State-of-the-Art Corrosion-Resistant
Steel UST Technology Makes "Rusty Steel Tanks" a
Thing of the Past

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Once upon a time, many years ago, there was a shiny new steel tank who was put into the
ground to store gasoline. The tank was very happy and proud to join the thousands of his
fellow steel tanks on whom the entire country depended for reliable petroleum storage.
People the world over marveled at how strong the little tank was and that no matter what
product you put into the tank, it got along well with the little tank - it seemed to be
compatible with everything!

But the tank had an Achilles heel -- it so loved the ore which it was made of that it
naturally wanted to return to ore. But if it did that, little holes would develop and the
people who depended on the tank would get angry at the little tank. Other tanks made out
of different materials would laugh at the steel tank and call the poor little tank nasty
names like "Rusty". This would make the little tank cry and the moisture would make the
holes grow even larger.

All of a sudden, a great white knight came along who called himself "CP". He told the
little tank that while he might not be able to save it, he could make sure that all the other
steel tanks that came after would be protected against nasty old rust. This made the little
tank very happy, for although he would have to be put to rest, the reputation and
reliability of steel tanks would be saved. CP (whose real name was Cathodic Protection)
indeed did as he promised and steel tanks lived long and happily ever after.

The story you have just heard is true - and the names haven't even been changed to
protect the innocent! Cathodic protection is real. And ever since it has been applied to
steel underground storage tanks way back in 1969, it put to rest all the concerns about
rusting steel tanks (although you wouldn't know it by some of the still-lingering
denigrations about steel USTs).

Today's state-of-the-art steel UST technologies provide various methods of reliable
corrosion resistance. This article will discuss each of these methods, beginning with the
advent of CP as applied to steel USTs with the 1969 introduction of the Steel Tank
Institute-developed sti-P 3 ®. But to understand corrosion protection, it's first necessary
to understand the principles of corrosion.

**Just How Does It Work?**
Galvanic corrosion is an electrochemical process where metals deteriorate through a
reaction between or within metals exposed to a common environment. It is a natural
activity through which matter moves from a high state of energy to a point of stability at
a lower energy level. Every piece of processed metal has had great amounts of energy
added to it during refining, metal forming and fabrication. If nothing is done to protect
those metals, nature will begin its corrosive attack upon them, releasing that energy and returning the metal to its natural state.

Simply put, placing an unprotected steel structure in soil subjects it to a potentially hostile environment which can attack the metal in a manner similar to the electrochemical reaction found in a common flashlight battery.

There are four components in each electrochemical corrosion cell:

1. an anode, where the electrons are leaving the metal and where corrosion occurs
2. a cathode, where the electrons are arriving and corrosion is not occurring
3. an electrical pathway along which the electrons travel between cathode and anode
4. an electrolyte through which the current flows to complete the electrical circuit

Eliminating any one of these four elements would eliminate corrosion. However, anodes and cathodes come naturally in the world of metals and who in their right mind would state that all moisture can be eliminated from the ground year-round? The electrical pathway might be obstructed, for instance, through isolation of the tank from other tanks, piping or components. Yet a pathway is still theoretically possible within a single tank. So if we can't eliminate the four elements, what can we do? Well, thinking like a rebellious teenager, if we can't change the rules, let's work around them!

**Enter the sti-P 3 ®**

How about if we make a sacrifice to the corrosion gods? Instead of the tank, let's give em a different, separate metal to eat! Enter the sti-P 3 ® system of galvanic, or "sacrificial anode", corrosion protection. Corrosion engineers learned that if either zinc or magnesium is connected to the tank, the higher energy (or "potential") of these materials relative to the carbon steel of the tank causes the zinc or magnesium to act as the anode and be consumed. The tank is the cathode and is thus cathodically protected. Simple, inexpensive, reliable - and predictable.

The sti-P 3 ® system further combats the corrosion gods by throwing up barriers to the other frontal attacks of corrosion: the electrolyte and the electrical pathway. A durable, dielectric coating isolates the metal from the moisture-laden surrounding soil, the electrolyte. In an ideal coating of no scratches or nicks, this alone would be sufficient to prevent corrosion. Finally, the electrical pathway is dealt with via dielectric bushings in the tank's fittings. This electrically isolates the tank and defines the area to be protected by the anodes. Stray currents are also prevented from entering the tank via piping and/or tank components. These three levels of corrosion protection led to the technology name of sti-P 3 ®.

**So What About Internal Corrosion?**

Before we move on to a discussion of other external corrosion prevention methods, let's bring that nagging question about internal corrosion out of the closet. Is internal corrosion possible? Of course it is. Is it a major problem? No.
The key element in internal corrosion is the presence of an electrolyte - typically, water in the bottom of the tank. The presence of water is generally monitored as part of good housekeeping and tank monitoring practices. Removal of the water eliminates the electrolyte. Also, most of today's fuels contain various inhibitors to prevent corrosion.

Sludge has also been known to cause internal corrosion, but since sludge causes problems with monitoring and pumping equipment, it too is typically addressed as part of housekeeping.

Finally, internal corrosion used to rear its ugly head in the days of yore due to repeated "sticking" of the tank with gauge poles. This repeated impact would sometimes cause corrosion, having compromised the thickness of the steel. Gauge pole sticking was equally unkind to fiberglass tanks, sometimes resulting in catastrophic rupturing of the tank. However, for years now, tank fabricators have routinely provided striker plates underneath the tank openings, thereby rendering these problems moot.

**Third-Party Standards**
It's important to note several third-party standards pertinent to steel tanks. Fabrication to recognized third-party standards ensure that regardless of the specific manufacturer, a tank can be trusted to meet certain minimum fabrication or performance criteria. A primary steel tank fabrication standard is Underwriter's Laboratories' UL 58 Standard for "Steel Underground Tanks for Flammable and Combustible Liquids". UL 58 dictates minimum fabrication criteria for tank wall thickness, tank heads, joints, bulkheads for compartment tanks, Type II secondary containment tanks, connections, striker plates and manholes. Specific testing and marking requirements are also dictated. All STI-developed UST technologies are fabricated to UL 58.

Pre-engineered corrosion protection systems for steel USTs are covered by the UL 1746 Standard, "External Corrosion Protection Systems for Steel Underground Storage Tanks". UL 1746 is divided into three parts. Part I covers factory-installed galvanic-type cathodic protection such as the sti-P 3 ®. Part II covers factory assembled composite systems such as STI's ACT-100®. Part III covers factory assembled jacket systems such as STI's Permatank®. Areas addressed include: construction of the components; physical properties of materials; corrosion evaluation tests; assembly tests; various manufacturing and production tests such as leakage testing for all tanks; and anode continuity or holiday testing for specific technologies.

The design and installation of cathodic protection systems for tanks and piping is also addressed in a Recommended Practice developed by NACE International (formerly known as the National Association of Corrosion Engineers), RP0285-95, "Control of External Corrosion of Buried, Partially Buried, or Submerged Liquid Storage Systems".

UL's standards have emerged as the predominant testing laboratory fabrication standards, but the standards as defined by Steel Tank Institute are probably the most recognized in the field. STI standards are referenced in various national fire codes, as well as within the EPA regulations 40 CFR. Much research has gone into the development of both UL and
STI standards and tank technologies bearing the labels of these respective organizations have been thoroughly tested to assure they meet the rigorous standards. Tanks built under STI standards are also subject to independent quality control verification, which paves the way for fabricators to obtain third-party warranty coverage.

Officials responsible for code conformance should look for the appropriate labels bearing the UL and/or the STI mark which indicate the tank has passed third-party inspection. Both UL and STI have serial-numbered labels, as well as specific guidelines pertaining to label placement. For example, STI technology labels are affixed to the heads of the tank.

**The Steel Tank Technology Gallery**

With over 1/4 million installations to-date, the sti-P 3 ® is the predominant corrosion prevention system for steel USTs. However, several other technologies have evolved which offer alternative systems for the tank owner or specifier. Like the sti-P 3 ®, each provides an excellent means of preventing corrosion as well as other merits. The remainder of this article will focus on the corrosion methods of each of the technologies, as well as various design advantages, installation and other considerations specific to each.

**sti-P 3 ®**

While the sti-P 3 ® is distinguished as the galvanic CP system pioneer, there are several other issues to be considered when choosing or installing a sti-P 3 ®. One is the monitoring of that CP system. Federal EPA regulations require that single-wall sti-P 3 ®'s be monitored every 3 years for sacrificial anode integrity, and that records be kept of the readings. Monitoring is a very simple matter of checking the voltage of the tank system relative to a copper/copper sulfate reference cell - if the readings are a minimum of -850 millivolts, the system is A-OK. In fact, the sti-P 3 ® is the only UST whose corrosion protection system can be so verified. An option called the PP4 CP Testing System allows an owner/operator to himself test the CP system in less than a minute's time.

I'd said earlier that if it were possible to entirely isolate the tank from the surrounding soil, this would alone be sufficient to prevent corrosion. Well, the EPA itself recognizes one sure-fire way to accomplish this with a sti-P 3 ® tank and thus eliminate the need to monitor the CP system: a double-wall tank. The outer wall of steel prevents any direct contact of soil with the inner tank. Of course, sti-P 3 ® tank fabricators still provide corrosion protection on the outer wall of steel - it's just that the EPA has said double-wall sti-P 3 ® tanks are not subject to the every-3-year monitoring requirement. (Do keep in mind, though, that state or local regulations may be more stringent and would take precedence.) Of course, secondary containment isn't a bad idea overall, for it provides an extra measure of "insurance" and expands the options one has for leak detection.

sti-P 3 ® tanks can also be compartmented, whereby multiple storage of products within one tank is accomplished via compartment separation by bulkheads. For example, within one vessel can be, say, an 8,000 gallon compartment and a 6,000 gallon compartment, or perhaps three (3) 4,000 gallon compartments, and so forth. Considerable cost savings can
be realized with compartmented USTs, from equipment costs to installation costs to reduced insurance premiums.

**Composite Tanks**
Composite tank technology, initially developed in the 1960's and standardized in the late 1980's, employs a thick fiberglass-reinforced plastic (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. Like the double-wall tank, the cladding removes one of the elements for corrosion to occur: the electrolyte, or soil, cannot contact the steel surface. Composite tanks are tested at the factory prior to shipping for "holidays", or voids, in the laminate, so when a composite tank is installed and buried, you can rest easy. Corrosion will not occur and no on-going monitoring is required. Composite tanks are made in both single and dual-wall configurations, and also can be cost-effectively compartmented.

STI has been researching new laminate materials as alternatives to the FRP laminate traditionally used. A material call "ureglass" may soon be part of the ACT-100 Standard. Yet another composite tank technology utilizing polyurethane laminate is currently being researched by STI, which would be fabricated under a new STI Standard. Both technologies are expected to be approved and available during 1996.

**Jacketed Tanks**
The merits of secondary containment have propelled its specification by engineers and tank users alike. Consequently, new secondary containment designs have been developed as alternatives to the traditional dual wall sti-P 3 ® and composite tanks discussed above. These technologies offer secondary containment through incorporation of primary tanks built of steel and outer walls fabricated of other materials. One such design is the Permatank® with an outer wall of FRP, built to Steel Tank Institute "Specification for Permatank® (F922-92)" and UL 1746. Several similar designs are being marketed by steel tank fabricators, such as one utilizing high density polyethylene material. These types of tanks are sometimes referred to as "jacketed" tanks. Jacketed tanks provide both containment and corrosion protection of the primary tank. Also, jacketed tanks can be compartmentalized.

**Field-Engineered Cathodic Protection**
Steel tanks that were built and installed prior to the advent of pre-engineered, factory-supplied protection against corrosion can be retrofitted with cathodic protection. Such field work should be done under the supervision of a corrosion specialist qualified by the National Association of Corrosion Engineers (NACE), according to NACE RP0285-95. Depending on various factors such as soil corrosivity and the total steel surface area to be protected, either sacrificial anodes or impressed current systems may be employed. In some cases, an internal lining of the tank is applied in conjunction either with or without the cathodic protection retrofit.

**A Word About Secondary Containment**
Combined with release detection devices, secondary containment provides the best insurance against accidental release of product into the environment for UST owners and the community. Even with the most sophisticated release detection system on the market today, leak detection alone will not ensure against contamination. An investment in sound secondary containment for both tanks and piping can avoid real headaches. Another benefit to the tank owner is that secondary containment allows the use of interstitial monitoring as a more economical choice for UST leak detection.

The technology for secondary containment of steel UST's has advanced significantly over the past 15 years, and under today's standards, several types of secondary containment tank constructions are permissible. As mentioned earlier, the sti-P 3 ®, various composite tanks, and FRP tanks are all manufactured in double-wall designs. But it is the jacketed tank which is the most recent product innovation in secondary containment.

Some of the most important factors for a good secondary containment tank system are the workmanship of the tank and its testability. The tank should be built to a national standard and be subject to quality control standards typically provided by UL or STI. The primary tank and secondary containment interstice area should be tested in the factory before the tank is delivered, as well as at the jobsite prior to final backfilling by the installer.

Vacuum has become a very common method to ensure secondary containment integrity and many manufacturers are applying a vacuum in the interstice between the steel walls, or between the steel and the outer jacket, at the factory. For example, the STI Permatank® Standard provides for tanks to be shipped with a minimum of 13 inches of mercury negative pressure. (Many manufacturers are actually applying a vacuum of 20 inches of mercury or more, which is comparable to a 10 lb. psi negative pressure.) The tank must hold that vacuum, with a slight tolerance for variations in atmospheric conditions, for at least 12 hours for 10,000 gallon tanks and 24 hours for larger tanks. If the vacuum should drop beyond its tolerance, further investigations into the tank's tightness are done.

It should be noted here that NFPA 30 requires only 5.6" of mercury vacuum be held for 1 hour. However, it is STI's position that the more stringent test as detailed in the above paragraph be conducted. 5.6" of mercury equates to a little over 2 psi. STI prefers a higher vacuum be used for such a short period of time, for greater testing sensitivity.

Upon verification that the interstice still has a vacuum, the installer need not conduct a separate air pressure test of the primary tank and the interstice. The vacuum already assures that both vessels are tight.

A standard double-wall UST (as opposed to a "jacketed" type) may also use vacuum as the interstitial integrity test method. However, another typical test method applies a 5 psi positive pressure to the primary tank. Air from the inner tank will be brought over to the interstice, where there's a very small volume of space, assuring the tanks never test beyond 5 psi. Some air compressors can put out a very significant flow of air and it's
important that the interstitial space not be over-pressurized.

In all cases, a soap test should be conducted to verify the integrity of the outer steel tank weld seams. After the tank has been installed and the integrity of the tank has been assured, the system is backfilled. Many installers then release the vacuum and place a release detection probe into the secondary containment monitoring tube.

A secondary containment system must also be able to allow quick communication of spills or breaches of either the primary tank or the secondary containment. If a leak is never discovered, or discovered too late, serious contamination may occur. Jacketed tanks should have a well-defined interstice so that reliable communication is assured. Compared to the Type I steel wall UST, where steel is laid over welded steel, jacketed tanks utilizing other materials over the steel have dramatically different characteristics. Some materials easily conform to the geometry of the steel inner tank, including at weld seams. Some plastics shrink as they cure. Some materials form a very smooth surface. Interstitial vacuums and heavy earthen backfill loads tend to push these materials against the steel. Hence, some means of separating the non-metallic outer containment material from the steel primary tank - to enable the communication of any liquids - is critical to the function of the system. In addition, the material used to define the interstice cannot interfere with system integrity testing. A smooth separation material can literally plug a pinhole in the primary or outer tank during a vacuum or air pressure test - obviously not a desirable feature in a secondary containment tank.

The Importance of Proper Installation Procedure
Field experience has shown that the development of technologies that protect against corrosion require careful installation. While tanks fabricated of all-FRP are particularly reliant upon bedding and backfill for structural support, all tanks generally require some attention to backfilling and other proper installation procedures. Steel and FRP tank manufacturers have developed installation instructions that cover the key points essential for reliable tank service. All STI technologies mentioned earlier have specific installation standards which are provided with every tank purchase. Further recommended installation practices are published by the Petroleum Equipment Institute (PEI), PEI/RP 100-94, "Recommended Practices for Installation of Underground Liquid Storage Systems" and American Petroleum Institute (API), API/RP 1615, "Installation of Underground Petroleum Storage Systems".

Below are some of the most significant installation concerns relative to corrosion protection:

An excavation free from hard or sharp materials that could damage tanks or adversely affect the exterior tank coating. Bedding and backfilling material must be clean, homogeneous, granular material made of either sand, fine gravel (#8) pea gravel, or crushed stone for steel tanks. The bedding and backfill material should be one and the same. Backfill should surround the tank and be at least one foot over the tank to avoid tank damage.
Careful tank handling. Lifting and lowering the tank into the excavation must be done with equipment that can adequately hoist the tank without dragging or dropping. Coating must be carefully inspected and any damage repaired in accordance with NACE and SSPC, Steel Structures Painting Council, Standards.

Careful connection of piping to the tank fittings or bushings. sti-P 3 ® tanks in particular rely upon bushings for electrical isolation from the piping system and composite steel tanks often use bushings as well. Continuity checks should be performed on both cathodically protected and composite steel tanks to ensure that piping and other metallic structures (conduit, anchor straps, gauges and probes) are indeed isolated from the tank.

Wrapping It Up
Like the baby boomers and hippies, steel underground storage tank technology has truly come a long way since the 60's. But unlike those maturing boomers who may have lost a bit on top or gained a bit around the middle, steel USTs have actually increased their lifespan with state-of-the-art corrosion-resistant technologies. By installing any of the steel UST technologies referenced in this article, you can be assured that "rusty old steel tanks" are a thing of the past.