SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS1435 REV. B

Issued 1995-04
Revised 2010-09

Superseding AMS1435A

(R) Fluid, Generic, Deicing/Anti-Icing Runways and Taxiways

RATIONALE

This specification covers deicing and anti-icing materials in the form of a fluid. In addition, runway and taxiway deicing/anti-icing compounds have abeen found to catalytically oxidize aircraft carbon brakes to varying extents. There is a need for users to understand the effect of these compounds on carbon brakes. This specification requires testing and reporting of such.

1. SCOPE

1.1 Form

This specification covers deicing and anti-icing materials in the form of a fluid.

1.2 Application

This deicing/anti-icing fluid has been used typically on runways, taxiways, and other aircraft maneuvering areas for the prevention and removal of frozen deposits of frost and ice. Fluids must not be used to deice/anti-ice aircraft.

1.3 Precautions

1.3.1 Material Compatibilities

While this specification covers technical requirements for fluid deicing/anti-icing materials, it does not address the compatibility issue of combining deicers/anti-icers during the operational phase. Fluids meeting this specification are unique to each manufacturer and may be adversely affected by mixing with other deicing/anti-icing fluids. It is the user's responsibility to become familiar with the safe and proper use of applying multiple deicers/anti-icers.

1.3.2 Pavement Friction Evaluation

Airport authorities should ascertain the friction coefficient of the runway after the application of deicing/anti-icing fluid prior to aircraft landing operations.

1.3.3 Caution should be exercised in the use of glycol-water deicing/anti-icing solutions in and around aircraft electrical/electronic circuitry with noble metal coated wiring or terminals which could come into contact with the fluid. Exothermic reactions, which may result in fire, have been reported. This may occur where defectively insulated wires, switches, or circuit breakers carrying direct current are encountered. Deicing/anti-icing fluids based on glycols should contain an inhibitor to minimize this potential fire hazard (3.1).

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

1.3.4 Airport authorities are advised that fluid products can cause failure of runway and taxiway lighting circuits. Damage potential depends on the condition of these systems, quantity of product usage, or the opportunity of product entry into electrical conduit systems. A comprehensive evaluation of the aeronautical lighting systems should be completed as part of winter operations planning.

1.4 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

1.4.1 Some deicing/anti-icing formulations may be mildly toxic and contact with human skin and eyes should be avoided. Prolonged exposure to concentrations of vapor and windborne mists should be avoided. Prolonged exposure to concentrations exceeding any established threshold limit values (TLV) for those products or its major components should be avoided.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS2470 Anodic Treatment of Aluminum Alloys, Chromic Acid Process

AMS2475 Protective Treatments, Magnesium Alloys

AMS2825 Material Safety Data Sheets

AMS4037 Aluminum Alloy, Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn, (2024, -T3 Flat Sheet, -T351 Plate), Solution Heat Treated

AMS4041 Aluminum Alloy, Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn, Alclad 2024 and 1-1/2% Alclad 2024, -T3 Flat Sheet; 1-1/2% Alclad 2024-T351 Plate

AMS4049 Aluminum Alloy, Sheet and Plate, Alclad, 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr, (Alclad 7075; -T6 Sheet -T651 Plate), Solution and Precipitation Heat Treated

AMS4376 Plate, Magnesium Alloy, 3.0Al - 1.0Zn – 0.20Mn (AZ31B-H26), Cold Rolled and Partially Annealed

AMS4911 Titanium Alloy, Sheet, Strip, and Plate, 6Al - 4V, Annealed

AMS5045 Steel, Sheet and Strip, 0.25 Carbon, Maximum, Hard Temper

AIR5567 Test Method for Catalytic Carbon Brake Disk Oxidation

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM C 672 Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

ASTM D 56 Flash Point by Tag Closed Tester

ASTM D 93 Flash Point by Pensky-Martens Closed Tester

ASTM D 891 Specific Gravity, Apparent, of Liquid Industrial Chemicals

ASTM D 1177 Freezing Point of Aqueous Engine Coolants

ASTM D 1193 Reagent Water

ASTM D 1568 Sampling and Chemical Analysis of Alkylbenzene Sulfonates

ASTM D 4057 Manual Sampling of Petroleum and Petroleum Products

ASTM D 4177 Automatic Sampling of Petroleum and Petroleum Products

ASTM E 70 pH of Aqueous Solutions with the Glass Electrode

ASTM F 483 Total Immersion Corrosion Test for Aircraft Maintenance Chemicals

ASTM F 484 Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds

ASTM F 485 Effects of Cleaners on Unpainted Aircraft Surfaces

ASTM F 502 Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces

ASTM F 519 Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals

ASTM F 945 Stress Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials

ASTM F 1105 Preparing Aircraft Cleaning Compounds, Liquid Type, Solvent Based, for Storage Stability Testing

ASTM F 1110 Sandwich Corrosion Test

ASTM F 1111 Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemicals

2.3 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-PRF-25690 Plastic, Sheets and Formed Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant

MIL-P-83310 Plastic Sheet, Polycarbonate, Transparent

MIL-STD-290 Packaging of Petroleum and Related Products

2.4 APHA Publications

Available from American Public Health Association, 800 I Street, NW, Washington, DC 20001-3710, Tel: 202-777-APHA, www.apha.org.

Standard Methods for the Examination of Water and Waste Water

2.5 EPA Methods 40 Code of Federal Regulations (CFR) Part 797.1300 and 797.1400

2.6 Organization for Economic Cooperation and Development

OECD Guidelines for Testing of Chemicals Methods 202 and 203

2.7 LFV Test Method Publications

Available from Swedish Civil Aviation Administration, LFV Teknik, Box 53, SE-190 45 Stockholm-Arlanda, Sweden.

3. TECHNICAL REQUIREMENTS

3.1 Material

The composition of the fluid shall be optional with the manufacturer. The fluid may contain additives, such as corrosion inhibitors, urea, formamide, etc., as required to produce a product meeting the requirements of this specification.

3.1.1 Environmental Information

The manufacturer of the fluid shall provide not less than the following information:

3.1.1.1 Biodegradability

Fluid shall be tested in accordance with APHA Standard Methods for Examination of Water and Waste Water. The manufacturer shall provide results of bioassays which shall contain not less than the following information:

3.1.1.1.1 The percent of fluid biodegraded in 5 days at 68 °F (20 °C).

3.1.1.1.2 The 5-day total oxygen demand (TOD) of the fluid based on theoretical oxygen demand (ThOD), whether calculated computationally or via measured chemical oxygen demand (COD), expressed in kilograms of oxygen per kilograms of fluid.

3.1.1.2 Ecological Behavior

A statement of the ecological behavior of the fluid, which shall include aquatic toxicity for the total formulation. The aquatic toxicity data shall be determined in accordance with EPA Methods 40 Code of Federal Regulations (CFR) Part 797.1300 and 797.1400 or OECD Guidelines for Testing of Chemicals (Organization for Economic Cooperation and Development, Methods 202 and 203, updated 1989) using test species required by regulatory agencies for permitted discharges. The LC50 concentration, the highest concentration at which 50% of the test species survive, shall be given in milligrams per liter.

3.1.1.3 Trace Contaminants

Report the presence, in percentage by weight, of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, and mercury).

3.1.2 Appearance

Fluid, as received by purchaser, shall be homogeneous, uniform in color, and free from skins, lumps, and foreign materials detrimental to usage of the product. If fluid is colored, it shall be blue.

3.2 Physical Properties

The fluid, as supplied by vendor, shall conform to the following requirements: tests shall be performed in accordance with specified tests on the product in concentrated form as delivered by vendor, unless otherwise specified herein:

3.2.1 Flash Point

Shall be reported and shall be not lower than 212 °F (100 °C), determined in accordance with ASTM D 56 or ASTM D 93. In case of dispute, flash point determined in accordance with ASTM D 56 shall apply.

3.2.2 Specific Gravity

Shall be reported and shall be within ±0.015 of the preproduction value established in 4.2.3, determined in accordance with ASTM D 891.

3.2.3 pH

Shall be 7.0 to 11.5 and within ±0.5 of the preproduction value established in 4.2.3, determined in accordance with ASTM E 70.

3.2.4 Freezing Point

3.2.4.1 Freezing point of fluid diluted 1:1 by weight with ASTM D 1193 Type IV water shall be reported and shall be lower than +6 °F (-14.5 °C) determined in accordance with ASTM D 1177.

3.2.4.2 Shall be reported and shall be within 7 °F (4 °C) of the preproduction value established in 4.2.3, determined in accordance with ASTM D 1177.

3.2.5 Effect on Aircraft Metals

3.2.5.1 Sandwich Corrosion

Specimens, after testing in accordance with ASTM F 1110, shall not show corrosion worse than control panels run using ASTM D 1193, Type IV, water.

3.2.5.2 Total Immersion Corrosion

The fluid, tested in accordance with ASTM F 483 except that panels of AMS4376 shall be tested for 24 hours, shall neither show evidence of corrosion of panels nor cause a weight change of any test panel greater than shown in Table 1.

TABLE 1 - TOTAL IMMERSION CORROSION

Test Panel	Weight Change mg/cm^2 per 24 hours
AMS4037 Aluminum Alloy, anodized as in AMS2470	0.3
AMS4041 Aluminum Alloy	0.3
AMS4049 Aluminum Alloy	0.3
AMS4376 Magnesium Alloy, dichromate treated as in AMS2475	0.2
AMS4911 Titanium Alloy	0.1
AMS5045 Carbon Steel	0.8

3.2.5.3 Low-Embrittling Cadmium Plate

Test panels, coated with low-embrittling cadmium plate, shall not show a weight change greater than 0.3 mg/cm^2 per 24 hours, determined in accordance with ASTM F 1111.

3.2.5.4 Hydrogen Embrittlement

The fluid shall be nonembrittling, determined in accordance with ASTM F 519, Type 1a, 1c, or 2a.

3.2.5.5 Stress-Corrosion Resistance

The fluid shall not cause cracks in AMS4911 titanium alloy specimens, determined in accordance with ASTM F 945, Method A.

3.2.5.5.1 The fluid shall be tested in accordance with ASTM F 945, Method A using AMS4916 specimens. Report shall detail the effect of the fluid and the effect of control solution. The results shall be reported for informational purposes only.

3.2.6 Effect on Transparent Plastics

3.2.6.1 The fluid, at 77 °F ± 4 (25 °C ± 2), shall not craze, stain, or discolor MIL-PRF-25690 stretched acrylic plastic, determined in accordance with ASTM F 484.

3.2.6.2 The fluid, at 77 °F ± 4 (25 °C ± 2), shall not craze, stain, or discolor MIL-P-83310 polycarbonate plastic, determined in accordance with ASTM F 484, except that the specimens shall be stressed for 30 minutes ± 2 to an outer fiber stress of 2000 psi (13.8 MPa).

3.2.7 Effect on Painted Surfaces

The fluid, at 77 °F ± 4 (25 °C ± 2), shall neither decrease the paint film hardness by more than 2 pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F 502.

3.2.8 Effect on Unpainted Surfaces

The fluid, tested in accordance with ASTM F 485, shall neither produce streaking nor leave any stains requiring polishing to remove.

3.2.9 Rinsibility

The fluid shall be completely rinsible in tap water, determined in accordance with 3.2.9.1.

3.2.9.1 A 3 x 8 inch (75 x 200 mm) panel of clear glass shall be cleaned to provide a surface free of waterbreak, dried, and coated with the deicer/anti-icer fluid by pouring the fluid over the panel while it is held in a horizontal position. The coated panel shall be inclined at an angle of approximately 45 degrees for 10 minutes ± 0.5, then placed in a horizontal position for 24 hours ± 0.25 at room temperature. After the 24 hour exposure, the panel shall be rinsed in tap water for 5 to 6 minutes, followed by a rinse with ASTM D 1193, Type IV, water, allowed to air dry at ambient temperature, and examined for visible traces of the deicer/anti-icer fluid.

3.2.10 Effect on Runway Pavements

3.2.10.1 Runway Concrete Surface Scaling Resistance

The condition of the runway concrete surface shall have a rating not greater than 1 for 50 freeze-thaw cycles, determined in accordance with ASTM C 672 except that concrete shall:

a. Be air-entrained with an air content as specified in ASTM C 672

b. Have a minimum cement content of 510 pounds per cubic yard ± 10 (302 kg/m^3 ± 6)

c. Have a slump, 1.5 inches ± 0.5 (38 mm ± 13)

A 25% by volume solution of the deicer/anti-icer fluid, as supplied by the manufacturer in commercial concentration, in tap water shall be substituted for calcium chloride. Performing more than one freeze-thaw cycle per day is acceptable.

3.2.10.2 Asphalt Concrete Degradation Resistance (Appendix A, valid for deicer/anti-icer products used in Europe)

The fluid shall be tested in accordance with LFV Method 2-98 (See Appendix A). The reduction in adhesion value of the runway asphalt concrete surface shall not be more than 50% of the adhesion value of the specimens not stored in deicing diluted compound. Adhesion values shall be determined and documented. The following test parameters shall be used:

1. Marshall test specimens with paving grade bitumen 160/220 (penetration value at 77 °F (25 °C) of 180 mm^{-1} ± 10 and softening point 102 °F ± 1 (39 °C ± 1)) shall be used,

2. Binder content 5.7% by mass,

3. Maximum aggregate size 0.625 inch (16 mm), and distribution as shown in Figure 1 below:

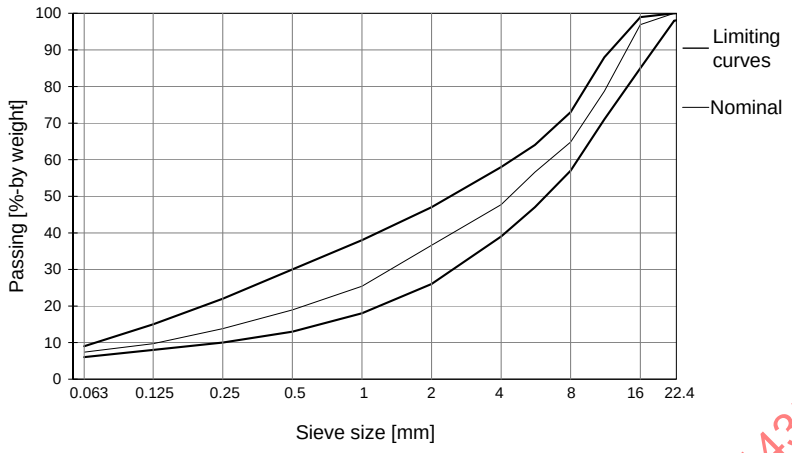

FIGURE 1 - AGGREGATE SIZE DISTRIBUTION

4. The aggregate used shall be characterized regarding variety of stone, origin and petrographical analysis. The aggregate shall be of good mechanical stability,

5. Air voids 7% ± 1 by volume,

6. Specimens are sawed to approximately 1.125 inch (30 mm) thickness.

3.2.11 Storage Stability

The fluid, after storage in accordance with ASTM F 1105, shall not exhibit separation or an increase in turbidity compared to unaged fluid. Any increase in turbidity shall be reported, but shall be acceptable if removed by mild agitation.

3.2.12 Performance

The fluid, used in accordance with manufacturer's recommendation, shall remove accumulated frozen deposits of frost and ice from airport taxiways and runways. Acceptance criteria and method of test shall be agreed upon by purchaser and vendor.

3.2.13 Effect on Carbon-Brake Systems

The fluid shall be tested for catalytic oxidation of carbon in accordance with AIR5567 and the results shall be reported as shown in 4.2 of AIR5567. The results shall be reported for informational purposes only.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The vendor of fluid shall supply all samples for conformance testing and shall be responsible for obtaining independent laboratory confirmation of conformance to the requirements of this specification. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the fluid conforms to the requirements of this specification.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Flash point (3.2.1), specific gravity (3.2.2), and pH (3.2.3) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests

Freezing point (3.2.4), effect on aircraft metals (3.2.5), effect on transparent plastic (3.2.6), effect on painted surfaces (3.2.7), effect on unpainted surfaces (3.2.8), rinsibility (3.2.9), runway concrete surface scaling resistance (3.2.10.1), and asphalt concrete degradation resistance (3.2.10.2, Appendix A, valid for deicer/anti-icer products used in Europe) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser, but in no case less than once every 2 years.

4.2.3 Preproduction Tests

All technical requirements are preproduction tests and shall be performed prior to or on the initial shipment of fluid to a purchaser, when a change in ingredients and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.3 Sampling and Testing

Shall be in accordance with all applicable requirements of 4.3.1 or 4.3.2; a lot shall be all fluid produced in one continuous manufacturing process from the same batches of raw materials and presented for vendor's inspection at one time:

4.3.1 Drum Shipments

In accordance with ASTM D 1568.

4.3.2 Bulk Shipments

In accordance with ASTM D 4057 or ASTM D 4177.

4.4 Approval

4.4.1 Sample fluid shall be approved by purchaser before fluid for production use is supplied, unless such approval be waived by purchaser. Results of tests on production fluid shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing procedures, and methods of inspection on production fluid which are essentially the same as those used on the approved sample. If necessary to make any change in ingredients or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in ingredients and/or manufacturing procedures and, when requested, sample fluid. Production fluid made by the revised procedure shall not be shipped prior to receipt of reapproval.

4.4.3 Whenever a fluid is to be produced by a licensee or subcontractor, all testing shall be required on fluid produced at the site, prior to initial shipment, as if the fluid were being initially qualified.

4.5 Reports

The vendor of fluid shall furnish with each shipment a report showing the results of tests to determine conformance to all technical requirements. These tests shall be carried out by an independent facility. This report shall include the manufacturer's product identification, lot number, AMS1435B, purchase order number, and quantity.

4.5.1 A material safety data sheet conforming to AMS2825, or equivalent, shall be supplied to each purchaser prior to or concurrent with the report of preproduction test results or, if the preproduction test be waived by purchaser, concurrent with the first shipment of fluid for production use. Each request for modification of the fluid formulation, or change in the reportable status of any of the raw materials used, shall be accompanied by a revised material safety data sheet.

4.6 Resampling and Retesting

If any sample used in the above tests fails to meet the specified requirements, disposition of the fluid may be based on the results of testing three additional samples for each original nonconforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the fluid represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY

5.1 Packaging and Identification

5.1.1 The fluid shall be packaged in containers of a type and size agreed upon by purchaser and vendor or shall be delivered in bulk.

5.1.2 Each container of fluid, except for bulk shipments, shall be legibly marked with not less than AMS1435B, manufacturer's identification, lot number, purchase order number, and quantity.

5.1.3 Labeling requirements shall meet all federal, state, and local laws. In the United States of America there are states whose Right to Know Regulations relate to labeling. Product manufactured, stored, or used in those states is subject to those regulations.

5.1.4 Containers of fluid shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, labeling, and transportation of the fluid to ensure carrier acceptance and safe delivery.

5.1.5 Packaging shall be in accordance with MIL-STD-290, Level C, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Fluid not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary: dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.3 Terms used in AMS are clarified in ARP1917.

8.4 Purchase documents should specify not less than the following:

AMS1435B
Size and type of containers desired
Quantity of fluid desired
Method of test and acceptance criteria for performance (See 3.2.12)
Level A packaging, if required (See 5.1.5).

8.5 Fluid meeting the requirements of this specification has been classified under Federal Supply Classification (FSC) 6850.

PREPARED BY AMS COMMITTEE "G-12"

APPENDIX A

This Appendix is valid for deicer/anti-icer products used in Europe. LFV Method 2-98 is a European standard method within CEN (European Committee for Standardization) named EN 12697-41.

LFV METHOD 2-98
EFFECT OF DE-ICING FLUID ON THE SURFACE TENSILE STRENGTH
OF ASPHALT CONCRETE FOR AIRFIELDS
- ADHESION TEST

A.1 INTRODUCTION

The purpose of the test is to determine the effect of storage in de-icing fluid on the surface tensile strength of asphalt concrete. The surface strength is the force in N/mm² required for failure to occur in the upper surface of the asphalt concrete under perpendicular ”pull off” tension with an increase in tensile force of 200 N/s.

The test is performed largely in the same way as the method used for testing the adhesion of road markings to a road pavement and/or the adhesion of bridge deck waterproofing to an underlying concrete or steel surface.

A.2 TEST METHODS

A.2.1 Principle

Testing shall be performed on a sawn cylindrical test specimen on which a well-defined test surface has been carefully drilled out in the asphalt concrete to a depth of about 5 mm. A steel plate shall be bonded to the test surface. The specimen with test plate shall then be stored in de-icing fluid. During testing, the plate is pulled off with an increase in tensile force of 200 N/s, the force being applied perpendicularly to the test surface. The surface strength upon failure and the type of failure shall be recorded.

The results are compared with those for specimens which have not been stored in de-icing fluid.

A.2.2 Apparatus and Materials

a. Vessel with tight-fitting lid for storing specimens in de-icing fluid.

b. Vacuum exsiccator.

c. Vacuum pump for evacuation of the exsiccator. The pump shall be capable of achieving a pressure of 6.7 kPa within 10 minutes and maintaining this pressure (within ±0.3 kPa) throughout the vacuum treatment.

d. Manometer for measuring absolute pressure in the exsiccator.

e. Approved equipment for laboratory mixing of bituminous asphalt mixture.

f. Approved equipment for compaction of Marshall specimens or other approved laboratory compaction equipment such as gyratory compaction machine, roller or vibrating hammer.

g. Circular steel plates with a diameter of 50 mm and a tolerance of 0.5 mm. The steel plate shall be attached by suitable means (e.g., screwed) to the tensile test machine. Minimum thickness of steel plate shall be 10 mm from bottom of steel plate to bottom of screw hole.

h. Suitable adhesive (e.g., two part epoxy resin) for bonding the steel plates to the test specimen.

i. Base and holder for fixing the specimen prior to testing (See Figure A1).