External corrosion protection systems for flammable and combustible liquids underground storage tanks

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Abstract

This paper gives an overview on the evolution and standards development of the external corrosion protection systems used for flammable and combustible liquids underground storage tanks (USTs) in North America. The paper first describes the different types of corrosion protected USTs for flammable and combustible liquids in North America. It then reviews the advantages and disadvantages of each of the corrosion protection systems used. Finally, it looks forward to some of the technical trends in the North American UST industry and the standard certification process for underground tank external corrosion protection, with updates on the technology and standards in the international UST industry.

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1. Introduction

The US Federal Highway Administration (FHWA) recently revealed a breakthrough 2-year study on the direct costs associated with metallic corrosion in nearly every US industry sector, from infrastructure and transportation to production and manufacturing (Brongers, 2001). Results from the study show that the total annual estimated direct cost of corrosion in the US is a staggering $276 billion US dollars – approximately 3.1 percent of the nation's gross domestic product. According to this study, the US has approximately 8.5 million regulated and non-regulated aboveground and underground storage tanks (USTs) that contain hazardous materials (HAZMAT), mostly petroleum products. The total cost of corrosion for the storage tanks is $7.0 billion US dollars per year, with an estimation of $4.5 billion for aboveground storage tanks (ASTs) and $2.5 billion for USTs. The total estimated number of tanks is summarized in Table I. In this study, the regulated tanks are divided into two groups – Federal EPA Spill Prevention Countermeasure and Control (SPCC)-regulated and Federal EPA Office of Underground Storage Tanks (OUST)-regulated.

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Table I Estimated number of ASTs and USTs for HAZMAT in the US (as of 2000)

Regulated by	Stored product	Number of tanks	
SPCC[a]	Petroleum	ASTs	2,373,276
		USTs[a]	133,400
OUST	Petroleum/HAZMAT	USTs	742,805
	Heating oil	ASTs/USTs	3,283,752
Unregulated	LPG/propane	Mostly ASTs	1,825,984
	Kerosene	Mostly ASTs	147,383
		Total	8,506,600

Notes: [a] Please note that under new EPA rules, USTs are no longer regulated by SPCC.

On 17 July 2002, the EPA issued a final rule amending the Oil Pollution Prevention regulation promulgated under the authority of the Federal Water Pollution Control Act (Clean Water Act). This rule addresses requirements for SPCC plans and some provisions may also affect facility response plans (FRPs). The new SPCC rule was effective on 16 August 2002. The new EPA rules exempt completely buried storage tanks subject to all of the technical requirements of the UST regulations (40 CFR Parts 280 or 281). Nevertheless, as it can be seen from Table I, USTs for flammable and combustible liquids (mostly petroleum) represent a very large and dominant portion of the HAZMAT storage sector in the US. The largest costs for these USTs are incurred when leaking USTs must be replaced with new tanks. The soil remediation and oil spill clean-up costs are significant as well. In Canada, it is estimated that the federal government has approximately 10,000 storage tanks on its lands for petroleum products alone. The Auditor General's 1995 report made reference to a Consulting and Audit Canada study that estimated that some 20 percent of these tanks have leaked (COMPROs, 1998).

Corrosion is estimated to be responsible for approximately 65 percent of the failure of these UST systems in North America, while 35 percent is due to other causes such as third-party damage. Experience has shown that the vast majority of USTs and piping failures are associated with external corrosion, primarily due to their exposure to corrosive soils, while only a small percentage can be attributed to internal corrosion (Brongers, 2001). The impact of these UST failures is more than just cost. Releases from USTs – from spills, overfill, or leaking tanks and piping – can cause fires or explosions that threaten human safety. Releases from USTs can also contaminate the groundwater that many of us depend on for the water we drink. With over 50 percent of the US population using ground-water as their main source of drinking water, the US Congress passed legislation in 1984, which resulted in the finalization of the US EPA regulations in 1988 to regulate USTs. Under the stringent regulations, all USTs need to have corrosion protection systems, overfill protection, and spill protection. The deadline for the compliance was 22 December 1998. Since 1988, the number of OUST-regulated USTs in the US has decreased from approximately 1.3 million to 0.75 million due to the regulations. During this period, a trend of replacing multiple small USTs with fewer larger ASTs was evident. Although the 1998 deadline has passed, many USTs still do not meet the requirements. As a result, while there are many USTs being closed, repaired, or replaced to achieve the necessary compliance with regulations over the past 10 years, the number of confirmed HAZMAT releases actually increased. As of September 2001, US EPA confirmed that there are over 418,000 UST releases in the US (RCRA, 2002), compared to that of 287,000 in April 1995 (USTs, 1995). Approximately 60 percent or more of these releases has affected groundwater. With most tank systems now having external corrosion protection, many of the failures of UST systems are from the pipes. As a result, the current trend is for releases to come from overfills, dispenser areas, and sump pumps. The FHWA corrosion study concluded that in the past 10 years, the most common problem and the major corrosion costs associated with USTs occurred at the gasoline service stations that did not comply with the regulation and did not have corrosion protection on their USTs. The owners of these USTs can be cited for violations and can be subject to penalty fees.

Fortunately, the USTs tank owners have choices to replace, upgrade or remove their tanks and the long-term prognosis for safe, economical USTs is good, as new corrosion protection and new tank technologies continues to evolve. Over the past 35 years the North American storage tank industry, together with efforts from manufacturers of corrosion protection systems (such as protective coatings), has addressed the challenges for applying excellent external corrosion protection systems to USTs for flammable and combustible liquids. The excellent R&D and standards development activities around the Underwriters Laboratories UL 1746 standard has made it possible for the industry to have the ongoing history of providing the end users with well-protected new USTs with almost zero failures due to external corrosion. This paper gives an overview on the evolution and standard development of the external corrosion protection systems used for flammable and combustible liquids' USTs in North America. The paper first describes the different types of corrosion protected USTs in North America. It then reviews the advantages and disadvantages of each of the corrosion protection systems used. Finally, it looks forward to some of the technical trends in the North American UST industry and the standard certification process for underground tank external corrosion protection, with updates on the technology and standards in the international UST industry.

2. Definitions and standardization of external corrosion protection systems for USTs

In the US, USTs for the handling and storage of petroleum and hazardous substance are regulated by the US EPA OUST (40CFP 280) (CFP, 1999a). OUST defines *a UST as a tank and any underground piping connected to the tank that has at least 10 percent of its combined volume underground*. The federal regulations apply only to USTs storing either petroleum or certain hazardous substances. Under the new EPA rules of 17 July 2002, ASTs that are 5.0 m^3 (1,320 gallon) or larger, and USTs of 159 m^3 (42,000 gallon) or larger were previously regulated by the EPA oil spill prevention program (OSPP) in conjunction with the SPCC plan (40 CFR 112) but is now regulated under SPCC (CFP, 1999b). Under the EPA-SPCC definition, USTs are those tanks that are 100 percent buried. Some kinds of tanks are not covered by these regulations:

- farm and residential tanks of 0.416 m^3 (110 gallons) or less capacity holding motor fuel used for noncommercial purposes,
- tanks storing heating oil used on the premises where it is stored,
- tanks on or above the floor of underground areas, such as basements or tunnels,
- septic tanks and systems for collecting storm water and wastewater,
- flow-through process tanks,
- emergency spill and overfill tanks.

While the standards for existing USTs are often identical to those for new USTs, there are limited circumstances where the standards for new USTs also require that they be designed and constructed in such a way as to protect them from external corrosion. As per EPA recommendation (RCRA, 2002), this can be accomplished by constructing the tank of materials that do not corrode, such as non-metallic polymeric materials, or by outfitting a steel tank with a thick layer of non-corrosive material. A third option, known as cathodic protection, uses sacrificial anodes or a direct current source to protect steel by halting the naturally occurring electrochemical process that causes corrosion. Piping that routinely contains product, and that is in contact with soils, must meet similar corrosion protection standards.

The EPA's three recommendations basically involve two types of USTs: one is a non-metallic tank and the other a steel tank with an external corrosion protection system of either a coating or cathodic protection or their combination. The idea of non-metallic tanks is to start from scratch with a corrosion-resistant material and to prevent corrosion altogether. The tanks can then be constructed of molded polymers or fiber-reinforced thermoset polymers. High-density polyethylene (HDPE) is commonly used for chemical storage tanks and for chemicals that contain water. However, HDPE is not applicable for the storage of flammable and combustible hydrocarbons in the US, neither can it be used for long-term storage at temperatures higher than 50°C. In the case of flammable and combustible liquids, if storing chemicals at temperatures higher than 50°C is a problem, fiberglass reinforced tanks made with resins (FRP), such as vinyl ester or epoxy, are normally used but the warranty for the tanks is limited to only 65.5°C. For more elevated temperatures, metal storage tanks are the only solution (Brongers, 2001). FRP tanks are built and installed up to 50,000 gallons. Neither FRP nor HDPE tanks are allowed by fire codes to be used to store flammable liquids aboveground, due to their lack of fire resistance. There is no right or wrong between the non-metallic tanks or steel tanks, and both types of tanks are accepted in the market.

In 2001, an inquiry to Underwriters Laboratories Inc. (UL) revealed that steel USTs and corrosion protected steel USTs accounted for 59 percent of all USTs labels sold by UL, the other 41 percent are mostly made of FRP (Geyer, 2002). Over the past 5 years, in North America, approximately 60,000 steel USTs have been built that can store approximately 1,892,706 m^3 (500,000,000 gallons) of flammable and combustible liquids (Geyer, 2002). Generally speaking, the non-metallic tanks, such as FRP tanks, are known for their inherent resistance to galvanic corrosion caused by moist soil. The steel tanks are known for their inherent structural strength. Tables II and III highlight the advantages and limitations of the two tank types, respectively.

The concept of standardizing tanks that hold flammable and combustible liquids has great appeal to tank owners, manufacturers, fire officials and insurers. Today, the North American storage tank industry is mainly governed by two standard organizations, Underwriters Laboratories Inc. (UL in the US or ULC in Canada) and the Steel Tank Institute (STI). STI was formed in 1916 as an association of steel tank manufacturers with suppliers as associate members. In 1997, the Steel Tank Association of Canada (STAC) merged with STI and formed an official STAC committee within STI's governing structure. Around the same time as STI was formed, UL, a third-party laboratory and agency specializing in certifying product safety through listing procedures, was developing its first safety standards for atmospheric steel storage tanks, UL 142.

There are two areas that each standard of UL and STI addresses. The first is the steel tank construction and the second area is steel tank anti-corrosion protection. The UL standards apply to all tank manufacturers regardless of whether they are members of the STI or not.

In 1925, UL published the first edition of its

Table II Advantages and limitations of non-metallic FRP USTs

	Advantages	Limitations
Construction	Manufactured in an automated process Standardized manufacturing and quality control procedures can be easily ensured with the automated process Constructed based on UL 1316 standard Routinely inspected by UL as the Quality Assurance contractor	Physical structural strength is not as strong as steel Environmental, health and safety issues in the workplace due to the flammable and HAZMAT used Relatively expensive set up for automated process Raw materials change due to both quality and the use of new materials to address the compatibility issue with stored products Not recommended for tanks operating at elevated temperatures (>65.5°C) Customized compartmentalizing is complicated and labor intensive
Installation	Very extensive installer training and oversight developed by the FRP industry Stiffening rings incorporated to assist the tank in resisting buckling and cracking Installation failure can be discovered quickly, and within a short period of time after installation	Very experienced and well trained installers required Tank could fail catastrophically if not installed properly or due to improper backfill Narrower and more costly backfill choice Undue stress and strain on the tank can be caused by substandard installation Tank deflection to be measured A 12 in. bedding is required Straps must be installed in pre-designated places to hold down a tank
Corrosion protection	Excellent resistance to external corrosion due to galvanic corrosion caused by moist soil Most tanks are made in a double wall form (secondary containment) to hold releases until detected and to prevent release to environment	Corrosion is not limited to metals only and FRP does corrode as well (for FRP USTs, it is internal corrosion causing concerns) Tank material degradation possible due to age Many FRP tanks produced in the early 1980s are not compatible with additives in the stored petroleum liquids such as methanol or ethanol Many single wall tank failures reported As the compositions of stored petroleum and chemicals change, the FRP tank materials have to be changed to address compatibility

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Table III Advantages and limitations of corrosion protected steel USTs

	Advantages	Limitations
Construction	Physical structural strength of steel is very strong The verification of whether a manufacturer's wall thickness is sufficient for a given installation has been developed in Roark's formula A minimum steel tank thickness can be derived for a given set of parameters, such as tank dimensional data and burial depth Customized compartmentalizing is easy and economical Constructed based on UL 58 or ULC 603M standard Routinely inspected by UL/ULC and STI	Manufactured in a job-shop application Multiple step manufacturing process (tank form, weld, test, anode installation, surface blasting, and coating)
Installation	The backfill is no longer considered an integral part of the tank's structural integrity when deriving a wall thickness with the Roark's formula When a 12 in. bedding is required, a 6 in. depth is acceptable for steel tanks anchored to a concrete pad	Single wall tanks need to be pressurized with 5 psi pressure Cathodic protection tests should be conducted Special care for piping needed to ensure the corrosion protection Steel straps should be placed over dielectric material to electrically isolate the strap and tank from each other
Corrosion protection	Various external corrosion protection systems available UL 1746 standards and STI standards available Routinely inspected by UL/ULC and STI Both single wall and double wall tanks are proven to be effective Most unprotected steel tank corrosion failures occurred at least 10-15 years after installation Steel provides complete compatibility with the full range of petroleum products available today and tomorrow	Unprotected steel tanks fail because of pitting corrosion Today, all steel USTs in North America are protected with an external corrosion protection system Continual monitoring and periodic testing is required for cathodically protected tanks

UL 58 standard for Steel Underground Tanks for Flammable and Combustible Liquids (UL, 1998). Later in 1989, UL introduced a new corrosion control standard for steel tanks; the UL 1746 Standard for External Corrosion Protection Systems for Steel USTs was developed, with the latest edition published on 8 February 2002 (UL, 2002). Local and federal regulations impose UL standards for USTs and ASTs as minimum construction requirements of any tank intended for flammable and combustible liquid storage. Tanks are listed and labeled with the UL or ULC label. Any fabricator can become qualified to obtain a UL listing by passing the minimum UL performance test requirements. STI standards, often more stringent than UL standards, are developed and regulated by STI as a service to its storage tank producing membership. All FRP USTs are made according to the UL 1316 standard.

Another standard critical to the development of the storage tank industry preceded the UL developments. It is known as NFPA 30 (the flammable and combustible liquids code), developed by the National Fire Protection Association (NFPA). Many governmental bodies today reference the NFPA standard either by legislation, statutes or ordinances to give local or regional officials an enforceable code document. NFPA 30 and the uniform fire code have language that mandates corrosion protection of ASTs and USTs. The NFPA code refers to various construction standards written by UL and STI, among other groups, as acceptable construction practices. In addition to NFPA 30, the American Petroleum Institute (API) has published several standards pertaining to the safe storage and operation of flammable and combustible liquids. The Petroleum Equipment Institute (PEI) has developed several important guideline documents for the proper installation of underground and aboveground shop-fabricated storage tank facilities. The FRP Pipe and Tank Institute serves as an organization overseeing codes and regulations to ensure that such documents are applicable to FRP tanks. Canada developed its latest requirements for USTs within the Federal Environmental Code of Practice for UST Systems Containing Petroleum Products and Allied Petroleum Products, Canadian Council of Ministers for the Environment (CCME), as published in March, 1993. All systems in Canada must

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provide secondary containment. Each province has its own set of requirements. Many of the equipment requirements are based upon ULC standards CAN4-S603M and CAN4-S603.1. ULC established a Committee on Stationary Steel Storage Containers for Flammable Liquids in 1994 to meet guidelines established under the National Standards Council of Canada for developing tank standards. The National Fire Code of Canada (1995) was prepared by the Canadian Commission on Building and Fire Codes and published by the National Research Council of Canada. It was prepared in the form of a recommended model code to permit adoption by an appropriate regional authority. Spurred by several developments during the 1990s, the Canadian and US tank markets are becoming more similar with each day – especially because of fabrication standards. The North American Free Trade Agreement (NAFTA) has been part of the reason – changing the commercial landscape on both sides of the border. Related to NAFTA's changes is the harmonization of tank standards developed by ULC and UL. Tank manufacturers in both countries have worked closely with their respective UL organizations on product safety issues for years. The effort to update steel UST corrosion control options in the Canadian ULC-S603.1 has been done using UL 1746 as a reference guideline document.

Mexico recently upgraded its requirements at service stations for USTs. PEMEX, Mexico's nationalized oil company, franchises all retail stations. In 1992 "General Specification for Project and Construction of Service Stations," all tank systems must employ secondary containment. There was a tremendous demand for USTs in 1993-94, shortly before Mexico's economy began to face some difficult times. However, nearly all chemical storage is aboveground in Mexico. The sudden demand for new UST system technology is common in various countries throughout South America also. In general, Mexico's UST standards follow closely with UL standard requirements.

Many more details of the above information about USTs and the development of standards can be seen from various articles and newsletters published by the STI at their Web site (www.steeltank.com) and from an excellent handbook on USTs, edited by Wayne Geyer (2002).

3. External corrosion protection systems for USTs

3.1 External corrosion protection systems used in the past

The external corrosion protection of USTs for flammable and combustible liquids in North America has relied heavily on the development of standards. Over the past 50 years, underground steel storage tanks have progressed from unprotected steel to the most modern coating systems that provide superior anti-corrosion protection while being environmentally friendly. Various corrosion protective coatings have been used, including bitumen, plastic baggie, tape coatings, coal tar epoxy, FRP, and 100 percent solids rigid polyurethane coatings, to accompany the development of various STI specifications and the UL 1746 standard.

Tanks installed during the 1950s were generally coated with a thin bitumen-based paint or red lead primer. Bitumen was the first anti-corrosion coating used in the external protection of USTs. These coatings were fine in preventing atmospheric corrosion; however, they were nearly useless for protection against corrosion in many underground environments. It is easy to apply and relatively inexpensive, but is environmentally unfriendly and can be removed and damaged by casual contact. Unfortunately, some tank buyers continued to install non-protected tanks underground until the US Congress in 1984 empowered the US EPA to prohibit such tanks.

The plastic baggie method was to install a steel tank in a plastic wrap or "baggie". The idea came from the fact that one major oil company had installed a number of baggie systems in the state of Michigan as early as 1959. About 12 years later, steel tanks from this initiative were uncovered and found to be free of any corrosion. In 1970, more than 1,000 plastic-wrap tanks had been installed in the US. However, the plastic film was quite thin and prone to tearing. Installers and manufacturers also discovered the difficulty of assuring a long-term seal between the pieces of plastic.

Tape coatings were then used to reduce underground steel tanks' exposure to corrosion from the surrounding soil. Tape coatings did offer some extent of corrosion protection; however, they were difficult to apply properly, labor intensive, easily damaged and did not offer long-term protection. Tape coatings disappeared quickly from the underground steel tank industry because of their inherent disadvantages. They are only occasionally used in the UST piping systems as an easy field repair for other coatings and the coating of joints and fittings when factory coated pipe is used.

3.2 UL1746 Part I tank or the Sti-$P_3^{®}$ tank technology (STI, 1999a)

In 1969, the STI developed a specification for underground steel storage tanks, the Sti-$P_3^{®}$ system. The Sti-$P_3^{®}$ system combines three basic methods of underground corrosion control, all installed on the tanks during manufacturing:

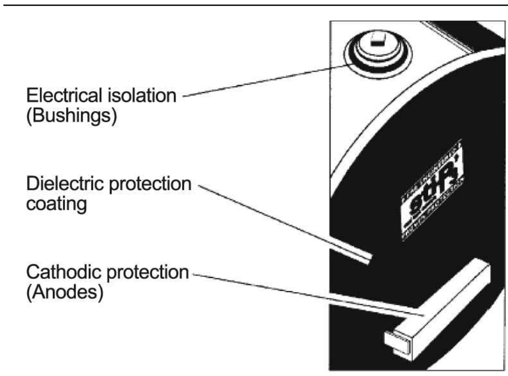
(1) cathodic protection,
(2) protective coating, and
(3) electrical isolation of the tank from

other underground metallic structures (Figure 1). Basically, the methods employed by the Sti-$P_3^{®}$ system to prevent exterior corrosion have been successfully used on pipelines and other underground structures for more than 50 years.

Coal tar epoxy was the earliest coating introduced in the Sti-$P_3^{®}$ system as an external coating for underground steel tanks. The coating itself provided superior anti-corrosion protection compared to tape coatings. Other advantages include more efficient and less expensive application, speed of application and long term protection. One of coal tar epoxy's greatest disadvantages is, however, its slow curing time, particularly during cold ambient temperatures, creating bottlenecks and delays in production.

Amongst the other disadvantages of the coal tar epoxy are its environmental and safety issues (e.g. coal tar is a known carcinogen), its lack of long-term protection (e.g. brittleness

Figure 1 The UL1746 Part I tanks or the Sti-$P_3^{®}$ tanks (USTs, 1995)



of the coating) and its relatively high VOC content. The coating process itself was more complex than tape coatings. It used more sophisticated equipment than tape coating and better operator training was required.

Hundred percent solids rigid polyurethane coatings were first developed specifically for the USTs in the early 1970s. In 1975, ULC issued the first listing for cathodically protected steel tanks with a polyurethane coating. In 1981, the aromatic polyurethane coating technology was approved for use in the Sti-$P_3^{®}$ tank by the STI, and American tank fabricators began to enjoy the same 100 percent solids rigid polyurethane technology as their Canadian cousins.

In addition to the introduction of 100 percent solids rigid polyurethane coatings, a number of improvements in the Sti-$P_3^{®}$ system were made during the 1970s and 1980s – including the development of enhanced methods of applying FRP as an external corrosion barrier. Magnesium anodes, attached to the tank by wire, were virtually supplanted during that time by an innovative weld-on zinc anode design.

The use of a 10 to 15 mil (250 to 375 micron) coating of either coal tar epoxy or 100 percent solids rigid polyurethane, together with isolating bushings and a sacrificial anode (such as the Sti-$P_3^{®}$ tank) is covered by Part I of the UL 1746 standard – "External Corrosion Protection Systems for Steel USTs". The requirements under UL 1746 cover factory-applied corrosion protection systems over carbon steel tanks whose construction complies with the UL Standard for Steel Underground Tanks for Flammable and Combustible Liquids, UL 58.

The UL1746 Part I tanks, or the Sti-$P_3^{®}$ tanks, have the longest history and an excellent record of good performance. This corrosion protection system is generally considered to be the least expensive to fabricate when a single wall steel tank is used. However, this type of underground tank system is required as per EPA regulations, to be monitored for 6 months after installation and then have a periodic inspection every 3 years in most jurisdictions.

Since the late 1980s, UL approved 100 percent solids rigid polyurethane technology has almost completely replaced coal tar epoxy and other coating technologies in manufacturing UL 1746 Part I tanks or Sti-$P_3^{®}$ tanks. STI reported that by January

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1998 over 250,000 STI-P_3 underground steel fuel storage tanks had been registered and installed in the US. In addition, the Steel Tank Association of Canada estimated that 100,000 steel tanks had been installed in Canada. In total, these tanks involved approximately 200 million square feet of steel, and over 80 percent of that area was coated with 100 percent solids aromatic polyurethane coating. The technology's performance has been nearly flawless, according to a 1993 report by a US-based risk-management consulting firm (Geyer, 2000). Most of these Sti-$P_3^®$ tanks were coated with the 100 percent solids rigid polyurethane coating.

3.3 UL1746 Part II tank or the STI ACT-100® tank technology (STI, 1999b)

If a non-metallic FRP tank could be installed to eliminate corrosion, why not coat the steel tank with that very same material? This idea resulted in the name "composite tank", a steel UST to which a laminate of fiberglass reinforced plastic (FRP) has been directly applied to the exterior. The FRP coating provides a corrosion-resistant barrier between the tank and surrounding soil and backfill.

The composite tank technology, initially developed in the 1960s based on STI-LIFE specification and then standardized in the late 1980s, employs a 100 mil (2.5 mm) thick FRP laminate that is bonded to the exterior surface of a steel tank. Known in some circles as "clad" tank technology, composite tanks most often are built to the STI "ACT-100®" standard "Specification for External Corrosion Protection of FRP Composite Steel Tanks (F894-91)" or to UL 1746 Part II. Composite tanks are tested at the factory prior to shipping for "holidays" using a high voltage of 15,000 V. Composite tanks are made in both single and dual-wall configurations. Typically, a single-wall, UL 1746 Part II or STI ACT-100® tank is 30 to 40 percent more expensive than a single-wall, Part I or Sti-$P_3^®$ tank, but no ongoing monitoring is required.

3.4 UL1746 Part III tank or the STI Permatank® technology (STI, 1998)

A secondary containment design was developed in the late 1980s and finalized in the early 1990s as an alternative to the traditional double wall Sti-$P_3^®$ and composite tanks discussed above. The technology offers secondary containment through incorporation of a primary tank built of steel and an outer wall fabricated of other materials. One such design is the STI Permatank® with an outer wall of 100 mil (2.5 mm) thick FRP, built to STI "Specification for Permatank® (F922-92)" and UL 1746 Part III. Several similar designs are being marketed by steel tank fabricators, such as one utilizing a 100 mil (2.5 mm) thick HDPE material. The FRP or HDPE materials are sometimes called jackets, and therefore these types of tanks mentioned above are also referred to as "jacketed" tanks. The tank and jacket are separated by an interstitial space with the jacket as a secondary containment. A permanent monitoring sensor in the interstitial space connects to an alerting device in the service station or control room. The cost of jacketed or UL 1746 Part III tanks are more expensive than single wall tanks to UL 1746 Part I, II or IV, but they are less expensive than dual wall steel tanks built to UL 1746 Parts I, II or IV.

3.5 UL1746 Part IV tank or the STI ACT-100U® technology (STI, 2000)

In 1996, a fourth category (Part IV) of the UL 1746 Standard was added based on a new 100 percent solids rigid polyurethane technology. Similar to the systems listed under UL 1746 Part II, the new system listed under Part IV is a 70 mil (1.75 mm) thick aromatic rigid polyurethane coating/cladding direct-to-steel substrate and requires no anode. No monitoring is required. The performance test requirements for Part IV include all those for Part II plus additional test requirements.

In 1997, new 100 percent solids polyurethane technology was approved by both UL and STI as an alternative to the traditional FRP laminate material for UL 1746 Part II or STI ACT-100® tanks. To make these tanks, however, less than 2 percent of fiberglass is allowed to be added into the polyurethane coating. This is to avoid any potential change of physical property to the polyurethane, should too many glass-fibers be used. The new polyurethane technology has obtained both UL and STI approvals as a coating for Sti-$P_3^®$ tanks as well.

Compared with traditional FRP laminate materials, the 100 percent solids rigid polyurethane coatings have numerous advantages.

- The 100 percent solids rigid polyurethanes are safer and more

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environmentally friendly than traditional anti-corrosion coatings such as coal tar epoxy and traditional FRP materials. The 100 percent solids rigid polyurethanes contain no solvent, styrene, amine, or carcinogens such as coal tar. The over-spray is a non-hazardous waste when cured. The polyurethanes are not affected by EPA, OSHA, and DOT scrutiny over the health and safety hazards associated with other polymer systems.

- Because of the rapid curing speed of the 100 percent solids rigid polyurethane coatings, the tanks can be quickly and easily coated. The cold temperature curing ability of the 100 percent solids aromatic polyurethane makes it possible to apply it at ambient temperatures as low as $-40^{\circ}C$ ($-40^{\circ}F$), which is impossible for other types of coatings such as coal tar epoxy and traditional FRP material. Therefore, production throughput and labor costs are largely improved. For example, a 25,000-gallon FRP-coated ACT-100® tank may take over 4 h to finish, whereas the 100 percent solids polyurethane coating can go on in under 1.5 h. As a result, even though polyurethane resins are more expensive than other coating resins, the total cost of the polyurethane cladding is lower due to the savings on labor.
- The rapid curing speed of the 100 percent solids rigid polyurethanes also enables their self-inspecting capability. If the coating is not applied correctly or the surface is not properly prepared, the 100 percent solids rigid polyurethane will signal the problem within a few hours to several days after application before the tank is buried.
- Differing from other available elastomeric polyurethanes, the 100 percent solids rigid polyurethane technology is a highly cross-linked and rigid system. The high cross-link density of the cured rigid polyurethane resin is such that it forms itself as a structural material at the thickness of 70 mils (1.75 mm). The exceptional strength of the 100 percent solids rigid polyurethanes enables them to meet and exceed the UL 1746 Part II and IV standards at a thickness of only 70 mils (1.75 mm), compared to traditional FRP laminate at 100 mils (2.5 mm).

Table IV compares 100 percent solids rigid polyurethane with coal tar epoxy. Table V highlights the minimum performance requirements in UL 1746, Part II standard for FRP and typical performance test results for 70 mil (1.75 mm) 100 percent solids rigid polyurethane.

Table VI summarizes the characteristics and major advantages and disadvantages of all the UL 1746 external corrosion systems used by the UST industry. Please note that all UL 1746 tanks are basically underground steel storage tanks built to the UL 58 standard with different external corrosion protection systems outlined in the UL 1746 standard. The UL 58 steel tanks can be either single wall or double wall. Single wall UL 58 tanks are constructed of mild carbon steel. Double Wall UL58 Type I tanks consist of a primary tank wrapped by an exterior steel shell that may be in direct contact with the primary tank, available with either a 305° (97 percent of tank volume) or 360° (100 percent of tank volume) wrap. Double Wall UL 58 Type II tanks consist of a primary tank wrapped by an exterior steel shell that is physically separated from the inner primary tank by standoffs. The inner steel tank is completely contained within the outer steel tank.

It is also important to note that secondary containment has become the most significant change in storage technology over the past 20 years. With non-petroleum underground tank systems storing chemicals, secondary containment is mandated by the US EPA regulations. States such as Florida, California, and most of the states in New England require secondary containment of petroleum products as well. Secondary containment achieved by double wall tanks is also in common use across Europe for USTs. Secondary containment prevents inadvertent releases from permeating into the soil.

In 1984, STI published its national Dual Wall Steel Tank Standard (STI, 2001). Under this STI standard, one steel tank is fabricated into another steel tank, and the outer can be wrapped directly onto the primary tank, which creates a significant cost reduction.

In reality, the outer containment merely has to contain the product that is released from the inner tank until it could be detected. The STI Double Wall Tank Standard also involves the detection of the release by various unique technologies for interstice monitors.

Table IV Comparison between coal tar epoxy and 100 percent solids rigid polyurethane

	Coal-tar epoxy	100 percent solids rigid polyurethane
Product type	Coal-tar, polyamide cured epoxy	Aromatic polyurethane
Solids content	74 percent	100 percent
Mix ratio	4:1	1:1
VOC	1.9 lbs/gallon	0
Contains coal tar and flammable solvents	Yes	No
Application methods	Brush, roller, conventional spray	Plural component spray
Recommended dry film thickness	16 mils	16 mils or more (for UL 1746 Part II and IV)
Surface preparation	SSPC-SP10	SSPC-SP10
Blast profile	2.0-3.0 mils	2.5 mils +
Application ambient temperature requirements	50 to 110°F (10 to 43°C)	−40 to 150°F (−40 to 65°C)
Substrate surface temperature	50 to 110°F (10 to 43°C) and 5°F (3°C) above dew point	−40 to 150°F (−40 to 65°C) and 5°F (3°C) above dew point
Airless spray pump	Single (30:1 ratio)	1:1 plural (30:1 ratio)
Spray pressure	2,100-2,500 psi	1,800-2,500 psi
Maximum DFT per coat	Up to 24 mils	Unlimited @multiple passes
Dry to touch	4 h @75°F (23°C)	1-10 min @75°F (23°C)
Dry to handle	12-24 h @75°F (23°C)	5-60 min @75°F (23°C)
Holiday testing	24-48 h @75°F (23°C)	5-60 min @75°F (23°C)
Backfilling	24-48 h @75°F (23°C)	30-180 min @75°F (23°C)
Ultimate cure	7 days @75°F (23°C)	7 days @75°F (23°C)
Recoat time	6 h (min), 24 h (max) @75°F (23°C)	0.5-1.5 h @75°F (23°C)
Repair material	Brush grade	Self or brush grade
Adhesion to steel, ASTM D4541	750 psi	2,000 psi
Abrasion resistance ASTM D4060, CS17, 1 kg, 1,000 cycles	160 mg loss	80 mg loss 35 mg loss (ceramic version)
Flexibility, ASTM D522	Failed at 180° 1″ mandrel	180° over 1″ mandrel
Elongation, ASTM D638	3.2 percent	4.8 percent
Cathodic disbondment CSA245.20M (−3.5 V, 48 h)	17.5 mm radius	4.0 mm radius
Dielectric strength, ASTM G149	5.1 kV @20 mils 255 V/mil (10 V/micron)	22.4 kV @40 mils 568 V/mil (23 V/micron)
Hardness, ASTM D2240	65 Shore D	72 Shore D @75°F
Impact resistance, ASTM G14	28 in-lbs	50 in-lbs
Penetration resistance, ASTM G17	13 percent	5.0 percent
Stability (wet), ASTM D870	−30°F to 120°F (−34 to 48°C)	−40°F to 150°F (−40 to 65°C)
Water absorption, ASTM D570	1.2 percent	1.4 percent
Water permeability, ASTM D1653	12 g/m^2/24 h	12 g/m^2/24 h
Volume Resistivity, ASTM D257	3.5×10^{14} ohm cm	5.8×10^{15} ohm cm
Salt spray, ASTM B117, 2,000 h	<3/8″ undercutting	Pass

3.6 Ancillary tank requirements

When dealing with external corrosion protection of USTs, it is important to realize the fact that pipe systems are not only an integral part of the UST system, but also contribute to a large portion of all UST release in EPA surveys. Piping systems installed 20-30 years ago were typically black steel or galvanized steel pipes without any other type of corrosion protection. These pipes were threaded together, often incorrectly, causing corrosion or product release at poorly joined connections. Today, many 2 in. diameter pipe systems are made with corrosion resistant materials or well-coated steel pipes. Commonly used coatings systems for underground piping associated with USTs are fusion bonded epoxy, extruded polyethylene jackets, tapes, and high build coatings such as epoxy and polyurethane coatings. A cathodic protection system is normally designed and installed. Secondary containment technology is also used in North American UST piping systems. For example, one popular type of

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Table V Minimum performance requirements in UL 1746, Part II standard for FRP and typical performance test results for 70 mil (1.75 mm) 100 percent solids rigid polyurethane

Property	Test	UL1746 Part II standard for FRP	70 mil (1.75 mm) 100 percent solids polyurethanes
Initial physical strength	UL 1746.14.2/14.3	< 3,000 psi	3,307 psi
Heat aging at 70°C (158°F), 180 days	UL 1746.14.2/14.3	80 percent strength retention	100 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (sulfuric acid, pH-3)	50 percent strength retention	100 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (saturated NaCl)	50 percent strength retention	100 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (distilled water)	30 percent strength retention	100 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (1 percent HCl)	30 percent strength retention	94 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (nitric acid)	30 percent strength retention	99 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (sodium carbonate-bicarbonate)	30 percent strength retention	100 percent strength retention
Resistance to environmental fluids, 180 days	UL 1746.14.4 (NaOH, pH-12)	30 percent strength retention	99 percent strength retention
Light and water exposure (360 h)	UL 1746.14.5	80 percent strength retention	94 percent strength retention
Impact and cold exposure at −2°C (−20°F) for 16 h	UL 1746.14.6	Passes @100 mils (2.5 mm)	Passes @70 mils (1.75 mm)
Corrosion evaluation for 180 or 270 days at 38°C (100°F)	UL 1746.15.2	No corrosion, however, poor adhesion	No corrosion, excellent adhesion
Permeation-cladding dissolution at 38°C (100°F)	UL 1746.15.3	Passes with weight loss > 1 percent	Passes with weight loss of < 0.39 percent
Pipe fitting test	UL 1746.16.2/16.3	Passes @100 mils	Passes @70 mils
Lifting fitting strength test	UL 1746.16.4	Passes @100 mils	Passes @70 mils
Tank impact test (a 12 pound or 5.4 kg steel ball at impact heights of 10-72 in.)	UL 1746.16.5	Holidays may be identified visually for impact heights as low as 40 in. @100 mils	No holidays detected visually or with 35 kV tester at a height of 70 in. @70 mils
Leakage test at 5 psi (35 kPa)	UL 1746.16.6	Passes @100 mils (2.5 mm)	Passes @70 mils (1.75 mm)
Holiday test at 35 kV	UL 1746.16.7	Passes @100 mils (2.5 mm) @35 kV	Passes @70 mils (1.75 mm) @35 kV

dual wall pipe used today is known as a "flexible pipe" system. The pipe is stored in rolls and is composed of various elastomeric/plastic compounds. In 1991, STI published "The Recommended Practice for Corrosion Protection of Underground Piping Networks Associated with Liquid Storage and Dispensing Systems" (STI, 1991).

3.7 Warranties

Due to the effectiveness of the external corrosion protection systems associated with UL 1746 (steel USTs) and UL 1316 (for non-metallic USTs) tanks, most newly constructed USTs for flammable and combustible liquids are warranted in North America against corrosion and structural failure. Neither the FRP Pipe and Tank Institute nor the STI provide a warranty to FRP USTs or protected steel USTs. However, STI mandates that the tank manufacturer warranty their tank for 30 years as part of the STI Technology license agreement in the US Regular STI Members are entitled to become shareholders in the Steel Tank Insurance Company (STICO, a captive mutual insurance company founded to offer tank fabricators pollution and product liability insurance on STI technology tanks). STICO insurers own the insurance company, and can rest assure that their dollars are buying the best protection available on their STI tanks. STICO also provides a 30 year limited warranty insurance for manufacturers building STI registered tanks which are to be installed in portions of North America. Only STI Regular Members can buy this

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Table VI External corrosion protection systems for steel USTs

UL designation	UL 1746 Part I	UL 1746 Part II	UL 1746 Part III	UL 1746 Part IV
STI designation	STI-$P_3^{®}$	ACT-100®	Permatank®	ACT-100-U®
Tank construction	A coated, single wall or double wall (Type I or II) UL 58 steel tank	A coated, single wall or double wall (Type I or II) UL 58 steel tank	A single-wall UL 58 inner steel tank coupled with a FRP or HDPE outer tank or jacket	A coated, single wall or double wall (Type I or II) UL 58 steel tank
Approved corrosion systems by UL, STI, and ULC	10 to 15 mil (250 to 375 micron) rigid polyurethane or coal tar epoxy coating with sacrificial anode and electrical isolation	100 mil (2.5 mm) FRP/100 mil (2.5 mm) polyurethane coating plus less than 2 percent fiberglass	A steel tank and a jacket of 100 mil (2.5 mm) FRP or HDPE	70 mil (1.75 mm) rigid polyurethane coating
The main protective system being currently used	10 to 15 mil (250 to 375 micron) 100 percent solids rigid polyurethane	100 mil (2.5 mm) thick 100 percent solids rigid polyurethane coating plus less than 2 percent fiberglass	A steel tank and a jacket of 100 mil FRP or HDPE	70 mil (2.5 mm) thick 00 percent solids rigid polyurethane coating
Corrosion protection monitoring requirement	Initial monitoring for 6 months after installation and then a periodic physical inspection every 3 years (single wall tank only)	Not required	Permanent monitoring in place	Not required
Total tank cost (4 = most expensive)	1 (single wall) 2 (double wall)	3 (single wall) 4 (double wall)	4 (single wall case) 1 (compared with other types of double wall)	2 (single wall) 3 (double wall)
Advantages	Longest proven track record Double protection Not labor intensive Regular monitoring ensures that the protection is ongoing Less coating application problems Easily inspected for tank damage No VOC/HAP issues	Fiberglass reinforced thick coating A high-voltage holiday test of the coating assures the effectiveness No extra monitoring or labor cost for end users Less damage to coating during shipment or installation No VOC/HAP issue with the use of polyurethane	Steel inner tank provides complete compatibility with petroleum products (vs all-FRP tanks) Designed shorter than an all-FRP made tank of the same capacity Reduced cost of installation Allow wider and less costly choice of backfill	No environmental, health and safety concerns Easy coating application compared with Part I and II tanks Fast throughput A high-voltage holiday test of the coating assures the effectiveness No extra monitoring or labor costs for end users
Limitations	Thin coating can be easily damaged in shipment or installation Sacrificial anodes may be exhausted earlier than anticipated Regular monitoring required at extra cost Cathodic disbondment resistance required for coating Plural component spray technique required	Health and safety of workplace to handle fiberglass and/or hazardous solvents Known carcinogens (FRP) Unable to determine coating continuity after installation Multiple coat cladding or coating application Plural component spray technique required for polyurethane	Labor intensive and costly compared with other types of steel USTs Health and safety of workplace to handle fiberglass and/or hazardous solvents Known carcinogens (FRP) Multiple cladding application Easily damaged Interstice leakage repair could be an issue	Plural component spray technique required Multiple coat coating application Unable to determine coating continuity after installation Limited coating recoat window
Overall remark	A highly effective system with low tank cost but extra costs for labor and monitoring	A steel/FRP composite tank with inner structural integrity and outer thick coating protection	A secondary containment tank with high inner strength and better compatibility	A steel/rigid polyurethane composite tank with a thick high performance coating

protection. For non-metallic tanks, some major FRP UST manufacturers provide their warranty separate from the FRP Pipe and Tank Institute. In any case, both steel and FRP tank manufacturers provide a 30 year warranty against corrosion and structural failure. The FRP tank industry mandates only certain types of backfill (pea gravel, but no sand) and the tank remains within certain deflection parameters. If the deflection exceeds the FRP tank manufacturer's recommendations, the tank no longer is warrantied due to a concern for structural failure (Geyer, 2002).

4. Technical trends and certification process

The North American world of USTs is a very dynamic one. Over the years, the industry has gone through a lot of changes, particularly due to the government's stringent regulations, such as the US EPA's 1998 deadline and market changes including globalization. These changes have made a significant impact on the technical/marketing activities of the North American storage tank industry and in turn have affected the activities associated with the external corrosion protection of USTs.

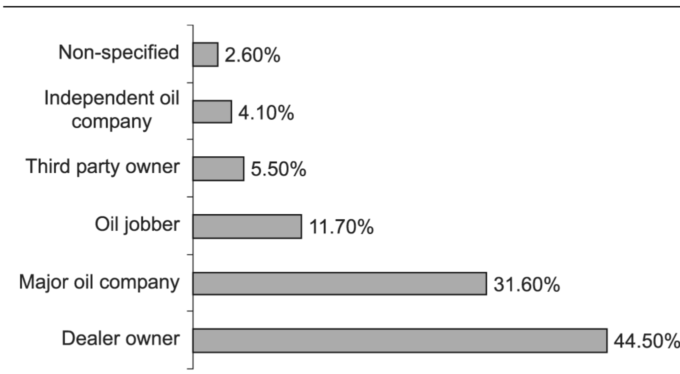
4.1 Increasing demands for non-metallic USTs while steel USTs are still the most common

Over the years, there has been an increasing demand for purchasing and installing non-metallic USTs rather than corrosion protected steel USTs. In the US, Containment Solutions (n.d.), a major US all-FRP tank manufacturer, published a statement on their Web site that claimed "major oil companies responded to our achievement by specifying fiberglass tanks for approximately 95 percent of their underground fuel storage installations" (Geyer, 2002). Major oil, in this context, is loosely defined, but generally includes Chevron, Mobil, Exxon, Arco, Amoco, BP, and Shell. It was later noted that this information is, however, not based on any absolute number of tank units, but rather on the case that 23 of the top 24 oil companies bought non-metallic tanks (Geyer, 2002).

A 1998 STI study and a survey conducted with US retail service station managers by the trade publication *Service Station Management* revealed that US USTs ownership was split as in Figure 2.

According to Wayne Geyer, (2002) there was some expert commentary stating that major oil companies owned about 25 percent of the service stations in the US in the mid-1980s and that service stations accounted for approximately 25 percent of all USTs in operation at that time. One of the petroleum industry representatives also revealed to him that major oil companies owned less than 10 percent of all USTs in the ground in the US in 2000. With the recent merger of all of the major oil companies into larger conglomeration companies, and with the economic downturn, the major oil companies have built very few new stations in the USA since the start of the new century. At the time that the US EPA UST regulations were written, EPA's data base indicated that 1,280,450 tanks in the US were of steel composition and 127,720 tanks were of non-metallic FRP composition. Many of these steel tanks were not protected from corrosion at that time. A 1989 survey indicated that with new tanks being installed in the US, approximately 70 percent were corrosion protected steel tanks. A 1993 study by C-Store News magazine indicated that corrosion protected steel tanks were being installed at 71 percent of all petroleum marketers' facilities and at 58 percent of all traditional convenience stores. Non-retail sectors performed similar surveys. A survey of aviation's fixed base operators in 1990 indicated that 31 percent of these operators would select a non-metallic system. An inquiry with UL indicated that steel USTs represented 67 percent of all UST labels they issued during 1996-97 and 59 percent in 2001. In 2000, STI was surveying some of the

Figure 2 US UST ownership



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state environmental agencies currently on this topic and found that:

- in Pennsylvania, 1,070 steel USTs were installed in 1998 versus 321 non-metallic tank installations,
- in Alabama, 384 steel USTs were installed in 1998 versus 167 non-metallic tank installations,
- in North Dakota, 440 steel USTs were installed in 1998 versus 55 non-metallic tank installations,
- in Kansas, 368 steel USTs were installed in 1998 versus 117 non-metallic tank installations, and 959 existing tanks were upgraded with field installed cathodic protection or internally lined or both were applied.

All of these numbers suggest that steel continues to be the most common material used for UST installations. Yet, here in the US, it is true that major oil companies purchase more non-metallic tanks than steel tanks, although steel tanks are still purchased and installed today by these same companies.

4.2 USTs down and ASTs up

While USTs for decades served as the standard means of HAZMAT storage in quantities of 50,000 or fewer gallons, the end users and owners who once stored flammable and combustible liquids underground began in the 1990s to replace them with small-capacity ASTs. One of the reasons for this trend was that some UST owners or operators mistook that they could avoid environmental and safety requirements by changing to ASTs. The other was the myth that ASTs are always cheaper than UST.

The impact of this change in market dynamic on North American USTs is very great. Due in part to the reduced demand for UST tanks, several small-scale tank manufacturers were forced to shut down their businesses. To tank manufacturers who are still producing USTs, it means more external work to educate end users about the differences between USTs and ASTs and to help with their tank selections. The STI has developed a decision tree to assist end users' in deciding whether an AST is appropriate – or allowable as an alternative to a UST (STI, n.d.). Internally, it means demanding more cost savings and improving application effectiveness and quality of workmanship, including corrosion protection, to make the USTs produced more competitive in the market. For this same reason, we are expecting more use of 100 percent solids rigid polyurethanes by tank manufacturers to replace traditional FRP materials in making UL1746 Part II or STI ACT-100 tanks.

4.3 The latest UL 1746 standard

The earlier UL 1746 standard did not require testing on touch-up or repair materials for external corrosion of USTs for flammable and combustible liquids. As tank manufacturers followed the trend toward the use of 100 percent solids polyurethane tank coating systems without anodes, the need to develop a standard to ensure the integrity of repair coatings became important. Damage repair is an integral part of external corrosion protection, therefore steps toward an improved standard were initiated. The results of these standardizing activities can be found in the 8 February 2002 edition of UL 1746. In this edition, specific testing requirements are given not only to main tank coatings but also to their repair materials. Table VII outlines the testing and sample requirements as below for UL 1746 Part IV. Compliance of this new edition came into effect on 15 July 2002. Discussions have also been made on whether or not to include the repair material testing requirements for all of the four types of UL 1746 tank technologies in the future.

4.4 Certification process to become UL listed or STI registered

There are many advantages to having the USTs produced bear a product listing mark of either UL or STI or both. Among them, two significant ones emerge. Instant credibility and recognition with regulators and specifiers in the US, Canada and internationally; and the ability to provide UST end users with STICO 30 year limited warranty insurance for STI registered tanks installed in North America against corrosion and structural failures through compliance with STI's technical standards, training and licensing program.

In order to achieve a UL or STI listing on the UST produced, a tank manufacturer will first need to establish its capability of making UL 58/UL 1746 steel tanks or UL 1316 all-FRP UST tanks. This is often done with the assistance of coating manufacturers who provide the external corrosion protection technology for underground tanks. After that,

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Table VII UL 1746 Part IV exposure/test requirements including repair materials (UL, 2002)

Exposure/test	Test standards	Testing coupon requirements
"As-received"	UL 1746 Par. 20B.4 and Par 20B.5	A, F, G
Air-oven aging	UL 1746 Par. 20B.6	A, F, G
Abrasion resistance	UL 1746 Par. 20B.7	E, D
Resistance to external fluids	UL 1746 Par. 20B.8	A, F, G
Light and water exposure	UL 1746 Par. 20B.9	A, F, G
Impact and cold	UL 1746 Par. 20B.10	B, D
Corrosion evaluation	UL 1746 Par. 20B.11	B, D
Permeation/cladding dissolution	UL 1746 Par. 20B.12	C

Coupon type

A – 7.5 by 9 in. (191 by 229 mm) coupons fabricated per the proposed production procedure of the minimum production coating thickness. Each coupon is then to be cut to provide one 2.5 by 9 in. (64 by 229 mm) sample and one 5 by 9 in. (127 by 229 mm) sample and both samples marked for identification. The 5 by 9 in. (127 by 229 mm) sample shall be edge-sealed as required with the coating used to manufacture the coupons.

B – 6 by 9 in. (152 by 229 mm) coupons with the minimum production coating thickness and fabricated per the proposed production procedure on one side of a flat No. 14 MSG (0.075 in. nominal) steel plate.

C – 6 by 6 in. (152 by 152 mm) flat coating coupons fabricated per the proposed production procedure of the minimum production coating thickness.

D – Same as coupon B except with a 2 in. (50.8 mm) diameter holiday in the coating to bare metal and repaired with the coating repair kit in accordance with the manufacturer's instructions.

E – 5 by 9 in. (127 by 229 mm) coated flat No. 14 MSG (0.075 in. nominal) steel plate fabricated in accordance with the proposed production procedure of the minimum production coating thickness. The coating shall be applied to both sides of the coupon and the edges.

F – 1 by 4 in. (25.4 by 101.6 mm) samples fabricated per the proposed production procedure of the minimum production coating thickness. The samples (in sets of two) shall be bonded together using the coating repair kit in accordance with the manufacturer's instructions. The bonded samples shall become a 1 by 7.5 in. (25.4 by 190.5 mm) coupon. The bonded samples are to be edge-sealed as required with the coating used to manufacture the samples.

G – Same coupon requirements as coupon type A except manufactured from the repair kit material.

Notes: 1 – When the material in the repair kit is the same as the coating material, the air-oven aging, light and water exposure and resistance to external fluids exposures are not required for coupon types F and G.

2 – The number of test coupons requested is often more than the number of coupons required for the test. Additional sample amounts are requested due to breakage that occurs when the coupons are milled into the specimen geometries for the tensile impact energy or tensile strength tests.

a request can be sent directly to UL. Necessary site visits and inspection testing may then follow, and once the UL certification is granted, a regular UL follow-up program will be implemented to ensure that the tank manufacturer produces the tanks in compliance with the UL standards. More information and application requests can be sent to: Mr John Silsdorf, Engineering Services, Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, USA. Tel: (847) 272-8800 (ext. 43130), Fax: (847) 272-8129, E-mail: John.A. Silsdorf@us.ul.com

In order to obtain an STI license on STI registered USTs, a tank manufacturer will first have to become a regular STI member. To qualify, the manufacturer will have to have been building USTs for at least 12 months to UL 58, UL 1746, ULC S603.1, or other international standards. Detailed information about application and qualification for becoming a regular STI member can be obtained through the STI Web site at www.steeltank.com or by directly contacting: Mr Wayne Geyer, Steel Tank Institute, 570 Oakwood Road, Lake Zurich, IL 60047, USA. Tel: (847) 438-8265, Fax: (847) 438-8766, E-mail: wgeyer@steeltank.com

4.5 Update on international technology and standards of UST

The excellent R&D and standards development work around the Underwriters Laboratories UL 58 / UL 1746 standard for USTs for flammable and combustible liquids is not only authorized and utilized in North America (the US, Canada, and Mexico), but

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is also greatly recognized by the international UST industry. A task group has been set up and has been working for more than 3 years to assist the merging of the ULC S603.1 standard for USTs with the UL 1746 standard. South America and Central America make use of the UL standards, as do some portions of Africa. UL standards have been specified for US military jobs in Korea. Some oil companies outside Singapore seem to want UL standards and Taiwan and Israel utilize all US standards.

One of the main objectives of the European Community is to ensure the removal of barriers to trade across Europe to form one single market. The benefits of membership in the single market include common safety standards on products. The UST standard for Europe has just been completed. At present, most European countries have their own standards for USTs; Germany, UK, France, Sweden, Holland, Finland etc. However, when the European UST standard is adopted later it will appear as EN 12285-1. This means that in the UK the standard will be BS EN 12285-1 and in Germany DIN EN 12285-1, etc. In addition to the development of the tank standards, progress in the standardization of other areas of petroleum filling station equipment has led to a variety of choice being made available to the equipment user as well. Among these other standards, closely linked to the UST standard, is EN 13160 Leak Detection Systems for Tanks and Pipes. It describes the methods of leak detection standards, which can be fitted to EN 12285-1 double wall tanks to ensure that any perforation of the skins is detected before stored products enter the environment. This standard also allows for the development of corrosion protection systems using either liners or jackets for single wall tanks. This single wall with a jacket type tank is similar to UL 1746 Part III or STI-Permatank® technology. It is noted that double wall tanks are in common use across Europe. Detailed review on the update on European UST standards can be seen from a recent STI's Tank Talk newsletter (STI, 2002).

5. Closing remarks

The evolution of various corrosion protection systems used for the external protection of USTs for flammable and combustible liquids in North America is a perfect example of how much research activities and standards development work can help change an industry's performance in corrosion protection. Without these excellent R&D and standards development activities, it would not be possible for the North American UST industry to back all of their new USTs with a 30 year warranty against corrosion and structural failure. Nor would it be possible for the North American STI to have the ongoing history of providing the end users with well-protected USTs with almost zero failures due to external corrosion.

Breakthroughs in high solids and 100 percent solids rigid polyurethane coatings technology have produced environmentally friendly and worker safe solutions to the external corrosion protection of USTs for flammable and combustible liquids. The 100 percent solids rigid polyurethane coatings offer high physical properties, substantial performance, safety and environmental benefits, as well as fast application throughput advantages over older and other current coating systems.

Corrosion protection systems applied to steel underground tanks today are curbing external corrosion. Greater efforts are made towards having owners provide proper maintenance of the inside of tanks to ensure that no corrosion takes place there, such as removing water, manufacturers adding striker plates, and so forth. Proper education of regulators, owners, and testers is an ongoing process to assure that cathodic protection is obtained on the UL 1746 Part I or Sti-$P_3^®$ tanks. Many new corrosion protection technologies and standards have been, and will continue to be, developed in this market. All these efforts, together with never ending demands from the users for new state-of-the-art storage tank systems for greater peace of mind, reduced liability, lower risks and extended tank life, ensures that the golden age for USTs for flammable and combustible tanks will return.

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Further reading

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