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**STANDARD FOR EXTERNAL CORROSION PROTECTION
SYSTEMS FOR STEEL UNDERGROUND TANKS FOR
FLAMMABLE AND COMBUSTIBLE LIQUIDS**

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CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE

STANDARD FOR EXTERNAL CORROSION PROTECTION SYSTEMS
FOR STEEL UNDERGROUND TANKS FOR FLAMMABLE AND
COMBUSTIBLE LIQUIDS

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TABLE OF CONTENTS

ULC STANDARDS COMMITTEE ON STATIONARY STEEL STORAGE CONTAINERS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS	I
ULC STANDARDS TASK GROUP ON EXTERNAL CORROSION PROTECTION SYSTEMS	II
PREFACE	III
1 SCOPE	1
2 REFERENCE PUBLICATIONS	1
3 GLOSSARY	4
4 PERFORMANCE – TANK ASSEMBLY	5
4.1 GENERAL	5
4.2 TANK TORQUE TEST	5
4.3 BENDING MOMENT TEST	6
4.4 STRENGTH OF LIFT FITTINGS TEST	6
5 CATHODICALLY PROTECTED TANK	6
5.1 CONSTRUCTION	6
5.1.1 General	6
5.1.2 Electrical Isolation	6
5.1.3 Isolating Bushings	7
5.1.3.1 General	7
5.1.3.2 Materials	7
5.1.3.3 Dimensions	7
5.1.3.4 Leakage Test	8
5.1.3.5 Supplementary Equipment	8
5.1.3.6 Marking of Isolating Bushings	8
5.1.4 Tank Monitoring Connection	8
5.1.5 External Tank Attachments	9
5.1.6 Application of Cathodic Protection	9
5.1.6.1 General	9
5.1.6.2 Anodes	9
5.1.6.2.1 General	9
5.1.6.2.2 Materials	10
5.1.6.2.3 Cores	10
5.1.6.2.4 Lead Wires for High Potential Magnesium Anodes	10
5.1.6.2.5 Dimensions	10
5.1.6.2.5.1 Weld On Zinc and H1, Grade A or Grade B Standard Potential Magnesium Anodes	10
5.1.6.2.6 Packaging	10
5.1.6.2.6.1 Weld On Zinc and H1, Grade A or Grade B, Standard Potential Magnesium Anodes	10
5.1.6.2.6.2 High Potential Magnesium Anodes	11
5.1.6.2.6.3 Chemical Backfill Mixture	11
5.1.6.2.7 Plastic Anode Sleeve	11

5.1.6.2.8 Marking of Anodes	11
5.1.6.2.9 Mounting of Factory Attached Packaged Anodes	11
5.1.6.3 Thin Film Dielectric Coating	12
5.1.6.3.1 General	12
5.1.6.3.2 Blast Cleaning	12
5.1.6.3.3 Thin Film Dielectric Coating Application	12
5.2 PERFORMANCE TESTS	12
5.2.1 General	12
5.2.2 Impact Test Following Exposure	12
5.2.3 Resistance To External Fluids Test	13
5.2.4 Flexibility Test	13
5.2.5 Abrasion Resistance Test	14
5.2.6 Cathodic Disbondment Test	14
5.2.7 Holiday Test	14
5.3 CATHODICALLY PROTECTED TANK ASSEMBLY TESTS	14
5.3.1 Leakage Test	14
5.4 MARKING	14
6 COMPOSITE TANKS (CLAD)	15
6.1 CONSTRUCTION	15
6.1.1 Blast Cleaning	15
6.1.2 Cladding Application	15
6.1.3 Optional Protection	15
6.2 PERFORMANCE TESTS	16
6.2.1 General	16
6.2.2 Air-Oven Aging Test	16
6.2.3 Resistance to Aromatic Fuels Test	16
6.2.4 Resistance To External Fluids Test	16
6.2.5 Light and Water Exposure Test	17
6.2.6 Impact Test Following Cold Exposure	17
6.2.7 Corrosion and Permeation Dissolution Evaluation Tests	17
6.2.7.1 General	17
6.2.7.2 Corrosion Evaluation Test	17
6.2.7.3 Permeation Dissolution Evaluation Test	18
6.3 COMPOSITE TANK ASSEMBLY TESTS	18
6.3.1 Impact Test	18
6.3.2 Leakage Test	18
6.3.3 Holiday Test	19
6.4 MARKING	19
7 JACKETED TANKS	19
7.1 CONSTRUCTION	19
7.1.1 General	19
7.2 PERFORMANCE TESTS	19
7.2.1 General	19
7.2.2 Air-Oven Aging Test	19
7.2.3 Resistance to External and Internal Fluids Test	20
7.2.4 Light and Water Exposure Test	20
7.2.5 Impact Test Following Exposure	21
7.2.6 Corrosion and Permeation Dissolution Evaluation Tests	21
7.2.6.1 General	21

7.2.6.2 Corrosion Evaluation Test	21
7.2.6.3 Permeation Dissolution Evaluation Test	21
7.3 JACKETED TANK ASSEMBLY TESTS	22
7.3.1 Impact Test	22
7.3.2 Leakage Test	22
7.3.3 Holiday Test	22
7.3.4 Interstitial Proof-Pressure Test	22
7.3.5 Interstitial Communication Test	23
7.4 PRODUCTION TEST	23
7.5 MARKING	23
7.6 SHIPPING	24
8 COATED TANKS	24
8.1 CONSTRUCTION	24
8.1.1 General	24
8.1.2 Blast Cleaning	24
8.1.3 Coating Application	24
8.1.4 Optional Protection	25
8.2 PERFORMANCE TESTS	25
8.2.1 General	25
8.2.2 Air-Oven Aging Test	25
8.2.3 Resistance to Aromatic Fuels Test	25
8.2.4 Resistance To External Fluids Test	26
8.2.5 Light and Water Exposure Test	26
8.2.6 Impact Test Following Exposure	26
8.2.7 Corrosion and Permeation Dissolution Evaluation Tests	27
8.2.7.1 General	27
8.2.7.2 Corrosion Evaluation Tests	27
8.2.7.3 Permeation Dissolution Evaluation Test	27
8.2.8 Penetration Test	27
8.2.9 Abrasion Resistance Test	28
8.3 COATED TANK ASSEMBLY TESTS	28
8.3.1 Impact Test	28
8.3.2 Leakage Test	28
8.3.3 Holiday Test	28
8.4 MARKING	29

9 INSTALLATION INSTRUCTIONS	29
TABLES	30
FIGURES	38
APPENDIX A (INFORMATIVE) – INSTALLATION	55
APPENDIX B (INFORMATIVE) – METHODS FOR MONITORING CATHODICALLY PROTECTED TANKS	64
APPENDIX C (INFORMATIVE) – RECOMMENDED PRACTICE FOR THE INSTALLATION OF NYLON BUSHINGS	80
APPENDIX D (INFORMATIVE) – ANODE DESIGN CRITERIA	81
APPENDIX E (INFORMATIVE) – WELDING SYMBOLS	82

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STANDARD FOR EXTERNAL CORROSION PROTECTION SYSTEMS FOR STEEL UNDERGROUND TANKS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS

PREFACE

This is the Fifth Edition of the Standard for External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids, CAN/ULC-S603.1.

This Standard is a companion document to CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids.

This Edition of the Standard was developed by the ULC Standards Task Group on External Corrosion Protection Systems and has been formally approved by the ULC Standards Committee on Stationary Steel Storage Containers for Flammable and Combustible Liquids.

This Standard has been developed in compliance with the requirements of SCC for accreditation of a Standards Development Organization.

Only metric SI units of measurement are used in this Standard. If a value for measurement is followed by a value in other units in parentheses, the second value may be approximate. The first stated value is the requirement.

Appendices A, B, C, D, and E, identified as informative, are for guidance and information purposes only.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

This Fifth Edition National Standard of Canada consolidates the requirements of, and supersedes, the Fourth Edition of CAN/ULC-S603.1, Standard for External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids, the Fourth Edition of ULC-S618, Standard for Anodes and Reference Electrodes for Cathodic Protection of Steel Underground Tanks, and the Second Edition of ULC-S631, Standard for Isolating Bushings for Steel Underground Tanks Protected with External Corrosion Protection Systems.

Attention is drawn to the possibility that some of the elements of this Canadian standard may be the subject of patent rights. ULC Standards shall not be held responsible for identifying any or all such patent rights.

Requests for interpretation of this Standard should be sent to ULC Standards. The requests should be worded in such a manner as to permit a “yes” or “no” answer based on the literal text of the requirement concerned.

The review and action to revise or reaffirm this Standard will not exceed 5 years from the date of publication, unless the Standard is identified as fitting within a stabilized category, whereby the review will commence within the appropriate time frame set out by ULC Standards.

This Standard is intended to be used for conformity assessment.

1 SCOPE

1.1 This Standard covers requirements for external *corrosion protection systems* on steel non-pressure tanks that are used for the underground storage of *flammable liquids* and *combustible liquids*. The requirements are structured as follows:

- A Section 5, Cathodically Protected Tanks, covers external *corrosion protection* using sacrificial magnesium and zinc anodes, low profile nylon isolating bushings with internal and external threads and component thread sealant, electrical isolation and thin film dielectric coating (*cathodically protected tank*);

NOTE: Informative material on zinc reference electrodes is included in Appendix B, Methods For Monitoring Cathodically Protected Tanks.

- B Section 6, Composite Tanks (Clad), covers external *corrosion protection* using dielectric fibre reinforced plastics or resins that are bonded to the tank (*composite tank — clad*);
- C Section 7, Jacketed Tanks, covers external *corrosion protection* and *secondary containment* using dielectric *jackets* (*jacketed tanks*); and

NOTE: *Jacketed tanks* as described in this Standard are also considered to be double walled.

- D Section 8, Coated Tanks, covers external *corrosion protection* using polyurethane (*coated tanks*).

1.1.1 These external *corrosion protection systems* are intended to be installed, operated and maintained in accordance with the manufacturer's instructions.

1.2 These requirements cover external *corrosion protection systems* for steel tanks manufactured in accordance with the applicable requirements of CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids, which are used for the underground storage of *flammable liquids* and *combustible liquids* that are compatible with the materials of construction.

1.3 This Standard does not cover requirements for the installation, maintenance and use of the tank. Tanks covered by these requirements are intended for installation and use in accordance with the *authority having jurisdiction* and other documents including but not limited to:

- A CCME PN 1326 Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products;
- B The National Fire Code of Canada; and
- C CSA B139, Installation Code for Oil-burning Equipment.

2 REFERENCE PUBLICATIONS

2.1 The documents shown below are referenced in the text of this Standard. Unless otherwise stated elsewhere in this Standard, such reference shall be considered to indicate the edition and/or revisions of the document available at the date on which the Committee approved this ULC Standard.

Document Published by the American Society of Mechanical Engineers (ASME)
3 Park Avenue, New York, NY 10016-5990 U.S.A.
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- ASME B1.20.1-2013, Pipe Threads, General Purpose (Inch)
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- ASTM B418-2012, Standard Specification for Cast and Wrought Galvanic Zinc Anodes
 - ASTM B843-2013, Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
 - ASTM D256-10 (E2015), Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
 - ANSI/ASTM D396-15 Rev C, Standard Specification for Fuel Oils
 - ASTM D448-12, Standard Classification for Sizes of Aggregate for Road and Bridge Construction
 - ASTM D471-15, Standard Test Method for Rubber Property – Effect of Liquids
 - ASTM D638-14, Standard Test Method for Tensile Properties of Plastics
 - ASTM D790-10, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
 - ASTM D1193-06, Standard Specification for Reagent Water
 - ASTM D1822-06 (R2011), Standard Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
 - ASTM D3164-03 (R2011), Standard Test Method for Strength Properties of Adhesively Bonded Plastic Lap-Shear Sandwich Joints in Shear by Tension Loading
 - ASTM E154/E154M-08 Rev A (R2013) (E2013), Standard Test Methods for Water Vapour Retarders Used in Contact with Earth Under Concrete Slabs, On Walls, or as Ground Cover
 - ASTM G8-96 (R2010), Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
 - ASTM G13/G13M-13, Standard Test Method for Impact Resistance of Pipeline Coatings (Limestone Drop Test)
 - ASTM G152-13, Standard Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
 - ASTM G153-13, Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
-

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- CCME PN 1326-2003 (UPD 2015), Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products
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- CSA B139 Series-15, Installation code for oil-burning equipment
 - CSA C22.2 No. 38-14, Thermoset-insulated wires and cables
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Documents Published by the National Association of Corrosion Engineers (NACE)
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- NACE SP0188-1999 (R2006), Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
 - NACE SP0285-2011, External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
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- National Fire Code of Canada, 2015
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- CAN/ULC-S660-08, Nonmetallic Underground Piping for Flammable and Combustible Liquid
 - CAN/ULC-S603-14, Standard for Steel Underground Tanks for Flammable and Combustible Liquids
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3 GLOSSARY

NOTE: Terms used in this Standard that are in *italic* print are defined as follows:

3.1 *ASTM REFERENCE FUEL C (FUEL C)* — A mixture of 50 % Iso-octane and 50 % Toluene by volume.

3.2 *AUTHORITY HAVING JURISDICTION* — The governmental body responsible for the enforcement of any part of this Standard or the official or agency designated by that body to exercise such a function.

3.3 *BACKFILL* — Material used to fill the excavation around the tanks and piping at an underground storage system site. Native soil removed from the excavation is rarely suitable as *backfill* material. *Backfill* material is generally specified to be pea gravel, crushed stone or sand. Sand is the preferable *backfill* material for a *cathodically protected tank*. The *backfill* material should be free of debris, snow, ice or organic materials.

3.4 *BEDDING* — When *underground tanks* and piping are being installed, industry recommended practices call for a layer of *backfill* to be placed on the bottom of the excavation, as well as on the bottom of pipe trenches. This layer of pea gravel, crushed stone, or sand provides a uniform bed that cushions and supports the bottom of the tank and piping. Sand is the preferable *backfill* material for a *cathodically protected tank*. The *backfill* material should be free of debris, snow, ice or organic materials.

3.5 *CATHODIC (CATHODICALLY) PROTECTED TANK(S)* — Steel tank(s) with a pre-engineered, factory installed, external *corrosion protection system* using:

- A Galvanic anodes to protect exposed metal;
- B Thin film dielectric coating to minimize metal exposed to soil; and
- C Electrical isolation of the tank from all other electrically conductive structures to limit and define the area to be corrosion protected.

3.6 *CLAD, CLADDED, CLADDING* — A dielectric coating using fibreglass-reinforced plastic (FRP) or resin, with a minimum thickness of 2.5 mm, as used on *composite tanks*.

3.7 *COATED TANK(S)* — Steel tank(s) with a non-reinforced external dielectric coating of minimum 1.8 mm thickness intended to protect against external corrosion by preventing contact of the steel substrate with the ambient soil conditions.

3.8 *COMBUSTIBLE LIQUIDS* — Any liquid having a flash point at or above 37.8 °C and below 93.3 °C and as defined by the National Fire Code of Canada.

3.9 *COMPOSITE TANK(S)* — Steel tank(s) externally *cladded* to provide external *corrosion protection* by preventing contact of the steel substrate with the ambient soil conditions.

3.10 *CORROSION PROTECTION SYSTEM(S)* — The corrosion protection technology applied to, but not including, the steel *underground tank*.

3.11 *FLAMMABLE LIQUID(S)* — Any liquid having a flash point below 37.8 °C and having a vapour pressure not exceeding 276 kPa (absolute) at 37.8 °C and as defined by the National Fire Code of Canada.

3.12 *HOLIDAY(S)* — A small fault or pinhole that results in current drainage through the coating material, including the bonded part of a *jacketed tank*.

3.13 **JACKET** — An external secondary encasement of nonmetallic, dielectric thermoset or thermoplastic resin of minimum 2.5 mm thickness wrapped over the steel tank.

3.14 **JACKETED TANK(S)** — Steel tank(s) totally enclosed in a *jacket* providing both *secondary containment* and external *corrosion protection*. The dielectric *jacket* forms an interstitial space, which can be monitored for leakage.

3.15 **KNUCKLE** — The curved portion of a circular piece of steel with a formed flange, when that piece comprises the bottom of a vertical tank or the head of a horizontal tank.

3.16 **MANWAY(S)** — Any opening on a tank designed to provide personnel access to the interior of the tank.

3.17 **PRIMARY TANK(S)** — The product storage tank.

3.18 **REMOTE FILL** — A filling point that is located some distance away and connected to a tank by a pipeline, instead of being positioned directly above the tank.

3.19 **SECONDARY CONTAINMENT / CONTAINMENT** — A structure, external to the *primary tank* designed to contain leakage.

3.20 **TANK ASSEMBLY** — A tank constructed in accordance with CAN/ULC-S603, Standard for Steel Underground Tanks Combustible Liquids for Flammable and Combustible Liquids, including the applied external *corrosion protection system*.

3.21 **UNDERGROUND TANK(S)** — A *tank assembly* that operates at atmospheric pressure and that has all of its storage volume below grade and the *tank assembly* completely surrounded by or in intimate contact with *backfill*.

4 PERFORMANCE – TANK ASSEMBLY

4.1 GENERAL

4.1.1 The tanks to which an external *corrosion protection system* is applied shall be manufactured in accordance with CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids.

4.1.2 A representative *tank assembly* shall meet the requirements of Section 4, Performance - Tank Assembly.

4.1.3 A representative *tank assembly* shall have a *corrosion protection system* that meets the requirements of Section 4, Performance - Tank Assembly.

4.2 TANK TORQUE TEST

4.2.1 Each fitting design shall be subjected to this test as specified in Clauses 4.2.2 and 4.2.3. There shall be no visible damage to the *corrosion protection system* as a result of this test. The *corrosion protection system* of a *composite* or *coated tank* and the bonded part of a *jacketed tank* shall have no *holidays* or leakage and a *cathodically protected tank* and the interstice of a *jacketed tank* shall not leak.

4.2.2 A length of Schedule 40 steel pipe (1.2 m maximum) shall be threaded into a fitting for pipe connection and shall be tightened to the torque specified in Table 1.

4.2.3 Following this test, the *tank assembly* shall be subjected to the *holiday* and leakage test as specified for the applicable *corrosion protection system*.

4.3 BENDING MOMENT TEST

4.3.1 Each fitting design shall be subjected to the test as specified in Clauses 4.3.2 and 4.3.3. There shall be no visible damage to the *corrosion protection system* as a result of this test. The *corrosion protection system* of a *composite* or *coated tank* shall have no *holidays* or leakage and a *cathodically protected* or *jacketed tank* shall not leak.

4.3.2 After removing the nylon bushing, a length of Schedule 40 steel pipe (1.2 m maximum) is to be threaded into the fitting. A force is then to be applied to the top of the pipe. The force is first to be applied parallel to the longitudinal axis of the tank and then transverse to the longitudinal axis of the tank. The applied force is to increase so that the bending moment is increased in increments of 339 N m until either a maximum bending moment of 2712 N m is reached or the Schedule 40 steel pipe bends.

4.3.3 Following this test, the *tank assembly* shall be subjected to the *holiday* and leakage test as specified for the applicable *corrosion protection system*.

4.4 STRENGTH OF LIFT FITTINGS TEST

4.4.1 A fitting intended to be used to lift and move a tank shall be subjected to this test. The fitting shall not crack or split, the threads shall not strip, and no damage to the tank, fitting, or *corrosion protection system* shall occur as a result of this test.

4.4.2 A fitting intended to be used to lift and move a tank shall be subjected to a load equal to twice that imposed by lifting the empty tank for 5 min. When more than one fitting is provided on a tank, the load shall be divided between the fittings in proportion to the loads to which they are subjected by lifting the tank as intended.

4.4.3 Following this test, the *tank assembly* shall be subjected to the *holiday* and leakage test as specified for the applicable *corrosion protection system*.

5 CATHODICALLY PROTECTED TANK

5.1 CONSTRUCTION

5.1.1 General

5.1.1.1 The exterior of each tank shall be protected from corrosion using materials that meet the requirements of Subsection 5.2, Performance Tests.

5.1.1.2 Each *cathodically protected tank* shall meet the applicable requirements of Section 4, Performance – Tank Assembly.

5.1.2 Electrical Isolation

5.1.2.1 Electrical isolation shall be made with isolating bushings, isolating unions, flanged fittings or non-conductive pipe with isolating gaskets and sleeves. (Refer also to Figure A1).

5.1.2.2 All opening sizes for threaded connections, as specified in CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids, shall refer to threaded connections after installation of isolating bushings.

5.1.2.3 Isolating bushings and sealant shall comply with the requirements of Subsection 5.1.3, Isolating Bushings, and shall be installed so that they are leak tight and shall not require removal or further tightening in the field.

NOTE: Refer also to Subsection A9, Electrical Isolation, in Appendix A (Informative) - Installation, and Appendix C (Informative) - Recommended Practice for the Installation of Nylon Bushings.

5.1.3 Isolating Bushings

5.1.3.1 General

5.1.3.1.1 Bushings shall be designed so as to:

- A Ensure that cold flow in the material will assist in attaining a sealed joint;
- B Prevent the possibility of cross threading between the bushing and either the tank fitting or the pipe; and
- C Be capable of attaining a leakproof joint.

NOTE: Moisture absorption by the bushing material is beneficial in attaining an adequate seal.

5.1.3.1.2 Bushings shall show no evidence of leakage when subjected to the test method described in Subsection 5.1.3.4, Leakage Test.

5.1.3.2 Materials

5.1.3.2.1 Bushings shall be manufactured from nylon. The installed bushing shall provide a minimum electrical insulation between the tank and pipe to withstand 500 V d.c. for 1 min at a maximum leakage current of 0.1 mA.

5.1.3.2.2 Bushing materials shall have an average tensile strength of 60 MPa when conditioned for 7 d at 80 % RH at 20 ± 2 °C.

5.1.3.2.3 Component thread sealant shall be of the nonmetallic type, compatible with the bushing material and be resistant to high aromatic fuel such as *Reference Fuel C* as specified in ASTM D471, Standard Test Method for Rubber Property-Effect of Liquids, with 10 % ethanol or 10 % methanol added.

5.1.3.3 Dimensions

5.1.3.3.1 Bushings shall have a maximum internal thread of 114.3 mm and a maximum external thread of 141.3 mm. Thread pitch shall comply with the requirements of ANSI/ASME B1.20.1, Pipe Threads, General Purpose (Inch). The thread taper may be designed to provide additional cold flow to assist in sealing the connection.

5.1.3.3.2 Threads shall be modified at their starting edges to facilitate ease of installation.

5.1.3.3.3 Bushings may have lugs on the lower surface or cavities in the upper surface to facilitate the manufacturing process.

5.1.3.3.4 A bushing with sealant applied shall seal itself with not less than 9 full threads of engagement in a standard threaded steel flange fitting when subjected to a torque of approximately 950 N m.

5.1.3.4 Leakage Test

5.1.3.4.1 Bushings shall be proved tight against leakage when tested as described in Clauses 5.1.3.4.2 through 5.1.3.4.7.

5.1.3.4.2 A sample bushing with sealant applied to the internal and external threads shall be installed in a threaded flange, welded to a test fixture as illustrated in Figure 1. The fixture with the bushing installed shall be partly filled with a fuel mixture as described in Clause 5.1.3.2.3 so as to be in complete contact with the bushing. A cast iron plug shall then be screwed into the bushing to seal the assembly.

5.1.3.4.3 The assembly shall be cycled five times through a sequence consisting of 16 ± 0.5 h at -18 ± 2 °C and 8 ± 0.5 h at 50 ± 2 °C. During the cycling period, the test fixture shall be inverted to ensure the bushing is flooded with the fuel mixture at all times.

5.1.3.4.4 The assembly shall be visually inspected and checked for leakage with soap solution as described in Clauses 5.1.3.4.5 and 5.1.3.4.6 after the -18 ± 2 °C hold period and after the 50 ± 2 °C hold period.

5.1.3.4.5 The test fixture shall be connected to a positive pressure air source and the pressure in the fixture established at 34 kPa.

5.1.3.4.6 The bushing shall be brushed or sprayed with a leak-detection solution over the entire surface and shall be visually inspected for leakage. Formation of sustained bubbles is evidence of leakage.

NOTE: It is recommended that the test assembly be cleaned and purged of all flammable and combustible vapours before the pressure test is performed.

5.1.3.4.7 At the end of the five cycles, the assembly shall be held at -18 ± 2 °C for 16 ± 0.5 h then brought to room temperature and again pressure tested as described in Clauses 5.1.3.4.5 and 5.1.3.4.6.

5.1.3.5 Supplementary Equipment

5.1.3.5.1 Each package of bushings shall be supplied with the following items:

- A An appropriate quantity of compatible sealant; and
- B Instructions showing the recommended installation details for nylon bushings.

NOTE 1 : Refer to Appendix C (Informative), Recommended Practice for the Installation of Nylon Bushings.

NOTE 2 : Where a bushing is installed prior to shipping to the installation site, the installation instructions for the bushing need not be included with the tank assembly.

5.1.3.6 Marking of Isolating Bushings

5.1.3.6.1 Each bushing shall be marked with the name of manufacturer.

NOTE: Manufacturers should be aware that the *authority having jurisdiction* may also require the mark of the certifying agency to be included on each bushing.

5.1.4 Tank Monitoring Connection

5.1.4.1 A wire connector and plate assembly as specified in Clauses 5.1.4.2 and 5.1.4.3 shall be welded as near to the longitudinal top centre point of the tank as practicable, as illustrated in Figure 2.

5.1.4.2 The wire connector shall be comprised of a bronze base with two integral studs and appropriate brass nuts and washers designed to accommodate a minimum 3.66 mm diameter wire (AWG #7). Refer to Figure 3.

5.1.4.3 The plate assembly shall be manufactured from 3 mm thick steel sheet with minimum dimensions shown in Figure 3. The wire connector shall be welded or brazed, as applicable, to the plate at both ends in the locations shown in Figure 3. The plate assembly shall be installed before the tank is blast cleaned and covered with thin film dielectric coating. The connector lugs shall be masked prior to the application of the thin film dielectric coating. The masking material shall be removed by the tank manufacturer prior to shipment.

5.1.4.4 Each tank manufactured to these requirements shall be provided with a means to accommodate a monitoring system.

NOTE: Refer to Appendix B (Informative), Methods for Monitoring Cathodic Protected Tanks.

5.1.5 External Tank Attachments

5.1.5.1 Where external attachments are welded to the tank, the welding shall be continuous.

5.1.6 Application of Cathodic Protection

5.1.6.1 General

5.1.6.1.1 Sacrificial anodes as detailed in Subsection 5.1.6.2, Anodes, shall be factory attached so that no further connections need to be performed in the field.

5.1.6.1.2 In addition to the requirements of Subsections 5.1.2, Electrical Isolation and 5.1.6.3, Thin Film Dielectric Coating, *cathodic protection* requires the dielectric isolation of the tank from all other metallic structures on the installation site. Where metallic anchor straps are provided by the manufacturer, the manufacturer shall also provide dielectric pads for field installation. The pads shall be of one-piece construction, extended a minimum of 300 mm beyond the contact area of the strap and the tank and be constructed of a material that does not deteriorate in contact with the *backfill* material. Dielectric unions shall not be in contact with the *backfill* material.

5.1.6.2 Anodes

5.1.6.2.1 General

5.1.6.2.1.1 *Cathodic protection* shall be provided by weld on protruding core type sacrificial magnesium and zinc anodes as follows:

- A Standard potential magnesium anodes;
- B Zinc anodes;

Sacrificial anodes shall comply with the applicable requirements in Subsections 5.1.6.2.2, Materials, 5.1.6.2.3, Cores, 5.1.6.2.4, Lead Wires for High Potential Magnesium Anodes, 5.1.6.2.5, Dimensions, 5.1.6.2.6, Packaging, 5.1.6.2.7, Plastic Anode Sleeve, and 5.1.6.2.8, Marking.

NOTE: High potential magnesium anodes are intended for field retrofit applications only and shall be sized according to the specifications of the corrosion specialist in charge of the field retrofit application.

5.1.6.2.2 Materials

5.1.6.2.2.1 Magnesium anodes shall be cast or extruded from high or H1, Grade A or Grade B, standard potential magnesium alloys specified in Table 2.

5.1.6.2.2.2 Zinc anodes shall be cast or extruded from zinc alloys specified in Table 3.

NOTE: For the electrochemical properties of zinc and magnesium anodes refer to Appendix D.

5.1.6.2.3 Cores

5.1.6.2.3.1 The cores of weld on zinc and H1, Grade A or Grade B, standard potential magnesium anodes, shall be a hot dipped galvanized mild carbon steel bar conforming to the requirements of Figures 4 and 5, respectively.

5.1.6.2.3.2 The cores of high potential magnesium anodes shall consist of not less than a 3 mm diameter galvanized steel bar located axially in the casting/extrusion and extending the full length of the casting/extrusion. The core shall extend on one end to permit the attachment of the lead wire in accordance with Subsection 5.1.6.2.4, Lead Wires for High Potential Magnesium Anodes.

5.1.6.2.3.3 The cores of the weld on 4.5 kg zinc and the 4 kg Grade B, standard potential magnesium anodes shall be a hot dipped galvanized mild carbon steel bar conforming to the requirements of Figures 6 and 7.

5.1.6.2.4 Lead Wires for High Potential Magnesium Anodes

5.1.6.2.4.1 Lead wires consisting of min 3.31 mm² (No. 12 AWG) stranded copper conductor covered with type RWU insulation conforming to the requirements of CSA C22.2 No. 38, Thermoset-insulated wires and cables, shall be connected to the core of the high potential magnesium anode by welding, brazing or silver-soldering.

5.1.6.2.4.2 The connection between the lead wire and the anode core shall be protected with a heat shrinkable plastic insulating sleeve as illustrated in Figure B7.

5.1.6.2.4.3 The lead wire shall be not less than 7600 mm in length and blue in colour for the high potential magnesium anode.

5.1.6.2.5 Dimensions

5.1.6.2.5.1 Weld On Zinc and H1, Grade A or Grade B Standard Potential Magnesium Anodes

5.1.6.2.5.1.1 Weld on zinc and H1, Grade A or Grade B, standard potential magnesium anodes, before packaging, shall be in accordance with the dimensions specified in Tables 4 and 5 for the corresponding anode mass.

5.1.6.2.6 Packaging

5.1.6.2.6.1 Weld On Zinc and H1, Grade A or Grade B, Standard Potential Magnesium Anodes

5.1.6.2.6.1.1 The weld on zinc and H1, Grade A or Grade B standard potential, magnesium anodes shall be packaged in a moisture absorbing cardboard container having a diameter and length of not less than that specified in Tables 4 and 5. The anode surfaces shall be surrounded by chemical *backfill* mixture as described in Clause 5.1.6.2.6.3.1 vibrated into the container. See Figures 4, 5, 6 and 7.

5.1.6.2.6.1.2 The zinc anode casting/extrusion shall be supported in the package by at least one non-conductive disc located at the longitudinal centre line as illustrated in Figure 5. If the anode used is in accordance with Figure 6, no disc is required.

5.1.6.2.6.2 High Potential Magnesium Anodes

5.1.6.2.6.2.1 A high potential magnesium anode shall be packaged in a moisture absorbing cardboard container having a minimum diameter equal to the anode diameter times 1.5 and a minimum length equal to the anode length plus 80 mm. The entire anode surface shall be surrounded by chemical *backfill* mixture as described in Clause 5.1.6.2.6.3.1 vibrated into the container.

5.1.6.2.6.3 Chemical Backfill Mixture

5.1.6.2.6.3.1 The chemical *backfill* mixture used for the zinc and magnesium anodes shall be of a composition by volume as specified in Table 6 and shall have a resistivity of less than 20 Ω -cm.

5.1.6.2.7 Plastic Anode Sleeve

5.1.6.2.7.1 Zinc and magnesium anodes shall have a protective plastic sleeve over the cardboard containing package to protect the anode during storage. Each sleeve shall be marked as specified in Clause 5.1.6.2.8.2.

5.1.6.2.8 Marking of Anodes

5.1.6.2.8.1 Each anode shall be clearly and permanently marked with the following information:

- A Name of anode manufacturer;
- B Type of anode, (zinc or magnesium, high or standard potential); and
- C Mass of anode, (kilograms).

NOTE: Manufacturer should be aware that the *authority having jurisdiction* may also require the mark of the certifying agency to be included on each anode.

5.1.6.2.8.2 Each plastic sleeve shall be clearly marked in letters 25 mm high in a contrasting colour, with the following information:

"REMOVE PLASTIC SLEEVE BEFORE PLACING IN THE EXCAVATION".

5.1.6.2.9 Mounting of Factory Attached Packaged Anodes

5.1.6.2.9.1 The quantity, size and location of the packaged anodes shall be in accordance with Figure 8 for the magnesium anode system, Figure 9 for the zinc anode system or Table 7 in conjunction with Figures 10 to 15 for the combined zinc and magnesium anode system.

5.1.6.2.9.2 The anode support brackets shall be welded to the tank heads and shell before the tank is blast cleaned and the thin film dielectric coating applied. The steel used in the fabrication of these support brackets shall be in accordance with the material requirements of CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids. For typical anode mounting detail, see Figure 16.

5.1.6.2.9.3 Depending on the design of the galvanized steel anode bar, the anodes may be attached to the tank by directly welding the anode bar to the tank prior to the tank being coated, or to the attached anode support brackets either prior to, or after the tank has been coated.

5.1.6.2.9.4 Where the anodes have been welded after the application of the thin film dielectric coating to the tank, all weld joints shall be repaired by the application of materials from the corrosion protection repair kit supplied by the manufacturer.

5.1.6.3 Thin Film Dielectric Coating

5.1.6.3.1 General

5.1.6.3.1.1 The application of the thin film dielectric coating shall be performed in the sequence as described in Subsections 5.1.6.3.2, Blast Cleaning and 5.1.6.3.3, Thin Film Dielectric Coating Application.

5.1.6.3.2 Blast Cleaning

5.1.6.3.2.1 The entire exterior surface of the tank shall be blast cleaned in accordance with SSPC SP 6/NACE No. 3, Commercial Blast Cleaning, Surface Preparation Specifications.

5.1.6.3.2.2 The blast cleaning shall take place after all fabrication work on the tank has been completed immediately prior to the application of the thin film dielectric coating.

5.1.6.3.3 Thin Film Dielectric Coating Application

5.1.6.3.3.1 The thin film dielectric coating shall be applied in accordance with the manufacturer's instructions to a minimum cured dry film average thickness of 0.4 mm. There shall be no area with a cured dry film thickness of less than 0.3 mm.

5.1.6.3.3.2 The cured dry film thickness shall be measured by the tank manufacturer using a non-destructive film gauge tester.

5.2 PERFORMANCE TESTS

5.2.1 General

5.2.1.1 Representative samples as specified in Table 8 shall be used for these tests. All representative samples shall show no *holiday* when tested in accordance with NACE SP0188, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

5.2.1.2 Each *cathodically protected tank* shall be provided with a *cathodic corrosion protection* repair kit and appropriate instructions, including instructions for protecting external attachments (such as lift lugs) and unused tank openings.

5.2.1.3 The *cathodic corrosion protection* repair kit shall be tested in accordance with Subsections 5.2.2, Impact Test Following Exposure, 5.2.3, Resistance to External Fluids Test, and 5.2.5, Abrasion Resistance Test.

5.2.2 Impact Test Following Exposure

5.2.2.1 A representative sample shall not be affected by an impact to the extent that *holidays* form further than 25 mm from the point of impact.

5.2.2.2 An unconditioned sample, and the samples conditioned as specified in Clauses 5.2.2.3, 5.2.2.4 and 5.2.2.5, shall be subjected to the impact test specified in Clause 5.2.2.6.

5.2.2.3 A representative sample shall be conditioned in an air-circulating oven at either:

- A 70 ± 2 °C for 30, 90 and 180 d; or
- B 60 ± 2 °C for 30, 90, 180 and 270 d.

5.2.2.4 A representative sample shall be conditioned for 180 and 360 ± 0.5 h, respectively, with light and water exposure in accordance with ASTM G152, Standard Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials, or ASTM G153, Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials. During each operating cycle of 120 min, the samples shall be exposed to light alone for 102 min and to light and water for 18 min.

5.2.2.5 A representative sample shall be conditioned for 16 ± 0.5 h at -30 ± 2 °C

5.2.2.6 Immediately following conditioning, each representative sample shall be clamped between two steel rings having an inside diameter of 108 mm. A 536 g steel ball is to be dropped once from at least a height of 1.8 m to strike the thin film dielectric coating. The representative samples shall then be tested in accordance with Subsection 5.2.7, Holiday Test.

5.2.3 Resistance To External Fluids Test

5.2.3.1 After being immersed as specified in Clause 5.2.3.2, the representative sample shall not crack nor flake, the thin film dielectric coating shall not dissolve from the surface to the extent that the base steel becomes visible, and shall not show disbondment in an area greater than 968 mm². The current demand of the representative sample without a *holiday* shall be measured (both before and after immersion) in accordance with Subsection 9.13 of ASTM G8, Standard Test Methods for Cathodic Disbonding of Pipeline Coatings, and shall not exceed 0.43 mA/m².

5.2.3.2 A representative sample shall be immersed in each of the test fluids specified in Table 9, Resistance to External Fluids Test. Immersion in Type A fluids shall be for 30, 90, 180 and 270 d and in Type B fluids for 30, 90 and 180 d. Four of the samples shall be prepared with a 6.5 mm diameter *holiday*. The test fluids shall be maintained at 38 ± 2 °C during the tests.

5.2.4 Flexibility Test

5.2.4.1 After being loaded as described in Clause 5.2.4.2, the representative sample shall show no *holiday* when subjected to a *holiday* test in accordance with Subsection 5.2.7, Holiday Test.

Exception: Holidays or other damage to areas in immediate contact with the supports or loading nose shall be disregarded.

5.2.4.2 The representative sample shall be placed in a constant rate of traverse testing machine with a span of 152.4 mm. The loading nose and supports shall be aligned such that the axes of the cylindrical surfaces are parallel and the loading nose is midway between the supports. The testing machine is to apply the load at 2.5 mm/min until a deflection is obtained, as determined by the following equation:

$$\text{Deflection} = \frac{10.43}{t}$$

Where:

t = sample thickness (steel plus coating) in mm.

5.2.5 Abrasion Resistance Test

5.2.5.1 After being tested as specified in Clause 5.2.5.2, the representative sample shall show no *holiday* when subjected to a *holiday* test in accordance with Subsection 5.2.7, Holiday Test.

5.2.5.2 The representative sample shall be subjected to ASTM G13/G13M, Standard Test Method for Impact Resistance of Pipeline Coatings (Limestone Drop Test), except that flat plate specimens shall be used, and three drops shall be performed.

5.2.6 Cathodic Disbondment Test

5.2.6.1 After being subjected to the test specified in Clause 5.2.6.2, the unperforated sample shall not disbond from the steel surface and the perforated sample shall not disbond more than 968 mm².

5.2.6.2 Representative samples shall be subjected to Method B of ASTM G8, Standard Test Methods for Cathodic Disbonding of Pipeline Coatings, except that flat panel specimens shall be used instead of pipe specimens. Half of the samples shall be perforated per ASTM G8, Standard Test Methods for Cathodic Disbonding of Pipeline Coatings. The electrolyte is to be maintained at a temperature of 23 ± 2 °C during the test and have a solution potential of -1.5 V to a copper/copper sulphate (Cu/CuSO₄) electrode when tested in potable tap water. The samples are to be subjected to the test for 28 d.

5.2.7 Holiday Test

5.2.7.1 A representative sample shall show no *holiday* when subjected to the Low Voltage Wet-Sponge *holiday* test in accordance with NACE SP0188, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

5.3 CATHODICALLY PROTECTED TANK ASSEMBLY TESTS

5.3.1 Leakage Test

5.3.1.1 There shall be no leakage when a *tank assembly*, including fittings and *manway*, is tested in accordance with either the Production Test or Factory Test, as applicable, as described in CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids.

5.4 MARKING

5.4.1 All marking requirements in CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids shall be applied to the tank after the application of the *corrosion protection system*.

5.4.2 The metal nameplate shall be clamped onto the mounting plate after the *corrosion protection system* has been applied to the tank.

Exception: When a label is embedded into the corrosion protection technology and not in direct contact with backfill material, the nameplate may be of a material acceptable to the certifying agency.

5.4.3 Alternative methods of attachment are permissible provided that the nameplate is affixed to the tank in a manner that will destroy the nameplate if it is removed from the tank.

5.4.4 In addition, where applicable, the tank shall be clearly marked in the locations shown in Figure 17 in letters 25 mm high, in a contrasting colour, with the following:

- A "WARNING - HANDLE WITH CARE" and / or << ATTENTION - MANIPULER AVEC PRÉCAUTION >>;
- B "NONMETALLIC ISOLATING BUSHINGS - DO NOT REMOVE - DO NOT CROSS THREAD";
- C "FASTEN BLACK MONITORING WIRE TO WIRE CONNECTOR LUG AND PLATE ASSEMBLY. TERMINATE AT GROUND LEVEL";
- D "REMOVE PLASTIC ANODE COVER BEFORE PLACING TANK IN THE EXCAVATION";
- E "EXTERNAL PIPING CONNECTIONS SHALL INCORPORATE THE USE OF ISOLATING UNIONS AT THE JUNCTIONS TO HEATING COILS AND HOT WELLS"; and
- F "FOR HEATED TANKS - INSTALL ANODES PER MANUFACTURER'S INSTRUCTIONS".

6 COMPOSITE TANKS (CLAD)

6.1 CONSTRUCTION

6.1.1 Blast Cleaning

6.1.1.1 The entire surface of the tank shall be blast cleaned in accordance with SSPC SP 6/NACE No. 3, Commercial Blast Cleaning.

6.1.1.2 The blast cleaning shall take place after all fabrication work on the tank has been completed, prior to the application of the *cladding*.

6.1.2 Cladding Application

6.1.2.1 The *cladding* shall be applied in accordance with the manufacturer's instructions to a minimum dry film thickness of 2.5 mm.

6.1.2.2 The *cladding* thickness shall be measured by the tank manufacturer using a non-destructive film gauge tester.

6.1.2.3 Subsequent to curing, the entire exterior surface of the tank shall be tested in accordance with Subsection 6.3.3, Holiday Test. There shall be no *holiday* detected.

6.1.3 Optional Protection

6.1.3.1 One or more sacrificial anodes may be connected to each tank at the point of manufacture, to provide optional protection. Please refer to Subsection 5.1.6.2.9, Mounting of Factory Attached Packaged Anodes, for guidelines.

6.2 PERFORMANCE TESTS

6.2.1 General

6.2.1.1 Representative samples as specified in Table 8 shall be used for performance testing.

6.2.1.2 *Composite tanks* shall be provided with a corrosion protection repair kit and appropriate instructions, including instructions for protecting external attachments (such as lift lugs) and unused tank openings.

6.2.1.3 The *composite tank* corrosion protection repair kit shall be tested in accordance with Subsections 6.2.2, Air-Oven Aging Test, 6.2.4, Resistance to External Fluids Test, 6.2.5, Light and Water Exposure Test, 6.2.6, Impact Test Following Cold Exposure, and 6.2.7, Corrosion and Permeation Dissolution Evaluation Tests.

6.2.2 Air-Oven Aging Test

6.2.2.1 The measured physical properties of each representative sample shall be at least 80 % of the as-received sample when conditioned in accordance with Clause 6.2.2.2 and tested in accordance with Clause 6.2.2.3.

6.2.2.2 Representative samples shall be conditioned in an air-circulating oven at 70 ± 2 °C for 30, 90 and 180 d, respectively.

6.2.2.3 Representative samples shall be prepared and tested to determine flexural strength as well as izod impact resistance. The flexural strength test is to be conducted in accordance with ANSI/ASTM D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, using a crosshead speed of 2.5 mm/min. The izod impact resistance test is to be conducted in accordance with ANSI/ASTM D256, Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics.

6.2.3 Resistance to Aromatic Fuels Test

6.2.3.1 Each cured representative sample shall show no blistering when tested in accordance with Clause 6.2.3.2.

6.2.3.2 Three cured representative samples shall be immersed to 75 % of their length in *ASTM Reference Fuel C* for a minimum period of 21 d in accordance with ASTM D471, Standard Test Method for Rubber Property-Effect of Liquids.

6.2.4 Resistance To External Fluids Test

6.2.4.1 The measured physical properties of each representative sample that has been immersed in a Type A fluid shall be at least 50 % of the as-received sample. The measured physical property of each representative sample that has been immersed in a Type B fluid shall be at least 30 % of the as-received sample. The representative sample shall also show no evidence of blistering, softening, crazing, or other damage that impairs the performance of the *cladding* when tested in accordance with Clauses 6.2.4.2 through 6.2.4.4.

6.2.4.2 The representative sample shall be immersed in the external fluids specified in Table 9. Representative samples shall be immersed in Type A fluids for 30, 90, 180 and 270 d. Representative samples shall be immersed in Type B fluids for 30, 90, and 180 d. The test fluids shall be maintained at 38 ± 2 °C during the immersion periods.

6.2.4.3 Following the immersions, the representative samples shall be removed from the test fluids and tested in accordance with Clause 6.2.2.3.

6.2.4.4 The test shall be discontinued when the results from the 30, 90 and 180 d Type A fluid immersion are reliably extrapolated (using a regression analysis technique which results in a correlation coefficient of 0.9 or greater) to obtain 270 d retention values and the extrapolated values are not less than 50 % of the as-received values. When the correlation coefficient is less than 0.9, or the extrapolated value is less than 50 % for a particular fluid, the Resistance to External Fluids Test, is to be continued to 270 d.

6.2.5 Light and Water Exposure Test

6.2.5.1 The measured physical properties of each representative sample shall be at least 80 % of the as-received sample.

6.2.5.2 The representative sample shall be subjected to 180 and 360 h of light and water exposure in accordance with ASTM G152, Standard Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials, or ASTM G153, Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials. During each operating cycle of 20 min, the representative sample shall be exposed to light alone for 17 min and to light and water for 3 min.

6.2.5.3 Following conditioning, the representative sample shall be tested in accordance with Clause 6.2.2.3.

6.2.6 Impact Test Following Cold Exposure

6.2.6.1 Representative samples shall not crack or show rupture of the *cladding* and the *cladding* shall not separate or uplift from the steel, when tested in accordance with Clauses 6.2.6.2 and 6.2.6.3.

6.2.6.2 The representative samples shall be conditioned for 16 ± 0.5 h in a cold box maintained at -30 ± 2 °C.

6.2.6.3 Immediately following the conditioning, the representative samples and an unconditioned sample shall be clamped, one at a time, between two steel rings having an inside diameter of 108 mm. A 536 g steel ball is to be dropped once from a minimum height of 1.8 m to strike the *clad* surface of the sample.

6.2.7 Corrosion and Permeation Dissolution Evaluation Tests

6.2.7.1 General

6.2.7.1.1 The *cladding* shall show no evidence of blistering, softening, crazing, or other damage that impairs the performance when tested in accordance with Subsections 6.2.7.2, Corrosion Evaluation Test and 6.2.7.3, Permeation Dissolution Evaluation Test.

6.2.7.2 Corrosion Evaluation Test

6.2.7.2.1 Following the exposure described in Clause 6.2.7.2.2, the base steel of the representative sample shall not corrode.

6.2.7.2.2 Nonmetallic cylinders measuring 127 mm in diameter by 254 mm in length shall be fitted perpendicular to the *clad* side of the samples and secured with an adhesive. The cylinders are then to be filled with each of the test solutions noted in Table 10 (capped to prevent evaporation) and placed in a chamber maintained at a temperature of 38 ± 2 °C for 30, 90, 180 and 270 d.