

**STANDARD FOR INTERNAL RETROFIT SYSTEMS FOR
UNDERGROUND TANKS FOR FLAMMABLE AND
COMBUSTIBLE LIQUIDS**

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**STANDARD FOR INTERNAL RETROFIT SYSTEMS FOR
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LIQUIDS**

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TABLE OF CONTENTS

ULC STANDARDS COMMITTEE ON STATIONARY NONMETALLIC STORAGE CONTAINERS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS	I
ULC STANDARDS TASK GROUP ON INTERNAL RETROFIT UNDERGROUND TANKS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS	II
PREFACE	III
1 SCOPE	1
2 REFERENCE PUBLICATIONS	2
3 GLOSSARY	4
4 CONSTRUCTION	5
4.1 GENERAL	5
4.2 LINING SYSTEMS	6
4.3 UPGRADE SYSTEMS	7
4.4 STRUCTURAL SYSTEMS	7
4.5 INTERSTITIAL SPACES	7
4.6 MANWAYS AND FITTINGS	7
4.7 TANK COMPARTMENTS	8
5 PERFORMANCE	8
5.1 GENERAL	8
5.1.1 Test Tank Preparation	8
5.1.2 System Installation	8
5.1.3 System Material Tests	9
5.1.4 System Leakage Tests	10
5.2 TANK BURIAL TESTS	11
5.2.1 General Sample and Test Preparation	11
5.2.2 Fitting torque and bending tests	11
5.2.3 Interstitial Strength Test	12
5.2.4 Saturated Soil Load Test	12
5.2.5 Interstitial Communication Test	13
5.3 LONG TERM COMPATIBILITY	13
5.3.1 General Sample and Test Preparation	13
5.3.2 Physical Property and Visual Exam Tests	14
5.3.2.2 Visual Exam Test	15
5.3.2.3 Bond Strength Test	15
5.3.2.4 Flexural Strength Test	15
5.3.2.5 Tensile Strength Test	15
5.3.3 Test Sample Exposures	16
5.4 INSTALLATION AND PRODUCTION TESTS	16
5.4.1 General	16
5.4.2 Tank Tests	17
5.4.3 Impact Test	17
5.4.4 Leakage Test	17

6 MARKINGS	17
7 INSTRUCTIONS	18
TABLES	20
APPENDIX A (INFORMATIVE) – TEST FUEL FORMULATIONS	22
A1 REPRESENTATIVE AGGRESSIVE COMBUSTIBLE TEST FUEL MIXTURES AND UL-B100 ...	22
A2 REPRESENTATIVE AGGRESSIVE FLAMMABLE TEST FUELS AND MIXTURES	22
APPENDIX B (INFORMATIVE) – PULL-OFF DISK PREPARATION	23
B1 BOND STRENGTH TEST PULL-OFF DISKS	23

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STANDARD FOR INTERNAL RETROFIT SYSTEMS FOR UNDERGROUND TANKS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS

PREFACE

This is the First Edition of the Standard for Internal Retrofit Systems for Underground Tanks for Flammable and Combustible Liquids, CAN/ULC-S669-14.

This Edition of the Standard was developed by the ULC Standards Task Group on Internal Retrofit Systems and was formally approved by the ULC Standards Committee on Stationary Nonmetallic Storage Containers for Flammable and Combustible Liquids.

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.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the fact that Canadian authorities may require markings and/or installation instructions to be in either or both official languages, except as may be stated elsewhere in this Standard.

Appendices A and B, identified as informative, are for guidance and informational purposes only.

This First Edition National Standard of Canada is based on, and now supersedes, the First Edition ULC/ORD-C58.4-2005, Requirements for Double Containment Fibre Reinforced Linings for Flammable and Combustible Liquid Storage Tanks.

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 initiation of the review of this Standard will commence within 5 years of 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 provides minimum requirements for nonmetallic internal *retrofit systems* intended for field installation in underground tanks for the storage of *flammable* and *combustible liquids*, such as:

- A Petroleum products, including petroleum hydrocarbon fuels with low bio-blends per specifications and similar *flammable* or *combustible liquid* petroleum derivatives, such as fuel components (cetane, hexane, heptane), and oils (lubricating, hydraulic, machine);
- B Oxygenated fuel blends, including all "petroleum products" liquids; plus petroleum hydrocarbon fuels with low-biofuels blends;
- C Oxygenates, including all "petroleum product" and "oxygenated fuel blends" liquids; plus pure/denatured or highest oxygenated blend stocks for use in mixing of dispensed lower fuel-blends and components, such as biodiesel and ethanol; and
- D Other *flammable* and *combustible liquids* that can be demonstrated to be compatible with the internal *retrofit system* materials.

Refer to Appendix A (Informative) for a list of Standards on fuels and other *flammable* and *combustible liquids*.

1.2 These *retrofit systems* are nonmetallic thermoset (such as fibre reinforced plastic [FRP], epoxy, polyurethane [PUR] or polyesters) or thermoplastic (such as polyethylene [PE]) materials that may or may not be bonded to the interior tank wall of the *host tank*, depending upon the system type. These products typically use pre-fabricated sections with coatings applied on site, or homogeneous or layered spray-on/roll-on materials applied on site, and may optionally cover minor *repair* prior to the installation of a *retrofit system*, and the installation of bulkheads to the *host tank*.

- A *Lining systems* provide only primary containment of stored fuels, and do not add significant structural strength to the *host tank*;
- B *Upgrade systems* provide both primary containment and *secondary containment* of stored fuels with interstitial monitoring, and are *co-structural* with the *host tank*; and
- C *Structural systems* provide both primary containment and *secondary containment* of stored fuels with interstitial monitoring. This system may provide a primary containment of stored fuels and utilizes the *host tank* as *secondary containment* of stored fuels with interstitial monitoring, or the system may provide both primary containment and *secondary containment* of stored fuels with interstitial monitoring independent of the *host tank*.

1.3 Products covered by this Standard are intended to be installed and used in accordance with, but not limited to, one or more of the following:

- A National Fire Code of Canada, Part 4;
- B CSA B139, Installation Code for Oil Burning Equipment;
- C CCME Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products; and
- D Regulations of the appropriate *authority having jurisdiction*.

1.4 These *retrofit systems* are intended for field installation, only by *qualified persons*, inside the *host tank* without a need for excessive excavation, in accordance with the manufacturer's instructions and the local requirements. Prior to installation, cleaning, inspecting, *repairing* and preparing the *host tank* interior surface is also conducted by *qualified persons* in accordance with the manufacturer's instructions.

1.5 These *retrofit systems* are intended to be periodically inspected and maintained for continued service, or taken out of service if deemed necessary by *qualified persons* in accordance with industry recommended practices, the manufacturer's instructions or applicable regulations.

1.6 These *retrofit systems* and the manufacturer's installation instructions have not been investigated for their physiological effect, if any, for safety of any persons during the installation process, and the potential risk associated with the opening, entering, purging, cleaning, inspecting, surface preparation, system installation, and testing of a tank that has been used to store *flammable* or *combustible liquids*.

1.7 These *retrofit systems* and requirements are not intended to cover or evaluate the installation equipment, safety of the installer, compliance with worker safety regulations (such as confined spaces or hazardous locations), or any environmental emissions or disposal regulations.

1.8 These *retrofit systems* have not been evaluated for use after natural disasters, or exposures to chemicals not representative of the test liquids or excessive physical damage beyond the expected installation and uses as identified in these requirements.

1.9 This Standard does not cover additional claims, if any, related to the effect, if any, of the product's materials on fuel quality or properties.

1.10 This Standard does not cover external corrosion protection systems for steel underground tanks, which are found in CAN/ULC-S603.1, Standard for External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids.

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. All undated references shall be interpreted as referring to the latest edition of that document.

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Telephone: (610) 832-9585
www.astm.org

- ASTM D471-12 (Rev A), Standard Test Method for Rubber Property - Effect of Liquids
- ASTM D664-11, Standard for Acid Number of Petroleum Products by Potentiometric Titration
- ASTM D638-2010, Standard Test Method for Tensile Properties of Plastics
- ASTM D790-2003, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Material
- ASTM D975-2014, Standard Specification for Diesel Fuel Oils
- ASTM D4541-2009 (E 2010), Standard Test Method for Pull-Off Strength of Coating Using Portable Adhesion Testers

- ASTM D6751-12, , Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
-

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c/o Manitoba Statutory Publications, Lower Level,
200 Vaughan Street, Winnipeg, MB R3C 1T5
Telephone: (204) 945-4664

- CCME PN 1326-2003, Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products
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Published by CSA Group
5060 Spectrum Way, Mississauga, On L4W 5N6
Telephone: (800) 463-6727
www.csa.ca

- CAN/CSA-B139, Installation Code for Oil Burning Equipment
-

Published by the National Research Council of Canada (NRC)
Publication Sales M20, Montreal Road, Ottawa, ON K1A 0R6
Telephone: (613) 993-2463
www.nrc-cnrc.gc.ca

- National Fire Code of Canada 2010
-

Documents Published by SAE International, Society of Automobile Engineers
400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A.
Telephone: (724) 776-4841

- SAE J1681-2000, Gasoline, Alcohol, and Diesel Fuel Surrogates for Material Testing
-

Documents Published by ULC Standards
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- CAN/ULC-S603-14, Standard for Steel Underground Tanks for Flammable and Combustible Liquids
 - CAN/ULC-S603.1-11, External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids
 - CAN/ULC-S615-14, Standard for Fibre Reinforced Plastic Underground Tanks for Flammable and Combustible Liquids
-

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- UL 969-1995 (R2008), Standard for Marking and Labelling Systems
- UL 1856-2013, Underground Fuel Tank Internal Retrofit Systems

3 GLOSSARY

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

3.1 *ADHESIVE FAILURE* - Failure (typically loss of strength and detachment) between the *host tank* surface and the system bonding adhesive.

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 *CO-STRUCTURAL* - A *retrofit system* that is designed to meet equivalent structural requirements of an underground tank standard, with shared structural strength between the *primary tank* and *retrofit system*.

3.4 *COHESIVE FAILURE* - Failure of materials or layers within either the *primary tank* or *retrofit system*, but not the bonding adhesive between them.

3.5 *COMBUSTIBLE LIQUID* - Any liquid having a flash point at or above 37.8 °C and below 93.3 °C and as defined in the National Fire Code of Canada.

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

3.7 *HOST TANK* - An existing storage tank into which a *retrofit system* is installed.

3.8 *MULTIPLE WALL TANK* - A tank, which incorporates additional integral layers of containment where the interstices are capable of being monitored.

3.9 *PRIMARY TANK* - The product storage tank or compartment.

3.10 *QUALIFIED PERSON* - A worker specifically trained by the manufacturer to perform proper field installation of its *retrofit system* in accordance with the specified instructions. The *qualified person* is not required to be an employee of the manufacturer.

3.11 *REFURBISH* - The addition of materials to an existing tank structure after surface preparations, for the intended purpose of returning the entire tank wall to at least its original design thickness and/or strength.

3.12 *REPAIR* - The localized addition of materials to an existing tank structure after surface preparations to plug a leak or intended to return a portion of the tank wall to its original design thickness and/or strength.

3.13 *RETROFIT SYSTEM* - Engineered nonmetallic (thermoset or thermoplastic) material(s) that are field installed inside of a *host tank*, and provide different *refurbished* levels of containment, optional *repair*, and other features as follows:

- A *LINING SYSTEM* - A *retrofit system* that is directly bonded to the interior wall of the *host tank*, provides only primary containment of stored fuels, and does not add significant structural strength to the *host tank*.
- B *UPGRADE SYSTEM* - A *retrofit system* that is directly bonded to the interior wall of the *host tank*, provides both primary containment and *secondary containment* of stored fuels with interstitial monitoring, and is *co-structural* with the *host tank*.
- C *STRUCTURAL SYSTEM* - A *retrofit system* that may or may not be bonded to the interior wall of the *host tank*, provides both primary containment and *secondary containment* of stored fuels with interstitial monitoring, and is *self-structural* from the *host tank*.

3.14 *RETROFITTED TANK ASSEMBLY* - A *host tank* with a *retrofit system* installed.

3.15 *SECONDARY CONTAINMENT (CONTAINMENT)* - Construction that is external to the *primary tank* and designed to prevent the contents of the *primary tank* from leaking outside the containment.

3.16 *SELF-STRUCTURAL* - A *retrofit system* that is designed to meet equivalent structural requirements of a tank standard, without any structural contribution from the *host tank*.

4 CONSTRUCTION

4.1 GENERAL

4.1.1 All *retrofit systems* shall be designed for field installation (without the need for excessive excavation or tank opening) inside of existing steel and/or FRP underground *host tanks* that are constructed and tested for full compliance with one of the following standards:

- A CAN/ULC-S603, Standard for Steel Underground Tanks for Flammable and Combustible Liquids;
- B CAN/ULC-S603.1, Standard for External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids; and
- C CAN/ULC-S615, Standard for Reinforced Plastic Underground Tanks for Flammable and Combustible Liquids.

NOTE: If necessary for system installation, tank top excavation and cut openings are permitted, provided these details are in the instructions.

4.1.2 All *retrofit systems* shall clearly define the above *host tank(s)* described in Clause 4.1.1 and basic parameters for which they are designed, including, but not limited to the items below.

- A System bonding to steel and/or FRP (if applicable);
- B Maximum tank diameter and length/diameter ratio;
- C Minimum tank opening size needed for installation;
- D Maximum hole or crack dimensions which may be *repaired*;
- E Minimum containment coverage in circumferential degrees; and
- F Minimum average thickness of any field applied material(s).

4.1.3 All *retrofit systems* shall clearly define for steel and/or fibre reinforced plastic (FRP) tanks as applicable, the process(es) and minimum specifications for each step in the installation, including, but not limited to the items below:

- A Tank cleanout, surface inspection, thickness measurement and any other manufacturer required procedures prior to *host tank repair* and system installation;
- B Identification of any tank, extent of damage (see item C), or material characteristics which would not be suitable for system installation;
- C *Repair* of any holes, cracks, dents, pits or other *host tank* damage prior to system installation;
- D Preparation of the *host tank* surface (such as sand blasting or chemical etching) for system installation;
- E Installation of the *retrofit system* (for each layer if applicable), any curing procedures, and any temperature limitations; and
- F Measurement of any thickness, hardness or other material properties, and leakage testing procedures of the *retrofit system*.

4.1.4 All *retrofit systems* shall be thermoset (such as FRP, epoxy, polyurethane [PUR], polyesters, etc.) or thermoplastic (such as polyethylene [PE], etc.) materials, that are installed in the *host tank* by using either pre-fabricated sections or joints with coatings applied on site, or homogeneous or layered spray-on/roll-on materials applied on site.

4.1.5 All *retrofit system* primary and/or secondary materials shall be designed for long term compatibility with the intended fuels as described in, and shall be evaluated in accordance with, Section 5, Performance.

4.1.6 All *retrofit systems* shall have deflection plates (also known as impact pads, or other shock absorbing devices), designed to prevent possible damage to the *retrofit system's* surface from repeated impact of dipsticks or other devices used to gauge tank contents, shall be installed under all openings potentially used as fill and gauging locations.

4.1.7 The deflection plate shall be of steel at least 1.35 mm thick or aluminum at least 3.2 mm thick. The deflection plate shall be overlaid with a minimum of 2 mm of the *retrofit system* material. The deflector plate shall be at least 230 mm wide, and at least 0.09 m² in area under each opening.

4.2 LINING SYSTEMS

4.2.1 *Lining systems* are permitted to be installed in double wall or *multiple-wall* steel or FRP *host tanks*, but shall provide only primary containment of stored *flammable* or *combustible liquids*.

4.2.2 *Lining systems* shall be bonded to 100% of the *host tank* interior surface, and have a minimum thickness of at least 1.8 mm (70 mils).

4.2.3 When completed, the system shall form a uniform, solid material. There shall be no hollow layers, fillers or voids in the liner.

4.3 UPGRADE SYSTEMS

4.3.1 *Upgrade systems* are permitted to be installed in steel or FRP *host tanks*, shall provide both primary containment and *secondary containment* of stored *flammable* or *combustible liquids*, and shall be designed to be *co-structural*.

4.3.2 *Upgrade systems* shall be bonded to 100% of the *host tank* interior surface.

4.3.3 All *upgrade systems* shall cover a surface area centered on the tank bottom corresponding to a minimum of 300° of the circumferential surface area of the *host tank*, or a surface area corresponding to 95% of the internal volume of the *host tank*, whichever is greater, including 100% coverage of the *host tank* heads excluding the area immediately adjacent to the tank fittings and manway(s).

NOTE: The *authority having jurisdiction* may require that the tank have 360° *secondary containment* except for the areas penetrated by fittings and manways.

4.3.4 The thickness of the system layers bonded to the *host tank* and newly formed *primary tank* shall not be less than 1.3 mm (50 mils).

4.4 STRUCTURAL SYSTEMS

4.4.1 *Structural systems* are permitted to be installed in steel or FRP *host tanks*, shall provide both primary containment and *secondary containment* of stored *flammable* or *combustible liquids*, and shall be designed to be *self-structural*.

4.4.2 *Structural systems* may or may not be bonded to the *host tank* interior surface.

4.4.3 All *structural systems* shall cover a surface area centered on the tank bottom corresponding to a minimum of 300° of the circumferential surface area of the *host tank*, or a surface area corresponding to 95% of the internal volume of the *host tank*, whichever is greater, including 100% coverage of the *host tank* heads excluding the area immediately adjacent to the tank fittings and manway(s).

NOTE: The *authority having jurisdiction* may require that the tank have 360° containment except for the areas penetrated by fittings and manways.

4.4.4 The thickness of the system layers facing the *host tank* and newly formed *primary tank* not be less than 1.8 mm (70 mils).

4.5 INTERSTITIAL SPACES

4.5.1 Interstitial spaces shall be capable of continuous monitoring by liquid, vapour, pressure, vacuum or other means, in accordance with Subsection 5.2.5, Interstitial Communication Test.

4.5.2 Access to the interstitial space shall be provided for monitoring.

4.6 MANWAYS AND FITTINGS

4.6.1 If manways or fittings are added to the *host tank* to facilitate installation of, or integration with, the *retrofit system*, they shall meet the construction requirements of the applicable tank Standard identified in Subsection 4.1, General.

4.7 TANK COMPARTMENTS

4.7.1 Fabrication of new tank compartments are permitted for only *upgrade* or *structural type retrofit systems*, provided they meet the applicable requirements in Section 5, Performance, and have interstitial monitoring between compartments.

4.7.2 Where new tank compartment bulkheads are installed, they shall meet the applicable requirements of CAN/ULC-S615, Standard for Fibre Reinforced Plastic Underground tanks for Flammable and Combustible Liquids.

5 PERFORMANCE

5.1 GENERAL

5.1.1 Test Tank Preparation

5.1.1.1 Each *retrofit system* shall be installed in worst case representative *host tank(s)*, in accordance with the manufacturer's instructions to demonstrate the complete process, and prepare sample tank(s) or sample materials for performance testing as defined in Table 1:

5.1.2 System Installation

5.1.2.1 The *host tank(s)* used for system installation and performance testing shall be steel and/or fibreglass within the specifications below, as applicable for the system rating(s).

- A Largest diameter and minimum thickness; and
- B No less than 75% of the maximum capacity.

5.1.2.2 The *host tank(s)* shall be primary types with an existing, *repaired* or new manway with means to attach a riser, and fill/withdraw openings that have been built in accordance with one of the following Standards as applicable:

- A CAN/ULC-S603 for steel tank ratings; and/or
- B CAN/ULC-S615 for FRP tank ratings.

5.1.2.3 The *host tank* shall be representative of a well-used condition to assess the effectiveness of tank cleanout and *repair*, surface preparation and inspection, lining process, and production testing in accordance with the manufacturer's instructions.

Exception: Structural systems are permitted to use new or used tanks in any condition as an installation "mold", but shall be capable of removal (unbonded) in order to facilitate self-structural tests in Subsection 5.2, Tank Burial Tests.

5.1.2.3.1 A tank that has been in service for at least one (1) year of fuel storage is considered to meet the above condition, but the tank shall either contain or simulate the maximum damage that is permitted to be *repaired* in accordance with the instructions (such as a hole or crack).

5.1.2.3.2 If a used or in service tank meeting the above criteria is not available, a new tank may be pre-conditioned by exposing the inner surface to a mixture of liquids and vapours below as applicable to the rated *host tank* material(s) at no less than 20 °C.

- A For steel tanks – at least 1/4 filled with either fresh water for 90 days or salt water for 30 days; and
- B For FRP tanks – at least 1/8 filled with commercially dispensed E10 gasoline for 90 days.

NOTE: The fuel temperature and tank level are averages over the conditioning time, and all tanks shall be normally vented. Fresh water sources may be from potable or non-potable sources. Salt water shall be at least 5% NaCl by mass.

5.1.2.4 If new or *repaired* fittings are allowed by the system, worst case sizes of the range shall be included in the test tank, in accordance with the requirement of the *host tank* Standard as described in Clause 4.1.1. These fittings shall also be subject to Subsection 5.2.2, Pipe Torque and Bending Tests.

5.1.2.5 The test tank is permitted to be buried or partially buried in a test pit in accordance with Subsection 5.2.1, General Sample and Test Preparation at any suitable location in order to facilitate testing. *Structural systems* shall remove the *host tank* “mold” from the test tank prior to burial.

5.1.2.6 Any special test samples required for Subsection 5.1.3, System Material Tests or Subsection 5.3.1, General Sample and Test Preparation shall use the same materials and processes, simulate the test tank surface(s) as best as possible, and shall use different *retrofit system* and *host tank* colors to facilitate test measurement and assessment.

5.1.2.7 For *lining and upgrade systems* in preparation for Subsection 5.2.4, Saturated Soil Load Test, (2) special test holes as sized below shall be cut into the *host tank* along the bottom centreline within 10.2 cm of the middle and corner. These holes may be temporarily plugged or covered in order to apply the system as intended without either expanding the internal unbonded area beyond the hole, or creating additional strength to the hole.

- A *Lining systems* - 10.2 cm (4.0 in) diameter; or
- B *Upgrade systems* - 30.5 cm (12 in) diameter.

5.1.2.8 For *upgrade and structural systems* in preparation for the Subsection 5.2.5, Interstitial Communication Test, a 3.2 mm test hole located no closer than the centre of the tank head opposite the monitor pipe, and feed tube shall be installed through the tank system’s internal or external shell to the interstitial space. The hole and tube may be created before or after installation, but shall be capable of temporary sealing (such as use of a shutoff valve) under other applicable pressure and vacuum test conditions.

5.1.3 System Material Tests

5.1.3.1 Following system installation in each test tank, the thickness of the overall system, and functional layers if necessary, shall be measured in accordance with the manufacturer’s instructions at several different locations (top, bottom, middle of heads and shell). At least 20 measurement points shall be taken, and the minimum and average thickness values shall be within the manufacturer’s specifications and Section 5, Performance.

5.1.3.2 Additional material properties identified as critical system requirements by the manufacturer prior to use of the tank, such as barcoll hardness and/or ash content for fibreglass, or tensile and/or elongation for thermoplastics, shall be conducted in accordance with the manufacturer’s instructions. These material property values shall comply with the manufacturer’s minimum specifications.

5.1.3.3 Additional post installation examinations or tests identified as critical system requirements by the manufacturer prior to use of the tank, such as seam inspection or spark testing, shall be conducted in accordance with the manufacturer's instructions. These tests shall comply with the manufacturer's specifications.

5.1.3.4 Any destructive tests are permitted to be conducted on specially prepared samples that are separate from the test tank, provided they use the same materials and processes, and simulate the test tank surface. See Subsection 5.3, Long Term Compatibility, for additional information on samples for specific Bond Strength, Flexural Strength and Tensile Strength tests.

5.1.4 System Leakage Tests

5.1.4.1 Following the System Material Tests for each test tank, there shall be no leakage or damage of the new *primary tank*, *secondary containment*, and/or interstitial space formed by the *retrofit system*, in accordance with the manufacturer's instructions. These minimum test methods for strength and leakage used shall be at least:

- A *Lining systems* - Either a pressure of 20.7 kPa for 6 h or 34.5 kPa for 4 h, or a vacuum of -20.7 kPa (minus 3.0 psi) for 6 h or -34.5 kPa (minus 5 psi) for 4 h applied to the new *primary tank*;
or
- B *Upgrade and structural systems* - Either a pressure of 20.7 kPa (3.0 psi) for 2 h or 34.5 kPa (5 psi) for 1 h, or a vacuum of -20.7 kPa (minus 3.0 psi) for 2 h or -5 psi (minus 34.5 kPa) for 1 h applied to the interstitial space..

NOTE: The above leakage tests are permitted to determine compliance by use of either leak detection or gauge differential methods.

5.1.4.2 Leak detection methods for pressurized air shall use a soap suds or equivalent solution applied to all surfaces of the inner or outer tank surfaces as applicable. Formation of any bubbles indicates leakage.

5.1.4.3 Gauge differential methods shall be defined as no more than a 0.34 kPa loss of the initial pressure or vacuum over the test time, using a calibrated gauge accurate to at least 0.07 kPa.

5.1.4.4 A pause time of approximately 15 min between reaching the desired test pressure or vacuum, and reading the initial gauge values shall be permitted to account for any tank deflections under these conditions.

5.1.4.5 If temperature variations during the test time may skew the results, it shall be permitted to adjust the pressure or vacuum by using the Ideal Gas Law, $PV = nRT$, based on the tank interior start and end primary or interstitial temperatures.

5.1.4.6 Damage of the *retrofit system* shall be defined as no visible cracking, crazing, warping, disbonding, delamination, or any additional unsuitable characteristics identified by the manufacturer in their instructions.

5.2 TANK BURIAL TESTS

5.2.1 General Sample and Test Preparation

5.2.1.1 The worst case representative test tank type(s) and size(s) shall be selected and installed with the *retrofit system* in accordance with all applicable requirements in Section 5, Performance, in preparation for conducting the appropriate Tank Burial Tests. The test tank(s) shall then be installed in a test pit and backfilled with sand or pea-gravel to the tank shell top.

5.2.1.1.1 For *retrofit systems* rated for *repairs*, the test tank shall contain *repairs* made to the maximum allowable damage of the *host tank* in accordance with Clause 5.1.2.3.1.

5.2.1.1.2 For *lining* and *upgrade systems*, the test tank shall contain special test holes in the *host tank* in accordance with Clause 5.1.2.7 to assess system strength.

5.2.1.1.3 For *upgrade* and *structural systems*, the test tank shall contain a special test hole in accordance with Clause 5.1.2.8 to assess interstitial communication.

5.2.1.1.4 For *structural systems*, the *host tank* "mold" as allowed by Clause 5.1.2.3 exception shall be removed prior to burial.

5.2.1.1.5 Any new or *repaired* manways and fittings shall be constructed in accordance with the *host tank* standard in accordance with Clauses 5.1.2.2 and 5.1.2.4.

5.2.1.2 The test tank shall be held in place using anchors or other hold down methods in accordance with the original tank manufacturer's instructions, and shall be capable of withstanding the buoyant forces imposed by the tests. The applicable tests shall be conducted in the order as written in this Subsection.

5.2.1.3 The test pit may be either a full below grade excavation or partial at grade mound, but shall be capable of simulating a burial depth combination of the test tank maximum diameter and burial depth for which the *retrofit system* is rated. The test pit shall also be capable of holding water to at least the tank top.

5.2.1.4 The test tank functional openings shall be provided with connecting pipes long enough to extend beyond the burial and water levels in order to facilitate testing and measuring. Unused openings shall be plugged.

5.2.1.5 The test tank interior (newly formed primary) shall be accessible through the manway/riser high enough to extend beyond the burial and water levels in order to perform necessary post-test inspection and evaluation.

5.2.1.6 Means of providing pressure and/or vacuum, and measurement of these values as required by the applicable tests shall be made through the openings. Any openings shall be capable of sealing to eliminate leaks.

5.2.2 Fitting torque and bending tests

5.2.2.1 Following the General Sample and Test Preparation, any new or *repaired* fittings added to the test tank and required to be tested in accordance with Clause 5.1.2.4 shall be connected to 1.2 m lengths of Sch 40 steel pipe, and subjected to the tests below before backfilling the tank top for the remainder of the Tank Burial Tests.

- A Pipe Torque Test - Each pipe shall be threaded into the fitting using common sealing compounds, then tightened to the torques for each size in accordance with CAN/ULC-S615, Standard for Fibre Reinforced Plastic Underground Tanks for Flammable and Combustible Liquids.
- B Pipe Bending Test - Each pipe shall then be subject to bending moments applied to the pipe top in parallel and perpendicular directions to the tank in accordance with CAN/ULC-S615, Standard for Fibre Reinforced Plastic Underground Tanks for Flammable and Combustible Liquids.

5.2.2.2 The fittings shall not crack, split, have stripped threads, or sustain other damage that leads to leakage. Repeat leakage tests in accordance with Subsection 5.1.4, System Leakage Tests, shall be used to determine compliance and damage as defined in Clause 5.1.4.6. These assessments may be conducted after each, or all, Tank Burial Tests.

NOTE: Leak testing of all fittings and surrounding system area is recommended prior to conducting other tests.

5.2.3 Interstitial Strength Test

5.2.3.1 Following the Fitting Torque and Bending Test, with the buried tank empty and *primary tank* vented, each interstitial space formed by the *retrofit system* shall be subjected to the simulated abnormal test and/or monitor conditions below for at least 1 hr at each condition as applicable:

- A Vacuum Systems - The lowest value of 1.5 X or 10.3 kPa below the rated interstitial test/monitor vacuum, or -34.5 kPa, applied to the interstitial space; and/or
- B Pressure Systems - The highest value of 2.0 X or 20.7 kPa above the rated interstitial test/monitor pressure, or 34.5 kPa, applied to the interstitial space.

5.2.3.2 There shall be no interstitial leakage during the test, and there shall be no damage to the *retrofit system*. Repeat Leakage Tests in accordance with Subsection 5.1.4, System Leakage Tests, shall be used to determine compliance and damage as defined in accordance with Clause 5.1.4.6. These assessments may be conducted after each, or all, Tank Burial Tests.

NOTE: Systems rated for liquid monitoring, such as brine, shall add the hydrostatic head to the pressure values.

5.2.4 Saturated Soil Load Test

5.2.4.1 Following the Interstitial Strength Tests, the test pit shall be flooded with water to the tank shell top, with structural test holes in accordance with Clause 5.1.2.7 uncovered, and the empty *primary tank* subjected to the simulated soil and water loads below at the maximum rated burial depth and additional vacuum:

- A Burial Loads - Combined vacuum of -17.9 kPa for the required 900 mm minimum burial depth rating, in addition, -19.9 kPa/m for any optional ratings exceeding the 900 mm minimum burial depth applied to the *retrofitted tank assembly* for at least 18 h, followed by;
- B Additional Vacuum - Additional vacuum of -6.9 kPa for *lining systems*, -10.34 kPa for *upgrade systems*, or -13.8 kPa for *structural systems* applied to the *primary tank* for at least 5 min.

5.2.4.2 There shall be no interstitial leakage during the test, and there shall be no damage to the *retrofit system*. Repeat Leakage Tests in accordance with Subsection 5.1.4, System Leakage Tests, shall be used to determine compliance and damage as defined in accordance with Clause 5.1.4.6. These assessments may be conducted after each, or all, Tank Burial Tests.

NOTE: The burial load vacuum may be adjusted using a -19.9 kPa/m value, if the water height is above the tank shell top.

5.2.5 Interstitial Communication Test

5.2.5.1 Following the Saturated Soil Load Test, with the pit still flooded to the tank shell top, the *primary tank* shall be filled with water to rated capacity, and all manufacturer recommended interstitial monitoring methods, shall demonstrate a leakage communication rate of not less than 914 mm/hr.

Exception: Systems with a continuous unobstructed interstitial space of at least 3.2 mm between primary and secondary walls are exempt.

5.2.5.2 The leak shall be simulated by introduction of either air or water through the 3.2 mm communication test hole in accordance with Clause 5.1.2.8 located no closer than the center of the tank head opposite the monitor pipe.

5.2.5.2.1 The test(s) shall be conducted with the interstitial space at the pressure, vacuum and/or atmospheric conditions that are least likely to detect a leak, based on the manufacturer's recommended rating(s).

5.2.5.2.2 Tests using water shall control the flow into the hole from a reservoir, valve and tube at a head maintained at no more than 91.4 cm (3.0 ft) above the tank top during the test.

5.2.5.2.3 Tests using air shall control the flow into the hole from a valve and tube from atmosphere without pumps or other means to assist interstitial changes in pressure or vacuum.

5.2.5.3 The length used to calculate the communication rate shall be the distance between water entry hole and the monitor detection area measured along the tank inner surface.

5.2.5.4 The test time shall start when liquid enters the interstitial space and shall end when a leak is detected as follows:

- A For vacuum or pressure monitors - a ± 3.4 kPa change in vacuum or pressure; and/or
- B For liquid sensing monitors - a positive indication of liquid detected in the collection sump.

5.3 LONG TERM COMPATIBILITY

5.3.1 General Sample and Test Preparation

5.3.1.1 All samples evaluated for the appropriate Physical Property and Visual Exam Test(s) as required for each *retrofit system*, *host tank* and material type as appropriate for the test(s) in accordance with Subsection 5.3.2, Physical Property and Visual Exam Tests, shall be representative of the *retrofit system* materials and processes applied to the *host tank(s)* for:

- A Visual Exam (All *retrofit systems*) - Cutting them from the tank(s) in accordance with Clause 5.1.2.3 after all Burial Tests are completed and/or preparing special samples that are equivalent to the tank in accordance with Clauses 5.1.2.6 and 5.3.1.5;
- B Bond Strength (*Lining or upgrade systems*) - Cutting them from the tank(s) in accordance with Clause 5.1.2.3 after all Burial Tests are completed and/or preparing special samples that are equivalent to the tank in accordance with Clauses 5.1.2.6 and 5.3.1.6, that evaluate the direct bonding layer; and

- C Flexural Strength or Tensile Strength (*upgrade* or *structural systems*) - Preparing special samples that are equivalent to the prepared tank in accordance with Clauses 5.1.2.6 and 5.3.1.7 or 5.3.1.8, except without the *host tank* backing.

NOTE: It is recommended these samples are initially cut or prepared in approximately 929 cm² sheets, which can then be further prepared and/or machined in final plaque/bar form before or after each required exposure.

5.3.1.2 Separate sample sets are required for each combination of *host tank* material (steel and/or FRP) and worst case *retrofit system* (*lining, upgrade* and/or *structural system*) based on material and thickness variations.

5.3.1.3 All samples shall be within the manufacturer's allowable thickness range, and requirements of Section 4, Construction, but are permitted to be either flat or of uniform curvature, provided comparative tests are conducted on the same surface shapes.

5.3.1.4 All samples shall not contain damage (as defined by Clause 5.1.4.6) from previous testing, and cutting or milling, and the test plaques shall not contain any areas of *repaired* damage from the *host tank*.

5.3.1.5 The Visual Exam Test in accordance with Clause 5.3.2.2 shall apply to all material types, and is intended to evaluate any damage to the system and/or *host tank*. Therefore, samples shall include the complete system and if applicable, bonded to the steel or FRP *host tank*.

5.3.1.6 The Bond Strength Test in accordance with Subsection 5.3.2.3, Bond Strength Test, shall apply to all material types, and is intended to evaluate the adhesive strength between the *host tank* inner surface and system layer directly bonded to it. Therefore, samples of multi-layer systems likely to have *cohesive failure* may be modified to increase the likelihood of *adhesive failure*, such as removing interstitial or top layers.

5.3.1.7 The Flexural Strength Test in accordance with Subsection 5.3.2.4, Flexural Strength Test, shall apply to FRP or similar thermoset materials, and is intended to primarily evaluate the flexural strength of the system. Therefore, samples of the system may be formed on a removable backing, or may be removed from the *host tank* layer after samples are formed or immersed.

5.3.1.8 The Tensile Strength Test in accordance with Subsection 5.3.2.5, Tensile Strength Test, shall apply to PE or similar thermoplastic materials, and is intended to evaluate the tensile strength of the system. Therefore, samples of the system may be formed on a removable backing, or may be removed from the *host tank* layer after samples are formed or immersed.

5.3.1.9 If potential wicking through cut sample edges or permeation through reduced sample layers normally protected from exposure could occur, it is permitted to seal the edges (wall materials and interstitial space) or coat the surfaces (tank back and system front), prior to exposure.

5.3.1.10 Any sealing or coating materials used for protecting exposed sample edges or surfaces shall be the same system material used on the front (primary containment side). The increased thickness shall not significantly increase material strength, or the as-received (AR) sample shall be prepared in the same manner prior to testing.

5.3.2 Physical Property and Visual Exam Tests

5.3.2.1 *Retrofit systems* shall be evaluated to the separate adhesion and/or material strength tests and pass/fail criteria described in Table 2, to measure and establish the initial as received (AR) benchmark strength characteristic for comparison with additional test values after each Test Sample Exposures in accordance with Subsection 5.3.3, Test Sample Exposure.

5.3.2.2 Visual Exam Test

5.3.2.2.1 After Sample Exposures in accordance with Subsection 5.3.3, Test Sample Exposure, all systems shall be visually examined for damage to the system materials, and/or *host tank* as applicable.

5.3.2.2.2 Three plaque samples at least 7.7 cm x 12.8 cm in size shall be prepared for each exposure condition. Systems intended to be bonded to the *host tank* shall include these material(s) in the test sample. Samples may be edge sealed and coated on the *host tank* side in accordance with Clause 5.3.1.9.

5.3.2.2.3 Following exposures, there shall be no damage to the system as defined in Clause 5.1.4.6, and there shall be no damage to the *host tank* /bonded system interface, such as loss of adhesion or metal corrosion.

5.3.2.3 Bond Strength Test

5.3.2.3.1 All adhesive strength measurements between the *lining* or *upgrade system* layer directly bonded to the *host tank* shall be conducted in accordance with ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Tester. Any of the portable test units may be used with the corresponding method, but shall be consistent throughout the evaluation. See Appendix B, Bond Strength Test Pull-Off Disks, for disk bonding recommendations.

5.3.2.3.2 A minimum of 10 failure measurements for the initial as-received (AR) and each exposed sample sets shall be taken. The failure pressure, location, and percent of tank or system area for each test shall be recorded for use in the evaluation, to assess acceptable results between AR and each exposed sample set as follows:

- A Min 70% of samples within each set with *cohesive failures* in at least 50% of the *host tank* substrate, regardless of failure strength;
- B Min 1.72 mPa failure strength (average of all samples) for sample sets with mixed *adhesive failures* and *cohesive failures*; or
- C Min 70% strength retention (average of all samples) for sample sets with mixed *adhesive failures* and *cohesive failures*.

5.3.2.4 Flexural Strength Test

5.3.2.4.1 All Flexural Strength measurements of thermoset materials shall be conducted on the complete system without the *host tank* substrate in accordance with ASTM D790, Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

5.3.2.4.2 A minimum of 5 samples shall be tested with the bar size and load rate determined by the system nominal thickness. The load shall be applied to the back (*host tank* side) center of the test bar.

5.3.2.4.3 The ultimate strength in Pascals (Pa) calculated from the break load and sample center area shall be used for the initial and subsequent comparative measures. The average flexural strength of each exposed sample set shall be at least 70% of original.

5.3.2.5 Tensile Strength Test

5.3.2.5.1 All Tensile Strength measurements of thermoplastic materials shall be conducted on the complete system without the *host tank* substrate in accordance with ASTM D638-91, Standard Test Method for Tensile Properties of Plastics.

5.3.2.5.2 A minimum of 5 samples shall be tested with the bar size and load rate determined by the system nominal thickness. Failures caused by end-grip stress shall not be used.

5.3.2.5.3 The ultimate strength in kPa calculated from the break load and sample center area shall be used for the initial and subsequent comparative measures. The average tensile strength of each exposed sample set shall be at least 70% of the original.

5.3.3 Test Sample Exposures

5.3.3.1 All samples required for applicable repeat Physical Property Tests in accordance with Subsection 5.3.2, Physical Property and Visual Exam Tests, shall be prepared in accordance with Subsection 5.3.1, General Sample and Test Preparation, and subjected to the long term exposure conditions described in Table 3.

5.3.3.2 Thermal Aging of samples shall be conducted in a circulating type air oven that maintains temperatures within ± 2.0 °C of the test temperature. Samples shall be arranged to allow air flow across front and back surfaces.

5.3.3.3 Test Fuel samples shall be stored in separate closed containers resistant to the specific fuels, and maintained at a temperature within ± 2.0 °C of the test temperature. Samples shall be fully immersed and arranged to allow unrestricted fuel exposure on all surfaces.

5.3.3.4 Following exposure, samples prepared for the Visual Exam Test in accordance with Subsection 5.3.2.2, Visual Exam Test, shall be visually examined within 12 hrs of removal from each exposure fluid, and any damage documented. The samples shall not show any noncompliant damage as defined in Clause 5.3.2.2.3.

5.3.3.5 Following exposure, individual test plaques/bars as necessary for the appropriate methods, shall be cut/machined and tested within 36 h of removal from each exposure fluid. Repeat Physical Property Test(s) shall be conducted in the same way as the as-received (AR) samples, and shall comply with the requirements of Subsections 5.3.2.3, Bond Strength Test, to 5.3.2.5, Tensile Strength Test, as appropriate.

5.4 INSTALLATION AND PRODUCTION TESTS

5.4.1 General

5.4.1.1 All *retrofit systems* shall be subjected to material, process, construction and performance tests required by the manufacturer in accordance with their instructions to adequately control the quality of the system(s). The manufacturer shall retain records to verify each system was properly installed.

5.4.1.2 The instructions per Section 6, Markings, shall include minimum details for *host tank* assessment, cleaning, *repair*, preparation and installation as applicable for each system; and production testing as necessary in accordance with Subsection 5.4, Installation and Production Tests.

5.4.1.3 The installer(s) shall be trained and qualified by the manufacturer for proper installation of their system(s) in accordance with their instructions. The manufacturer shall retain training records.

5.4.1.4 For systems that utilize pre-fabricated materials or components, any necessary quality controls or production tests are permitted to be conducted at the factory prior to shipment to the installation site.

5.4.2 Tank Tests

5.4.2.1 Prior to installation of the *retrofit system*, the *host tank* shall be verified as meeting the manufacturer's minimum criteria, for which it has been evaluated, based on Clause 4.1.1 and Subsection 5.1.2, System Installation.

5.4.2.2 The *host tank* shall be within the system's evaluated design parameters, including tank type/material and dimensions, opening size, and allowable damage, as identified in Clause 4.1.2.

5.4.2.3 The *host tank* shall be readied for system's evaluated installation, including tank cleanout, inspection, measurement, *repair*, leak testing and surface preparation, as identified in Clause 4.1.3.

5.4.3 Impact Test

5.4.3.1 The manufacturer or installer shall conduct applicable analytical tests on critical materials, such as identification tests (Infrared Spectroscopy [IR], Differential Scanning Calorimetry [DSC], Thermogravimetric Analysis [TGA], etc.), component mixing tests (ash content, density, QMS, etc.), property tests (hardness, adhesion, strength, etc.), to ensure the correct material(s) are being/have been used in the system construction, and have been properly installed prior placing the tank in service.

5.4.3.2 The installer shall conduct applicable measurement tests on critical material layers and/or the overall system thickness during or after installation to verify the recommended minimums were applied. Other necessary tests to verify full and complete coverage of the *host tank*, such as visual exams or spark testing, shall be conducted. The thickness measurements and other tests shall be similar to those evaluated in 5.1.3, System Material Tests.

5.4.4 Leakage Test

5.4.4.1 Following system installation, each new *primary tank* and/or interstitial space formed by the *retrofit system* shall be tested for leakage in accordance with the manufacturer's instructions. The test methods and values shall be similar to those evaluated in 5.1.4, System Leakage Tests.

5.4.4.2 There shall be no leakage. If leaks are found, they are permitted to be *repaired* in accordance with the manufacturer's instructions, and re-tested for leakage.

6 MARKINGS

6.1 Each *retrofitted tank assembly*, after successful completion of tests in accordance with Subsection 5.4, Installation and Production Test, shall be marked with the required information on or near the manway. Markings types shall be permanent and legible tags or labels, or equivalent types that are permanently bonded. Reduced language or abbreviations may be used if the full information is also provided in the instructions.

6.2 Permanent markings are defined as use of die or ink stamping, paint stenciling, etching or molding. Adhesive labels shall be evaluated for the intended surface for outdoor use in accordance with UL 969, Standard for Marking and Labeling Systems, using minimum/maximum temperature ratings of -29 °C to 60 °C, exposure to water, exposure to ultraviolet light, and occasional exposure to fuels.

6.3 Legible markings are defined as raised, indented, or printed text in minimum 2.0 mm high letters in a contrasting color to the product or label surface. Other methods that are equivalent may be alternatively used.

6.4 Each *retrofitted tank assembly* shall be marked with the following general information and ratings:

- A System manufacturer's name, trade name, trademark; serial number and model number; and the qualified installation company name and installation date (minimum month and year);
- B System Type - "Tank Internal _____ Retrofit System" where () is "Lining", "Upgrade" or "Structural" as applicable;
- C System Ratings - for "Automotive Fuels" and for "Max ___m Burial" where (___m) is the evaluated system maximum burial depth;
- D Leak Test Values - "Leak Test @ Max ___kPa " where (___kPa) are the evaluated system maximum leak test P/V values; and
- E Interstitial Monitor Values - "___ Monitor @ Max ___ kPa (___psi)" where (___kPa) are the evaluated system maximum interstitial monitor P/V values.
- F "SUITABLE FOR PETROLEUM PRODUCTS, OXYGENATES AND OXYGENATED FUEL BLENDS, or X"

where X is the special fluid specified in Table 3, Part B, and to which the *retrofit system* has been tested.

- G Standard number with year under which the *retrofit system* was tested,
e.g. CAN/ULC-S669-XX.

NOTE: Manufacturers should be aware that the *authority having jurisdiction* may also require that the mark of the certifying agency be included on each *retrofit system* in an equivalent location as described in Clause 6.1.

7 INSTRUCTIONS

7.1 Each *retrofit system* shall be provided with manufacturer instructions in either hard copy or e-copy form, that identify all details necessary for *qualified persons* to properly install the evaluated system(s) in a used tank.

7.2 The instructions shall be transferred by the *qualified person* or manufacturer to the owner, operator or other responsible person of the facility where the installation is done.

7.3 All instructions shall be preceded by the following statements in bold text minimum 8.0 mm high:

“IMPORTANT INFORMATION - FOLLOW ALL INSTRUCTIONS”

and

« INFORMATION IMPORTANTE – VEILLER SUIVRE TOUTES LES INSTRUCTIONS »

“FOR INSTALLATION ONLY BY MANUFACTURER QUALIFIED PERSONS”

and

« POUR INSTALLATION PAR UNE PERSONNE QUALIFIÉ PAR LE MANUFACTURIER »

“CONTACT AUTHORITY HAVING JURISDICTION PRIOR TO INSTALLATION”

and

« CONSULTER L’AUTORITÉ COMPÉTENTE AVANT L’INSTALLATION »

and shall include at least the minimum required information as follows:

- A General system information and ratings as specified in Clause 6.4;
- B Specific *host tank* selection, *repair* and preparation steps as specified in Subsection 5.4.2, Tank Tests, prior to system installation;
- C Specific system material, component and installation steps as specified in Subsection 5.4.3, Impact Test;
- D Specific system post installation inspection, measurement and leakage tests as specified in Subsection 5.4.4, Leakage Test; and
- E Specific instructions for inspection and maintenance of the system.

TABLES

TABLE 1
PERFORMANCE TESTS FOR RETROFIT SYSTEMS

(Reference: Clause 5.1.1.1)

	<i>Lining systems</i>	<i>Upgrade systems</i>	<i>Structural Systems</i>
Section 5 – Performance			
Subsection 5.1 – General			
5.1.2 System Installation	Yes	Yes	Yes
5.1.3 System Material Tests	Yes	Yes	Yes
5.1.4 System Leakage Tests	Yes	Yes	Yes
Subsection 5.2 – Tank Burial Tests			
5.2.2 Fitting Torque and Bend Tests	<i>New and Repaired</i>	<i>New and Repaired</i>	Yes
5.2.3 Interstitial Strength Test	No	Yes	Yes
5.2.4 Saturated Soil Load Test	Yes	Yes	Yes
5.2.5 Interstitial Communication	No	Yes	Yes
Subsection 5.3 – Long Term Compatibility Tests			
5.3.2 Physical Property and Visual Exam Tests	As Applicable	As Applicable	As Applicable
5.3.2.2 Visual Exam	Yes	Yes	Yes
5.3.2.3 Bond Strength	Yes	Yes	No
5.3.2.4 Flexural Strength	No	Thermosets	Thermosets
5.3.2.5 Tensile Strength	No	Thermoplastics	Thermoplastics
5.3.3 Test Sample Exposures	Yes	Yes	Yes

TABLE 2
PERFORMANCE TESTS FOR RETROFIT SYSTEMS

(Reference: Clause 5.3.2.1)

	<i>Lining systems</i>	<i>Upgrade systems</i>	<i>Structural systems</i>
Visual Exam	All Materials	All Materials	All Materials
See Subsection 5.3.2.2 Details	<ul style="list-style-type: none"> • No disbonding • No system damage • No tank corrosion 	<ul style="list-style-type: none"> • No disbonding • No system damage • No tank corrosion 	<ul style="list-style-type: none"> • No system damage
Bond Strength	Bond Layer @ Min	Bond Layer @ Min	N/A
See Subsection 5.3.2.3 Details	<ul style="list-style-type: none"> • 70% PP retention, or • 1.72 mPa failure, or • 70% <i>cohesive failure</i> 	<ul style="list-style-type: none"> • 70% PP retention, or • 1.72 mPa failure, or • 70% <i>cohesive failure</i> 	
Flexural Strength	N/A	Thermosets @ Min	Thermosets @ Min
See Subsection 5.3.2.4 Details		<ul style="list-style-type: none"> • 70% PP retention 	<ul style="list-style-type: none"> • 70% PP retention
Tensile Strength	N/A	Thermoplastics @ Min	Thermoplastics @ Min
See Subsection 5.3.2.5 Details		<ul style="list-style-type: none"> • 70% PP retention 	<ul style="list-style-type: none"> • 70% PP retention

**TABLE 3
LONG TERM EXPOSURE CONDITIONS**

(Reference: Clause 5.3.3.1)

	Thermal Aging per 5.3.3.2	Combustible Liquids per Clause 5.3.3.3	Flammable Liquids per Clause 5.3.3.3
All retrofit systems	180 days @ 70 ° ±2 °C Air Oven	180 days @ 40 °C Immersion in: a) Fuel F (!) and b) FB25a (!)	180 days @ 40 °C Immersion in: a) CE25a (*) and b) CE85a (*)
(!) The chemical formulation for aggressive biodiesel used in mixing FB25a can be found in Appendix A. Fuel F = ASTM D975 Diesel Fuel #2 Grade S15 and B = UL B100.			
(*) The chemical formulation for aggressive alcohols used in mixing CE25a and CE85a can be found in Appendix A. C = ASTM Ref Fuel C and E = Ethanol.			

APPENDIX A (INFORMATIVE) – TEST FUEL FORMULATIONS

A1 REPRESENTATIVE AGGRESSIVE COMBUSTIBLE TEST FUEL MIXTURES AND UL-B100

A1.1 The following test fuels represent chemical and physical characteristics of typical commercial diesel, biodiesel and blends thereof with aggressive contaminants that may be found in these fuels:

1. F75/B25a where the numbers indicate the percentage by volume mixture and

F = ASTM D471 (Standard Test Method for Rubber Property – Effect of Liquids) Reference Fuel “F” except Grade D2 S15 is to be used

B = ASTM D6751, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels, Biodiesel except 100 percent Soy Feedstock types are to be used.

a = Aggressive components mixed with B to form UL B100 Aggressive Biodiesel Stock for additional blending with F.

2. UL B100 Aggressive Biodiesel Stock containing less than 0.5 percent volume combined water and decanoic acid shall be based on the approximate formula below (*) to achieve a final 1.00 ± 0.02 Acid Number of the mixture per ASTM D 664, Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration.

1.00 L Biodiesel (per “B” above)

2.00 g DI Water (!)

2.60 g Decanoic Acid (!)

Final adjustments after measuring the mixture per ASTM D 664 shall be done by adding biodiesel or decanoic acid as necessary to achieve the 1.00 ± 0.02 Acid Number

(*) The formula is approximate since each source of biodiesel may have variations in specific gravity and initial Acid Number that require measurement and final adjustment as specified.

(!) Decanoic acid crystals are insoluble in water, so it is recommended they be finely ground and thoroughly dissolved in the biodiesel before adding water to the overall solution.

A2 REPRESENTATIVE AGGRESSIVE FLAMMABLE TEST FUELS AND MIXTURES

A2.1 The following test fuels represent chemical and physical characteristics of typical commercial Gasoline, Oxygenated Gas, Low Blend Ethanol, High Blend Ethanol, and Mid-range Blends thereof with aggressive contaminants that may be found in these fuels:

1. CE25a and CE85a where the numbers indicate the percentage by volume mixture and

C = ASTM D 471 Reference Fuel “C” (50/50 mix of iso-octane and toluene)

E = Ethanol per SAE J1681 App E

a = Aggressive components in aggressive alcohols per SAE J1681 App E

APPENDIX B (INFORMATIVE) – PULL-OFF DISK PREPARATION

B1 BOND STRENGTH TEST PULL-OFF DISKS

B1.1 Since available adhesives for attachment of the pull-off disk to the test sample surface may either have less strength than the system material evaluated, or may become degraded from liquids absorbed during exposures, it is permitted to do any of the following to assure adequate disk attachment:

- A Attachment of the disk after fuel exposure, provided only a surface adhesive is used, with minor surface preparation (cleaning).
- B Attachment of the disk within the material matrix or surface using the evaluated system material(s) prior to exposures.
- C Use of surface grinding, chemical etching or other cleaning/preparation techniques to attach the disk before or after exposures.
- D Use of thermal, chemical or other curing techniques to attach the disk as recommended by the adhesive or material supplier.

It is also recommended that a sufficient number of extra samples for each fuel be immersed to ensure the minimum number for evaluation.

