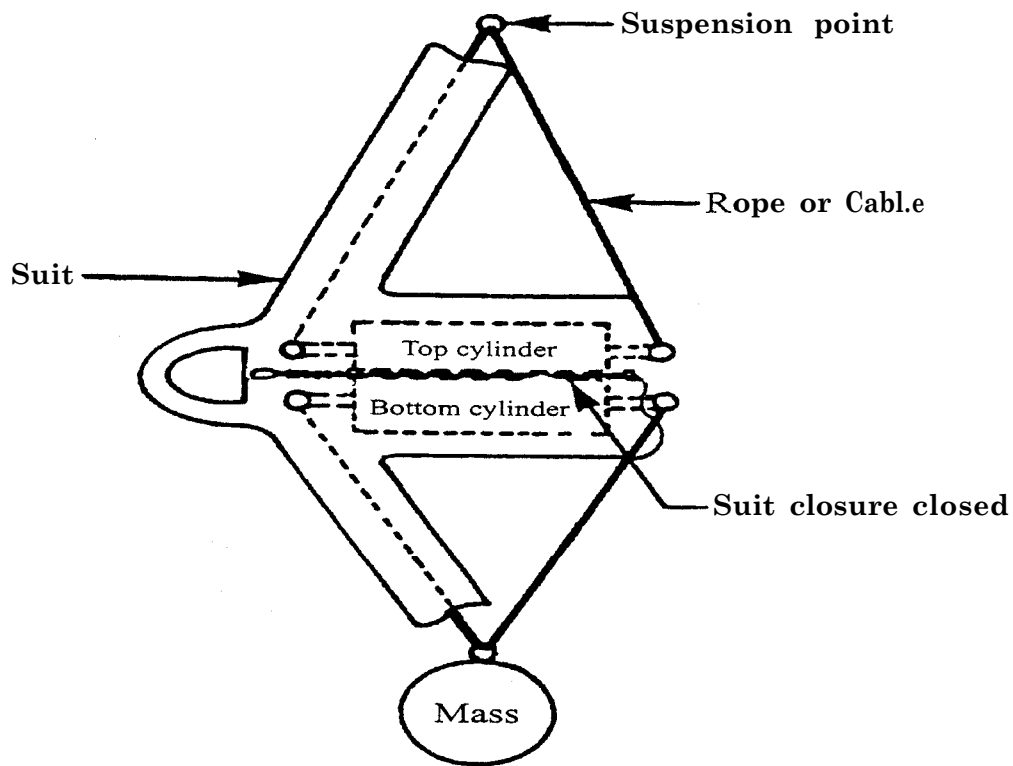


FIGURE 4

Body Strength Test

- 8.1.9 **Buddy Line** — The buddy line breaking strength shall be tested under the following conditions and procedures:
- 8.1.9.1 A rigid cylinder of approximately 125 mm, with an eye at each end is placed in the suit in such a way as to pass through the part where the buddy line is attached. The end of the buddy line is then secured overhead.
- 8.1.9.2 Two lines are attached to the eyes, and then a mass of 135 kg is attached to the lines and allowed to hang for 2 min.
- 8.1.10 **Corrosion Resistance** — Expose five samples of each metal part that is critical to the performance of the suit system in accordance with par. 5.5 of TSO C 13. At the conclusion of the exposure, each sample of the test metal and metal combination shall be tested to ensure it performs its intended function.
- 8.1.11 **Flame Exposure** — Test the suit system for resistance to flame under the following conditions and procedures:
- 8.1.11.1 **Test Equipment** — The following equipment is required for this test:
- a. A metal pan at least 300 mm wide, 450 mm long and 60 mm deep. The pan shall have at least 12 mm of water on the bottom with approximately 40 mm of n-heptane floating on top of the water.
 - b. An arrangement to hold the suit system over the n-heptane.
- 8.1.11.2 **Flame Exposure Test Procedure** — The suit system is held from the top by the holding arrangement. The n-heptane is ignited and allowed to burn for approximately 30 s in a draft-free location. The suit system is then held with the lowest part of each foot 240 mm above the surface of the burning n-heptane. After 2 s, measured from the moment the flame first contacts the suit system, remove the suit system from the fire. If the suit system is burning, it is allowed to continue to burn for 6 s before extinguishing the flames. If the suit system sustains any visible damage other than scorching, subject it to the stability test (par. 8.1.3.7) using one subject, the impact test (par. 8.1.3.9) using one subject, the thermal protection test (par. 8.1.6 or 8.1.7) and the buoyancy test (par. 8.1.5) except that the immersion time shall be for 2 h instead of 24 h.

8.1.12 *Temperature Cycling (Storage)*

8.1.12.1 Each suit system in its storage container shall be alternately subjected to surrounding temperatures of -40°C and 65°C. These alternating exposures need not follow immediately after each other. The following procedure shall be repeated for a total of 10 cycles.

- a. Expose the suit system at 65°C for 8 h.
- b. Remove the suit system from the warm chamber and leave it exposed for a period of 8 h at room temperature.
- c. Then expose the suit system at -40°C for 8 h.
- d. Remove the suit system from the cold chamber and leave it exposed for a period of 8 h at room temperature.

8.1.12.2 On completion of the final cold exposure the suit system shall be removed from the chamber. The system should be opened up by three subjects, allowed to stand in the air at room temperature (21°C) for 10 minutes. Then it should be capable of being donned within 4 min.

8.1.12.3 Upon completion of the test, the suit system shall be examined and shall show no sign of cracking, swelling, dissolution or change in mechanical properties that would affect its performance.

8.1.13 **Water Penetration** — Test each different type of seam in the suit system (par. 6.1.2.2) and the exterior fabric (par. 6.1.3) in accordance with SATRA PM 34 “Maeser” procedure. Before performing the test, ensure that the fabric is not damaged.

8.1.14 *Oil Resistance*

8.1.14.1 At least two samples of each type of exterior fabric and each type of seam are required for this test.

8.1.14.2 Immerse the samples of the suit system exterior fabric and each type of seam in No. 2 Marine diesel oil and allow them to soak for not less than 6 h.

8.1.14.3 Upon completion of the 6 h soak period remove the samples from the oil and wipe off each of them.

8.1.14.4 Test one sample of each type of exterior fabric and of each type of seam in accordance with CAN/CGSB-4.2 No. 9.2 and No. 32.2, respectively. As well, for dry suit systems, test one sample of each type of exterior fabric and of each type of seam in accordance with CAN/CGSB-4.2 No. 26.1, under a 1 m head of water, for a period of not less than 1 h.

8.2 **Test Report** — After the approval tests are completed, a test report shall be prepared by the independent laboratory. The test report shall contain:

- a. The name and address of the applicant
- b. The name and address of the independent laboratory
- c. A detailed description of the test procedure and apparatus used
- d. Detailed test results including all data recorded and a description of each test failure and each other discrepancy
- e. The date and location of testing
- f. The name of each participant and observer.
- g. Photographs, where necessary, showing at least one overall view of the suit, enough views to show all major design details, test apparatus, and each failure occurring during testing.

9. MARKING

9.1 Each suit shall be clearly marked with the following information:

- Manufacturer's name
- Date of manufacture
- Model size
- Lot number
- Serial number, if assigned
- Department of Transport Approval Number.

10. NOTES

10.1 Related Publications

10.1.1 Underwriters Laboratories Inc. (UL)

UL 1191 — Standard for Safety for Components for Personal Flotation Devices, First Edition dated January 2, 1976, revision pages to January 16, 1984.

UL 1197 — Standard for Safety for Exposure Suits, February 1977.

10.1.2 U.S. Federal Register, Vol. 49, No. 26, Tuesday February 7, 1984, Rules and Regulations, Part 160 Lifesaving Equipment, Subpart 160171 Immersion Suits.

10.2 Sources of Referenced Publications

10.2.1 The publications referred to in par. 2.1.1 may be obtained from the Canadian General Standards Board, Sales Centre, Ottawa, Canada K1A 1G6. Telephone (819) 956-0425 or 1-800-665-CGSB (Canada only). Fax (819) 956-5644.

10.2.2 The publications referred to in par. 2.1.2 may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, U.S.A. or from Global Info Centre Canada, 240 Catherine Street, Suite 305, Ottawa, Ontario K2P 2G8. Telephone (613) 237-4250 or 1-800-854-7179. Fax (613) 237-4251.

10.2.3 The publication referred to in par. 2.1.3 may be obtained from the Shoe and Allied Trade Research Association House (SATRA), Rockingham Road, Kettering, Northamptonshire NN 16 9JH, England.

10.2.4 The publications referred to in par. 2.1.4 and 10.1.1 may be obtained from the Underwriters' Laboratories Inc., Publications Stock, 333 Pfingsten Road, Northbrook, IL 60062-2096, U.S.A. or from Global Info Centre Canada, 240 Catherine Street, Suite 305, Ottawa, Ontario K2P 2G8. Telephone (613) 237-4250 or 1-800-854-7179. Fax (613) 237-425 1.

10.2.5 The publications referred to in par. 2.1.5 may be obtained from the Federal Aviation Administration, Office of Airworthiness, Aircraft Engineering Division (AIR- 100), 800 Independence Avenue S.W., Washington, D.C. 2059 1, U.S.A.

10.2.6 The publication referred to in par. 10.1.2 may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, U.S.A.

SUIT SYSTEM EXTERIOR FABRIC GUIDELINES FOR INSULATION**A1. REQUIREMENTS**

A1.1 The thermal conductivity of the exterior fabric of the suit system should be less than or equal to that of a control sample of 4.75 mm thick, closed-cell neoprene foam when they are submerged to a depth of 1 m in water and when tested as described in A2. The control samples of neoprene foam shall have a thermal conductivity of not more than 0.050 W/(m.K) as determined by ASTM C 5 18 or C 177.

A2. TEST METHOD

A2.1 **Insulation** — Test the suit system material under the following conditions and procedures except that if the suit system exterior fabric meets the requirements for the control sample in par. A2.2 c., the test procedure in par. A2.3 is not required.

A2.2 **Test Equipment** — The following equipment is required for the test:

- a. A sealed copper or aluminum can that has at least two parallel flat surfaces and that contains at least 2 L of water and no air. One possible configuration of the can is shown in Figure A1.
- b. A thermistor or thermocouple with an accuracy of $\pm 0.1^{\circ}\text{C}$ arranged to measure the temperature of the water inside the can.
- c. A control sample of two flat pieces of 4.75 mm thick, closed-cell neoprene foam of sufficient size to enclose the can between them. The control sample shall have a thermal conductivity of not more than 0.050 W/m.K. The thermal conductivity of the control sample shall be determined in accordance with the procedures of ASTM C 177 or C 518.
- d. Two flat pieces of the suit system material of sufficient size to enclose the can between them. The surface covering, surface treatment, and number of layers of the material tested shall be the same as those of the material used in the suit system. If the material used in the suit system varies in thickness or number of layers, the material tested shall be representative of the portion of the exterior fabric of the suit system having the least thickness or number of layers.
- e. A clamping arrangement to form a watertight seal around the edges of the pieces of material when the can is enclosed inside. A sealing compound may be used. Figure A2 shows one possible configuration of the clamping arrangements.
- f. A tank of water deep enough to hold the entire assembly of the can, material, and clamp at least 1 m below the surface of the water.
- g. A means to control the temperature of the water between 0 and 1°C.
- h. A thermistor or thermocouple with an accuracy of $\pm 0.1^{\circ}\text{C}$ arranged to measure the temperature of the water at the depth at which the can, material and clamp are held.

A2.3 **Test Procedure** — The temperature of the water in the tank shall be between 0 and 1°C. The temperature of the water in the can shall be at or above 45°C. Hold the can under the water and clamp it between the two pieces of the neoprene foam control sample, so that the assembly formed conforms as closely as possible to the shape of the can, and water fills all void spaces in the assembly. Submerge the entire assembly with the water temperature in the can at or above 45°C in the tank of water to a depth of 1 m at the highest point of the assembly. No part of the assembly may touch the bottom or sides of the tank. Every 2 min, shake the assembly and then invert it from its previous position. Record the time for the water inside the can to drop from 45 to 33°C. Repeat this procedure three more times using the suit system material instead of the neoprene control sample. The shortest time for the drop in water temperature when the suit system material is used shall be greater than or equal to the shortest time when the neoprene control sample is used.

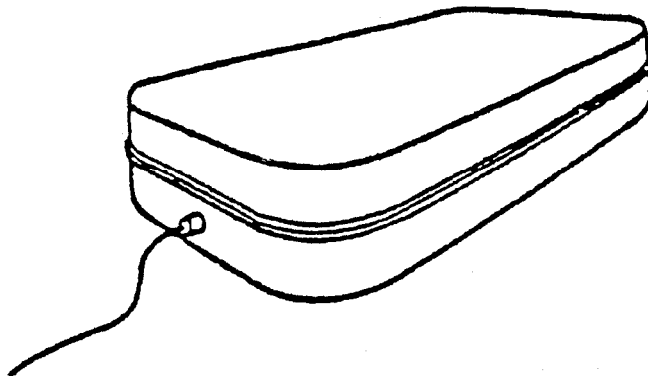
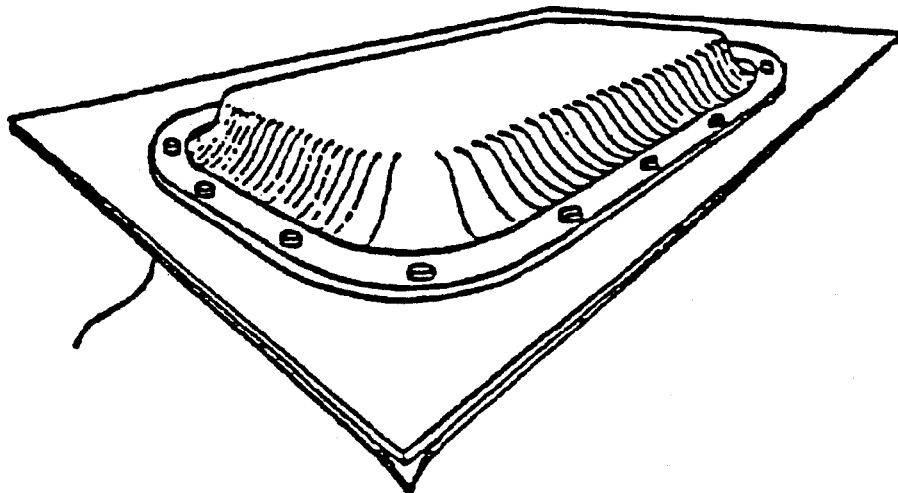


FIGURE A1
Water Can for Insulation Test Shown with Thermistor Lead



Assembly formed with water can, two pieces of material, and clamping device, with thermistor lead brought out of the assembly between the pieces of material.

FIGURE A2
Insulation Test Assembly

WATERPROOF ZIPPER REQUIREMENTS AND TEST METHODS**B1 SAMPLE REQUIREMENTS**

- B1.1 The following number of waterproof zippers are required:
- 4 of 750 mm long samples (2 open end and 2 closed end)
 - 2 of 305 mm long samples.

B2. PREPARATION OF SAMPLES

- B2.1 Prepare two 305 mm long zippers as follows:
- Each shall be glued and secured to a 356 mm long piece of 5 mm thick N2S (nylon both sides) neoprene to form a 127 mm diameter cylinder.
 - The bottom end of the cylinder shall be sealed with another piece of 5 mm N2S neoprene.

Note: It is recommended that the insides of the glued seams be checked for their tightness as these samples will be used for the leak test, and the adhesive used be resistant to diesel oil as these samples will be tested for their resistance to diesel oil.

B3. TEST METHODS AND REQUIREMENTS**B3.1 Opening and Closing Force Tests**

- B3.1.1 Conduct opening and closing force tests on 4 samples of the 750 mm long zippers after conditioning in the half-way-open position as follows:
- Test one sample in the as-received condition.
 - Test one sample after conditioning for 720 h in a salt spray of 5% sodium chloride in accordance with ASTM B 117.
 - Test one sample after conditioning for 24 h under a 100 mm head of No. 2 Marine diesel oil at 18 to 20°C.
 - Test one sample after being folded in half lengthwise to form a radius of not more than 10 mm and subjected to the temperature cycling test in par. 8.1.12.1.
- B3.1.2 The opening and closing test are to be conducted on completion of the final cold exposure, while the samples are maintained at -30°C. The opening test described in ASTM D 2062, section 16, is to be conducted on the samples conditioned in the closed position. The closing test described in ASTM D 2062, section 16, is to be conducted on samples conditioned in the open position.
- B3.1.3 The test results shall not exceed:
- 40 N opening and closing force after conditioning as described in B3.1.1 a.;
 - 60 N opening and closing force after conditioning as described in B3.1.1 d.; and
 - 175 N opening and closing force after conditioning as described in B3.1.1 b. and c.

B3.2 Point Breaking Strength Test

- B3.2.1 On completion of the opening and closing tests under B3.1.1 subject all samples to this test as follows:
- at the top
 - at the bottom end
 - at the centre (at the point of folding as described in B3.1.1 d).
- B3.2.2 Test the point breaking strength as described in UL 1191.
- B3.2.3 The point breaking strength shall not be less than 440 N (averaged results).

B3.3 **Diagonal Pull Test**

B3.3.1 Three samples of the 750 mm long zippers are required for this test as follows:

- a. one sample in the as-received condition
- b. one sample after conditioning as described under B3.1.1 b. and
- c. one sample after conditioning as described under B3.1.1 c.

B3.3.2 Open and mount the sample securely onto a hard flat surface such as a woodboard, as follows:

- a. one of each sample as in B3.3.1 a., b. and c., secured with the left side of the zipper secured.
- b. one of each sample as in B3.3.1 a., b. and c., secured with the right side of the zipper secured.

B3.3.3 Close the zippers as follows:

- a. Close zippers secured on the left side by pulling the slider at an angle of approximately 25° to the right of the line of the zipper (Figure B 1 a.)
- b. Close zippers secured on their right side by pulling the slider angle of approximately 25° to the left to the line of the zipper (Figure B1 b.).

B3.3.4 When closed, the unsecured part of the zipper shall be pulled at an angle of 90° to the line of the zipper away from the secured part with a force of not less than 45 N (Figure B2).

B3.3.5 The zipper points shall not pull free.

Note: The procedures described in B3.3.2 a. and b. and B3.3.3 a. and b. apply to asymmetrical zippers only. Symmetrical zippers shall be tested on either the left or the right side.

B3.4 **Leakage Resistance Test**

B3.4.1 Test the cylindrical samples of zippers as prepared in B2.2 as follows:

- a. Place a wire mesh fixture 300 mm in length and 125 mm in diameter inside the sample and close the zipper fully.
- b. Place the sample in a water tank with the closed end of the sample down to a depth sufficient to submerge 90% of the zipper's effective length (the portion measured from the top of the bottom stop to the bottom of the slide when the slide is in the fully closed position).
- c. Remove the sample from the water and blot the inside with the pre-weighed blotting paper to absorb any water which has ingressed in excess of 20 g.

Note: The acceptable value will be established based on the volume of the sample compared to the volume of a typical adult "Universal" size suit system.

B3.4.2 Following the water leak test, allow the sample to dry and then place it in No. 2 Marine diesel oil at a depth as prescribed in B3.4.1 b. for a period of 24 h.

B3.4.3 Remove the sample, blot it dry and resubject it to the water leak test as described in B3.4.1.

B3.4.4 The zipper will be considered acceptable if the amount of water which has ingressed is minimal, and there is no sign of degradation as a result of its exposure to the diesel oil.

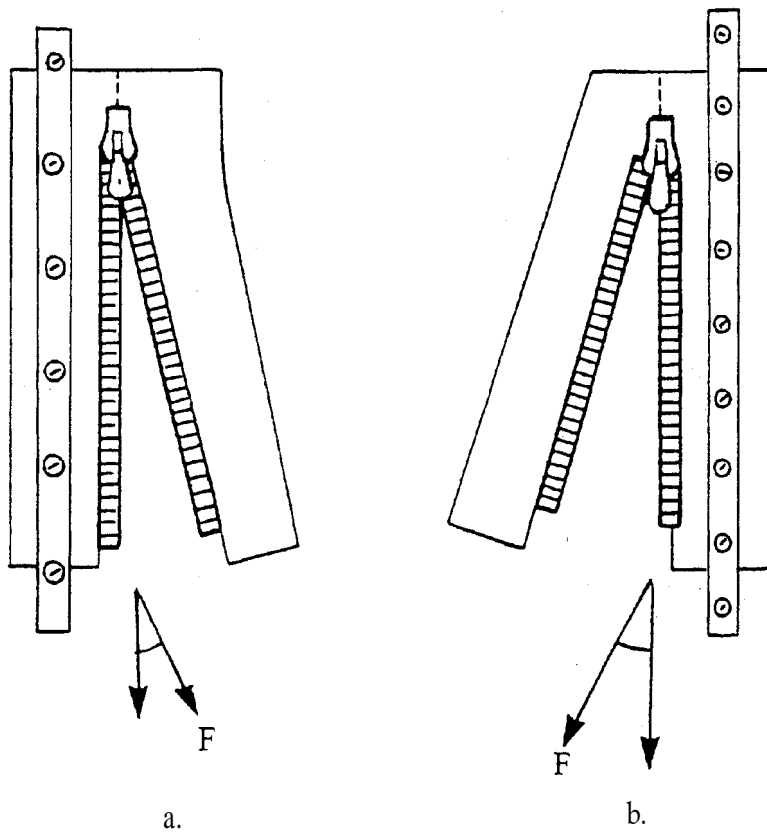


FIGURE B1

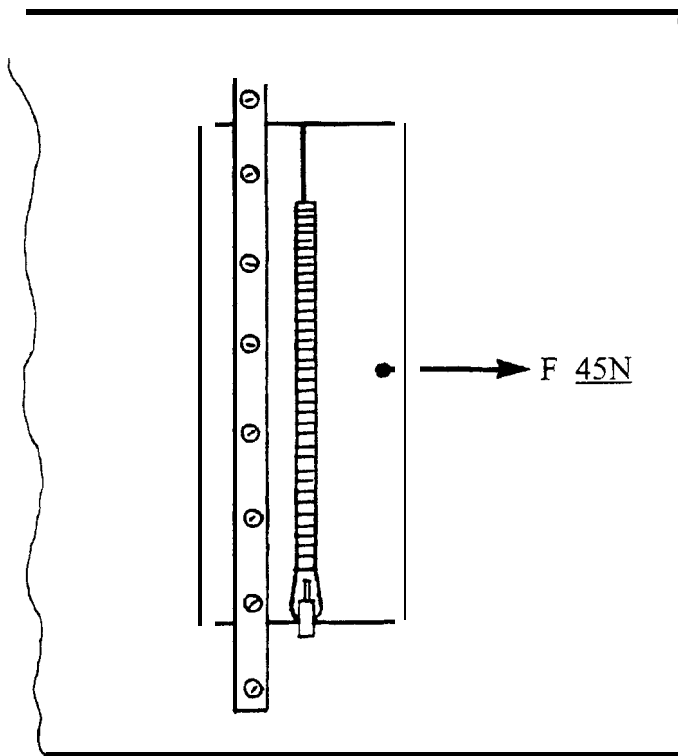


FIGURE B2