New Underground Understandings
As EPA's 1998 Compliance Deadline Approaches,
UST Managers and Manufacturers
Address Evolving Issues

By Wayne B. Geyer

The world of underground storage tanks (USTs) has been turned inside out.

End users once occupied themselves with concerns about the corrosion of steel tanks and the deflection of fiberglass-reinforced plastic (FRP) vessels.

Today, they're likelier to wonder about the corrosion of FRP tanks and the structural integrity of some lighter-weight steel USTs.

In fairness, because of the advancement of tank technologies, these new concerns are extremely rare compared to the end-user issues of the early 1980s. But they exemplify how completely the industry has changed during the last 15 years.

Here are some key examples:

Alternative Fuels Impact. As the Clean Air Act raises the stakes for reducing hydrocarbon and nitrogen oxide (NOx) emissions, oil companies increasingly are looking at the addition of alcohol-based mixtures to gasoline blends. The corrosive effect of higher concentrations of alcohol on older-vintage non-metallic tanks and various elastomeric/plastic components has been the focus recently at meetings of important trade group tank users.

Thin Is Not In. Steel Tank Institute (STI) and the American Iron and Steel Institute (AISI) in recent years have co-funded research on the structural integrity of underground tanks built with designs that combine reduced steel thicknesses and FRP coatings. Research findings have shown that the external plastic cladding does not compensate for the measurable loss of structural strength associated with the use of thinner-gage steel.

What Goes Down Must Come Up. While USTs for decades served as the standard means of storing petroleum and chemicals in quantities of 50,000 or fewer gallons, thousands of companies that once stored fuels and chemicals underground have begun during the 1990s to place their trust in small-capacity aboveground storage tank (AST) systems.

These are but a few of the trends that will shape the underground storage of flammable, combustible and hazardous liquids for years to come. They represent significant shifts in tank usage and design that will challenge storage system managers -- and manufacturers' abilities to meet technical and marketplace demands.

To understand how all of the changes will eventually play out, it helps to examine
statistics collected by industry groups, regulators and private researchers.

At a March, 1996 EPA conference, a 26-state survey indicated that:

42% of all USTs were in compliance with the regulatory mandate of corrosion control. The EPA deadline that mandates corrosion control for USTs is December 1998. Another 54% were declared to meet release detection requirements. As of December 1993, every regulated UST system was supposed to have a leak-detection system in place. About 37% were estimated to have overfill prevention and containment. Such equipment is required on all existing UST systems by December 1998 and upon all new installed systems. Only 26% of today's active underground storage tank systems were thought to be in compliance with all applicable EPA requirements at the time of the survey.

A separate survey by the Petroleum Marketers Association of America, a group representing thousands of oil jobbers, indicated that 61% of its members' underground storage tanks were in compliance. Their survey indicated that 7% of PMAA members intended to close their tank systems, 18% intended to upgrade, and 10% intended to replace their tanks.

A 1995 study performed by Havill and Associates indicated that 52% of industrial/commercial facilities representing 406,000 tanks/locations were in compliance. The study projected that by 1998, only 374,000 of 769,000 USTs will remain at these locations. The government and the construction industry were found to be two of the larger primary tank owner classifications in this study who will be significantly impacted by the 1998 deadline.

EPA has reported that 1.1 million of the 2 million regulated tanks have been either upgraded, replaced or closed since 1988. Obviously, this means that a significant number of tank systems will need to be acted upon during the next two years. If these estimates are even close to accurate, the demand for new storage tank installation, old tank removal, or existing tank upgrade available through qualified contractors will far outstrip the current supply -- or the industry's capacity to provide products or services.

When the federal regulations were announced in 1988, there were close to 50,000 new underground storage tanks installed annually. During the 1990s, this number has decreased by half.

Let's assume that with about two-and-a-half years until the regulatory deadline UST manufacturers produced tanks at their plants' full capacities. Under the most optimistic scenario, fewer than 100,000 USTs would be fabricated. That still leaves a void of hundreds of thousands of tanks.

In short, from now until the end of 1998, expect tremendous UST backlogs. Tank system equipment and service suppliers can in no way satisfy all the unmet demand before the
EPA deadline. It's already too late to say, "Don't wait until the last minute." Equipment will become more expensive and the availability of qualified contractors will be virtually non-existent from now until the deadline.

This raises an intriguing enforcement situation for EPA and state agencies that administer UST regulations. When the December, 1998 deadline passes and an underground storage tank system doesn't meet requirements, will the owner/operator be punished -- even if he can produce work orders that haven't been fulfilled? Will that be fair to the UST owner? Conversely, would a lack of enforcement be fair to the thousands of UST owners who did the right thing by depleting cash flow and upgrading their systems years ahead of deadline?

EPA officials in Washington have steadfastly maintained that there will be no extension of the December 1998 compliance deadline. Ten years is enough time to meet the regulations, they have repeatedly said.

**historical backdrop**

The seeds of the 1998 requirements actually go back more than a decade. In 1984, after Congress passed legislation, the U.S. Environmental Protection Agency (EPA) issued an Interim Prohibition to regulate underground storage tanks (USTs). While more detailed regulations were being promulgated, this interim rule scored a bull's eye on tank requirements, even by today's standards. Tanks had to be corrosion resistant, compatible with the product stored, and structurally capable of holding the product.

In 1988, EPA finalized these federal regulations. Tank owners were given 10 years to bring their tank systems into compliance. Besides the important traits described above for tanks; release detection, overfill prevention and containment, financial responsibility, and clean-up requirements were mandated by law. Some states developed more stringent requirements.

Today's environmental regulations exist as a result of buying and operating practices primarily dating from the early 1960s through the early 1980s. Steel tanks and pipes then were installed without corrosion protection. Non-metallic tanks were fairly new and users were scaling a learning curve about their benefits and drawbacks. Little was known about the impact of leaks or spills upon human health and the environment. Fuel was relatively inexpensive.

**current trends**

A broad range of factors resulting from environmental regulations is affecting owners and managers of storage tank systems:

As a backlash to UST regulation, aboveground storage tanks increasingly are specified for capacities of 50,000 gallons and under.

New chemicals and fuels continue to be developed, which means compatibility with tank
and piping materials will always be a concern. Secondary containment continues to become more prominent as a requirement for fuel storage, whether located underground or aboveground. Tank owners have choices to either replace, upgrade or remove their tanks, but the long-term prognosis for safe, economical storage tanks is good, as new technologies continue to evolve.

The economics of alternative materials and design types is very competitive.

**AST Action**

Competition induced by the advent of regulations had an unintended effect. Since 1990, the storage tank industry has witnessed a remarkable shift of demand as tank owners sought alternatives to underground storage tank systems. Probably the biggest change was with the greater acceptance of hazardous products stored aboveground.

Major fire codes have rewritten language to enable operation of an AST system at a motor vehicle fleet facility. Just as UST technology has evolved during the last two decades, AST equipment has also changed because tank owners and regulators re-examined operating practices. New rules went into effect to assure safety. The fire codes pursued adopting language upon AST systems, attempting to emulate the underground storage tank system environment with its requirements, by specifying additional protection from hazards such as vehicular traffic, vandalism, and ballistics.

Statistics reflect this tremendous shift toward AST preferences. Over five years ago, steel storage tank fabricators were building well over twice as many underground tanks as aboveground tanks. Today, the opposite is true in many tank shops.

Regulations obviously account for some of this dramatic change. Since the release of the UST regulations, a perception among storage tank users -- that aboveground tanks are less regulated -- has influenced purchase decisions. In reality, ASTs are more regulated, particularly by the fire codes. EPA also has AST jurisdiction under the Clean Water Act's Spill Prevention Control and Countermeasures (SPCC) mandates and the Oil Pollution Act.

In addition, there have been several congressional attempts to further regulate ASTs. The most recent bills would likely require clean-up of contaminated soils, a loophole in today's AST regulations, particularly if human health and the environment is at risk. The latest bill on Capitol Hill proposes consolidation of all AST rules into a single regulation. It also calls for creation of a new EPA office, the Office of Storage Tanks, which would represent a merger of AST enforcement efforts from various federal agencies with the EPA's Office of Underground Storage Tanks.

Support for new AST legislation has fluctuated with time and with the mood of Congress upon new legislative proposals. Major pollution incidents from aboveground storage systems, such as those which took place in Fairfax, Virginia and Pittsburgh,
Pennsylvania, create momentum for additional legislation or regulation. On the other side of the coin, industry has responded with a number of good standards during this time period, which new legislation is strongly encouraging dependence upon.

Another reason ASTs are often chosen over underground tanks is due to the inherent ability of the tank owner to visually inspect the tank. Even with today's sophisticated monitors for underground tanks and piping, the ability to see the aboveground equipment gives some owner/operators greater visceral peace of mind.

Other storage system owner/operators took a close look at their strategic plan and cash-flow projections. Paralleling the "less-regulated" misconception is the myth that AST systems are always cheaper than UST systems. The final configuration of a system will ultimately determine its long-term cost. Part of this legend grew from the inability of many storage-system operators to get loans from banks for new USTs. The cash-crunch issue was eased somewhat in 1995 when EPA spelled out a lender-liability ruling to give banks greater comfort with their role in making loans on UST projects.

Tank Integrity: Failure Mechanisms
The material used to construct tanks really hasn't changed much since the 1960s. Generically, steel and FRP materials continue to dominate the tank market. It is how these materials are designed for use in tank construction today that differs markedly from how the tanks were built just 30 years ago.

From a historical perspective, the non-metallic fiberglass reinforced plastic (FRP) tank could fail catastrophically, particularly if it was not installed properly. When one occurred, an FRP tank failure usually would be discovered quickly, and within a short period of time after installation, due to cracking. FRP tanks were known to fail from improper backfill and installation. Substandard installation would cause undue stress and strain on the tank, which was supported over its useful life by backfill that enabled the vessel to retain its round shape.

Conversely, the unprotected steel tank would typically fail because of a minuscule corrosion hole, often difficult to detect by olden-day standards, and only after a significant period of time elapsed. Most steel tank corrosion failures occurred at least 10 to 15 years after installation. Steel tanks with insufficient coating would naturally want to revert back to iron ore.

Therefore advantage of each tank material addressed the other material's perceived primary weakness. The FRP tank has been known for its inherent resistance to galvanic corrosion caused by moist soil. The steel tank has been known for its inherent structural strength. Steel tanks have been relatively self-supporting without reliance upon the backfill for structural integrity.

Steel tank manufacturers during the 1960s began offering a number of options to protect external surfaces from corrosion. During the last quarter century, corrosion resistance has been eliminated as a drawback of steel USTs. Production of non-corrosion protected steel
tanks ended at least 10 years ago by the steel tank industry.

FRP tank manufacturers also began to address product weakness by incorporating stiffening rings to assist the tank in resisting buckling and cracking. The FRP industry has also done a credible job of training installers to place tanks properly in either pea gravel or compacted sand.

**Tank Integrity: Compatibility**

If one were to try to find any controversy among the two materials today, one might discover a surprising role reversal.

For instance, old FRP tanks were made with inferior plastic resins, as measured by today's standards. Resins used today are more compatible with oxygenated fuels employed in the 1990s. Tanks built in the 1970s and early 80s were not intended for continuous exposure to alcohols. Due to clean air rules, many of the major metropolitan areas mandate oxygenated fuels. Ethanol, MTBE (methyl tertiary butyl ether), and methanol have been the most common oxygenates added to fuels during the last decade.

As a result, many of the early FRP tanks are not warranted when subjected to the higher concentrations of alcohol blended into new fuel mixtures. The alcohols can soften the incompatible tank walls and reduce the physical strength properties of the FRP. Today's FRP tanks can be purchased with an Underwriters Laboratories (UL 1316) listing indicating the fuel tanks to be compatible with alcohol contents from 5% to 100%. One could conclude that corrosion has become an issue with plastic tanks. After all, the National Association of Corrosion Engineers (NACE) defines corrosion as the deterioration of a material within its environment. In other words, corrosion is not limited to metals only.

For steel tanks, compatibility is also very important, particularly given the large range of chemicals that require storage. Petroleum and alcohols are considered compatible with mild steel as evidenced by the warranties supplied by tank manufacturers. Of course, if carbon steel is not compatible, there exists a large number of alternative metallic materials which might serve this role. For example, stainless steels are commonly used to store chemicals.

**Tank Integrity: Reduced Thickness Steel**

In 1989, Underwriters Laboratories introduced a new corrosion control standard for steel tanks, UL 1746, "External Corrosion Protection Systems for Steel Underground Storage Tanks.". One part of the standard enabled FRP composite steel tank walls to be reduced one gage when certain performance tests were met. The rationale was that the outer FRP cladding of 100 mils would reinforce the thinner steel without a loss of strength or resistance to soil loads.

This provision was heavily debated throughout the 90s by Steel Tank Institute technical
staff and member manufacturers. The issue was buckling, a phenomenon unheard of for steel tanks built to UL 58 standards. The UL 58, Standard for Steel Tank Underground Tanks for Flammable and Combustible Liquids, was originated in 1925.

However, several STI research initiatives, in conjunction with the American Iron and Steel Institute, during the 1990s indicated that a reduction of steel within the UL 1746 standard would diminish the steel tank's resistance to buckling by 60%. High water tables, combined with deep burials, would exert a large hydrostatic pressure upon the tank bottom, possibly pushing the tank bottom upwards. An excessive deflection could push the tank into the drop tube used for filling and removing product. It also could cause errors in tank gage or computerized tank inventory readings. Excessive deflection could cause weld seams to tear. Since steel tanks were commonly installed with various types of sand backfill, the type of sand, its moisture content, and its compaction effort would have to play a pivotal role on a tank that depended on backfill for its structural integrity.

The thin-wall steel tank was a new design; therefore, there was virtually no historical data to evaluate. STI was concerned about the environmental protection implications if such tanks failed from buckling. In STI's most recent study, experiments were conducted at Ace Tank & Equipment in Seattle during 1993-1995, which successfully showed the relationship between steel tank wall thickness, diameter and buckling resistance to hydrostatic pressures. The experimental data correlated with formulas published in Roark's Formula for Stress and Strain. As a result of STI's study, a minimum steel tank thickness can be derived for a given set of parameters, such as tank dimensional data and burial depth.

This is a real bonus for specifying engineers. The results of the study enable for the first time the verification of whether a manufacturer's wall thickness is sufficient for a given installation. The backfill is no longer considered an integral part of the tank's structural integrity when deriving a wall thickness with the formula. With the UST, the backfill will act as a safety factor. As result of the STI research, UL is proposing revisions to industry with its UL 1746 and UL 58 standards to incorporate this design philosophy and the associated formula.

The other contention that required study was that the FRP cladding stiffened the tank sufficiently to adequately reinforce the thinner steel wall. STI hired Battelle Laboratories in 1990 to perform a theoretical study on this aspect. The data obtained, along with the findings of the full-scale tests, showed that the FRP added about 5% additional stiffness to steel tanks with capacities around 8,000 to 12,000 gallons. This percentage is greater for smaller tanks and diminished for the larger factory fabricated FRP clad steel composite tanks, such as the 50,000-gallon tank. The STI studies showed that FRP cladding certainly did not replace the 60% of stiffness lost when the steel wall was reduced -- thereby making these thinner-gage tanks more susceptible to buckling.

**Secondary Containment**

Secondary containment is the most significant change in storage technology during the
past 15 years. It is more than just an upgrade in tank or piping. It has really become a philosophical statement unto itself. When we think of pollution prevention or the phrase "environmentally safe", secondary containment is one of the first thoughts that come to mind.

With non-petroleum underground tank systems storing chemicals, secondary containment is mandated by EPA regulations. However, states such as Florida, California, and most of the states in New England require secondary containment of petroleum products as well. States such as Michigan and many others will require secondary containment when a fuel-storage facility is in close proximity to a water well or other important water source.

To minimize pollution risk, most large corporations have lassoed requirements for secondary containment into their own company standards. (It is interesting to note that secondary containment has worked its way into the thoughts of aboveground storage tank system owners as well. In 1990, secondary containment of ASTs was rare indeed. Today, about a third of ASTs have integral factory attached secondary containment.)

STI in 1984 was the first organization to develop a national standard for secondary containment. Some of the standard's key design features actually originated in Germany. Members of STI's committee developing this standard visited and consulted with German manufacturers, who had years of experience with secondary containment design and fabrication.

Under the STI standard, one steel tank was fabricated into another steel tank -- virtually layer upon layer. Until STI discovered this German technique, double-wall tanks in the U.S. were separated by angle iron to create a channel that could be as wide as 6 inches. Prior to 1984, the philosophy was that a secondary containment system must contain 110% of the primary tank. The new STI standard enabled the outer steel tank to be wrapped directly onto the primary tank, which created a significant cost reduction. In reality, the outer containment merely had to contain the product which was released from the inner tank until it could be detected. One will never need more than 100% of the primary tank capacity to contain a release.

Detection of the release was the second key parameter with STI's Dual Wall Tank Standard. STI did not want to limit how that product was detected. The key was retaining product for quick detection. This enabled a whole slew of new technology to develop for monitoring purposes. Today's interstice monitors use an assortment of technology to detect product or water -- optics, pressure sensing switches, electronics, etc.

EPA officials drew upon this thought process within their final regulations. The EPA allowed an assortment of leak detection methodologies to meet its requirements, such as groundwater and vapor monitoring systems. An interstitial monitor of double wall tanks was also considered acceptable. EPA requires that the interstice be monitored every 30 days for releases.

Secondary containment is a pretty simple idea. STI's standard was less than 4 pages in
length. But it has helped to create a whole new approach to storage and handling of fluids. Today's tank and piping equipment has evolved far beyond the rudimentary concepts of the dual wall tank standard. All sorts of unique materials are being used for containment. For instance, one popular type of 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.

New Technologies

As evidenced by the misconceptions cited earlier about ASTs, underground storage tank systems have received a broad-brush bad rap, due to media coverage of occasional old-technology or unprotected tank failures or improper operating practices. It is really unfortunate, particularly when one looks at how far technology and training for tank managers and installers have progressed through the years.

For example, sophisticated tank and pipe secondary containment systems have been developed to meet the EPA's secondary containment mandate for underground storage of non-petroleum chemicals. Computerized in-tank monitoring devices for tracking inventory, evolutionary tank integrity testing equipment, statistical inventory reconciliation analysis, leak free "dry-disconnect" pipe and hose joints for loading and unloading, and in-tank fill shut-off valves are just a few of the many pieces of equipment which have surfaced as marketplace solutions.

Today's state of the art systems are safe. In many cases and with the right equipment, they can be made virtually goof-proof. This may surprise many people with fresh memories of crisis mode when their facility encountered problems with an underground tank or piping system. Nevertheless, it is worth stating -- underground storage of product with today's equipment provides a storage location with the least amount of liability to today's storage tank owner/operator. There are no worries about vehicles impacting an aboveground tank system, no vandalism concerns, and best of all, it can provide a leak-free, fire-resistant environment.

Economics: Compartment Tanks

Compartment tanks are an old idea that gets a lot of attention in today's marketplace as a means for reducing tank-system cost. Buy and install one tank. However, the one tank has several bulkheads within it to divide the vessel into compartments or separate storage areas. One paint manufacturer recently purchased a seven-compartment tank to store all of its bulk chemical needs.

This type of construction has several advantages. It reduces installation costs as the excavation is much smaller. Sometimes, it entails reduced state registration costs and smaller insurance premiums. The overall cost of the compartment tank is reduced too, especially if the tank is secondary contained. Only one containment, one external corrosion control system, and one monitor is necessary. Again, it reduces initial capital expense, reduces operating costs, and tends to simplify things a little bit. All things being
equal, pipe, pumps and other liquid handling systems will still cost about the same.

Steel tank manufacturers can build compartment tanks to almost any configuration and size. This includes the placement of fittings and fitting sumps in pre-designated areas. FRP manufacturers can also fabricate compartment tanks.

**Economics: Upgrading Existing Tanks**

Another cost issue examined by tank owners has been whether it's best to replace or upgrade a non-compliant UST. Owners who want to extend the life of their tank system a few years routinely choose to upgrade. For instance, the owner may have facility-expansion plans that call for tank replacement at a later date.

EPA allows tanks without corrosion protection to be lined internally if the tanks are structurally sound. Tanks would have to be inspected 10 years later and then inspected on a five-year interval to assure that the lining was still viable. EPA also allows a tank to be upgraded with cathodic protection. An impressed current system can be specifically designed for external protection of the tank and piping system, which then must be checked every 60 days to ensure that the equipment is operating properly. In addition, cathodic protection readings must be recorded every three years.

For tanks less than 10 years of age, integrity tank tests are required upon cathodic protection upgrades both before and after the system is modified. If the tank is over 10 years in age, it must first be internally inspected and tested. Of course, the tank could be lined and cathodically protected to avoid additional preliminary tank integrity tests and ensuing tank lining inspections. When 1998 arrives, internal lining will no longer be accepted as a means to upgrade a tank system, since the regulations by then will already have mandated external corrosion protection upon all existing tanks.

Many times, the issue of whether to replace or upgrade is based purely on economics. Normally, the cost to upgrade will not be as expensive in the short run. However, one should look at the costs extended over the life expectancy of the tank system, including the additional testing, inspection, and monitoring costs with upgrading. Don't limit this analysis to just the tank. The piping system will also need to be replaced. Vapor recovery may be mandated by law. More sophisticated pumping and dispensing equipment may also be necessary.

Then there are all the intangibles with owning a new tank system. In the case of a fleet manager with a fueling system at the truck terminal, there is the knowledge that product is only being used in the fleet vehicles and that workers aren't turning a five-minute refueling process at an off-site location into a 30-minute adventure. One fleet operator tells the story of the monthly experience where a driver takes off with the dispensing hose still in the vehicle. Today's modern computerized storage and handling systems can identify the driver responsible for such a mishap. Old technology will not.

In many cases, tank owner/operators simply prefer to install a new state-of-the-art
system. This brings greater peace of mind, reduced liability, lower risks and extended tank life.

Warranties

When purchasing tanks, it is also important to look at how the tank will be supported over the long term. Most tanks are warranted for 30 years in the United States against corrosion and structural failure. Companies come and go and it is important to make sure that the warranty will have some meaning over the long haul. For example, two prominent UST fabricators, which only a few years ago were expected to be around for a long time, are no longer in the tank business. Buffalo Tank Corporation, a steel tank manufacturer once owned by Bethlehem Steel, went out of business about three years ago. Owens Corning, the first fabricator of non-metallic FRP tanks, sold its tank business in 1994.

To assure that tank buyers receive meaningful, long-term warranties, STI manufacturers formed a captive insurance company in 1988 that covers many tanks subject to the Institute's quality control program.

tank construction and materials

Steel Tank Technologies and Standards
The basic standard for steel tank construction has been UL 58. This standard specifies acceptable steel joints, fittings, manways and bulkheads, and dimensional parameters. In Canada, Underwriters Laboratories of Canada ULC-S603 offers comparable requirements.

Cathodically Protected Tanks. For pre-engineered factory fabricated cathodically protected tank construction standards, the UL 1746 Part I and ULC-S603.1 act as two third-party testing laboratory standards. The most popular tank in the United States has been the sti-P 3 ® tank. Nearly a quarter million of these tanks have been installed since 1969 when the sti-P 3 ® tank came into existence.

Several older sti-P 3 ® tanks have been removed due to new construction requirements at a specific site. Tank-removal crews have attested to the excellent condition of the vessels, which demonstrates how well cathodic protection works. A few of these tanks were improperly installed or were never monitored for cathodic protection readings, yet they performed flawlessly. (STI highly recommends that tanks be installed strictly in accordance with the manufacturer's instructions.) Common dielectric coatings for the P3 tank include urethane, coal tar epoxy, and FRP coatings. Anodes of magnesium or zinc can be wired on or welded onto the tank. Nylon bushings serve to electrically isolate the tank from pipe and related tank appurtenances.

In 1993, Tillinghast, a major risk-management consulting firm, was asked by the Steel Tank Institute to conduct a survey of tank owners, installers, and regulators to identify any instances of failures attributed to external corrosion with the P3 system. The final
report indicated a near negligible percentile of corrosion instances, less than 0.04% and no incidents of corrosion failures upon tanks properly installed and maintained.

Special multi-site testing studies have been performed to indicate that galvanic anodes would last well over 50 years with a well-coated structure and with electrical isolation from all tank appurtenances. With thick film coatings, tests have shown anodes will last as much as 100 years or longer, based upon standard corrosion control anode-life calculations.

UST systems designed for field-applied cathodic protection usually fall under the National Association of Corrosion Engineers standard RP0285-95.

Composite tanks. There are several systems which depend upon a thick film coating without cathodic protection. Traditionally this has been the FRP clad tank, often called a composite tank. The FRP coating is 100 mils thick, (0.1”). Acceptable coatings traditionally pass a series of performance tests specified in UL 1746.

The Steel Tank Institute began its program for the ACT-100® steel composite tank in 1990. Although its numbers in STI's tank-registration database are dwarfed by the sti-P 3 ® tank, the ACT-100® technology also has never seen an external corrosion failure with tanks properly installed and fabricated. To prove that these factory applied corrosion resistant steel tanks will be free of voids, a 35,000-volt holiday test, or spark test, is performed upon the external shell of the completed product.

This year, a new type of material has entered the field of thick film coating systems that do not require anodes. Thick urethane coatings have passed Underwriters Laboratories performance test requirements. Some of these claddings have glass and some do not. STI is currently bringing this new technology into its tank programs for member manufacturers. Thick film coated tanks without anodes and jacketed tanks continue to gain a higher percentile share of today's underground tank market.

Jacketed Tanks. The latest trend in the steel tank industry is to take the thick-film cladding material and separate it from the primary tank to form a jacketed tank system. A jacketed tank system meets the definition of secondary containment by containing product until it is detected within an interstice that can be monitored for fluids.

Common jacketed steel tank materials are made from FRP and high density polyethylene, although other materials are also under development. Two critical parameters are the means used to separate the outer jacket from the primary tank, and how quickly a breach can be communicated to the monitoring probe. Most of these tanks are shipped with a vacuum between the steel primary tank and the outer jacket. The vacuum serves as an integrity test verifying both walls are sound until the leak-monitoring probe is installed on site. It is important to gain a high level of confidence that the vacuum shown at the gage is representative of a vacuum surrounding the entire tank system. A tank without a clear means of separating the jacket from the tank may inhibit the vacuum.
Jacketed tanks are made to the UL 1746 Part III requirements. The Steel Tank Institute oversees a program for Permatank®, as an FRP jacketed steel tank, although several other systems also are available nationally.

FRP Tank Technologies and Standards. Non-metallic tanks can be purchased in single wall or double wall configurations. Tanks are normally stiffened with ribs. Well-defined installation instructions accompany each tank. Some double wall tank systems will use a hydrostatic monitoring system, where water is placed between the walls and a reservoir above the tank is monitored for level changes.

ancillary tank equipment

It is important to remember that piping contributed to nearly two-thirds of all equipment releases according to EPA surveys from the 1980s. Unfortunately, tanks often receive the blame even when the pipe is the culprit. The same pattern is surfacing today with aboveground tank releases. The releases are more apt to come from piping than from the tank bottom.

Why is that? Pipe systems installed 20-30 years ago were typically black steel or galvanized steel pipes without any other type of corrosion protection. The pipes were threaded together, often incorrectly. Many of these pipe systems released product due to corrosion or at poorly joined connections. Old practices contrast with many of today's 2-inch diameter pipe systems, which are made with unique corrosion resistant materials. Some of these systems are joined with chemicals. Other flex pipe systems do not have any direct buried joints, with connections placed in accessible sumps or designated boxes. This enables access to all joints at any time. Finally, well-coated steel pipes are still a material of choice for many chemical systems due to compatibility, permeability, or size. A cathodic protection system can be easily designed and installed.

Three other storage-system zones where releases can commonly occur, besides the tank and pipe, include the dispenser, the tank fill pipe, and the product pump. The EPA requires that product loaded into the tank be stopped when its level reaches 95% of tank capacity. To prevent accidental spillage of the remaining product within the delivery hose, a 5-gallon sump commonly is placed around the fill connection opening. Normally, this product can be directly drained into the tank.

Submersible turbine pumps are commonly installed upon USTs, but are often placed within a large sump, capable of being entered for physical maintenance of the pump. Some pumps use suction and are installed at the point where product is withdrawn. Piping systems under suction minimize risk of contamination compared to pressurized pipes. Hence, EPA has more stringent leak detection requirements for pressurized piping, as well as operational testing requirements.

The sumps in themselves have become quite elaborate. Water has been the biggest hurdle in the past as rainwater or groundwater would commonly find its way into the sump. Today's sumps are made to be free of water. Product and water-sensing devices are
installed in the sumps to monitor for liquids.

Finally, dispenser systems also continue to evolve technically with elaborate electronics. This is best exemplified by today's typical service station. A customer can stick a credit card into the dispenser and fuel his vehicle without taking more than a few steps from his car. Basins are installed under dispensers to catch any leakage during maintenance activities performed upon the dispensers.

**liability exposure**

Underground storage tanks continue to be an important issue today. Obviously, the 1998 deadline and the requirement to meet regulations is important. A good public image is just as crucial as regulatory compliance to a company storing chemicals. Newspaper headlines that present the organization as a polluter or as a company disregarding regulations can be very damaging to employee, community and investor relations.

The liability created by chemicals leaching into soil or groundwater is tremendous. Average clean-up costs can range from $50,000 for simple soil remediation to millions of dollars when groundwater becomes contaminated. The good news today is that new technology has evolved to clean-up sites more efficiently and at a lower expense.

**clean-up**

As of the end of 1995, EPA said 303,000 underground storage tanks were reported to have spills or releases since December 1988. Of these, according to National Petroleum News Magazine, 131,000 sites had been cleaned, but 600 new petroleum leaks are reported each week. While this again may sound troublesome to a tank owner who has not assessed their tank site, some good news can be reported here. In-situ remediation is growing in popularity as an acceptable clean-up method for fuels. The governor of California recently made headlines announcing that it may be most cost effective to simply allow nature to clean a site with alluvial soils via natural remediation, as long as drinking wells are not nearby. The main point here is that natural processes may degrade hydrocarbons in soils at the same rate as expensive technologies. On the other hand, less research has been made upon the characteristics of more volatile and hazardous chemicals within a soil environment. Thus, some chemicals may present a greater human health and environmental risk and may not naturally degrade within soil, perhaps necessitating an immediate clean-up.

Standards have also been developed that provide guidance in attaching priorities to clean-up sites based upon comparative levels of risk. A "Guide for Risk-Based Corrective Action at Petroleum Release Sites" was recently published as a new ASTM standard, ASTM E-1739-95. States, too, are prioritizing their efforts where the need is greatest. Once upon a time, the easiest solution was to haul the contaminated material to an authorized landfill, regardless of the degree of contamination. With a more refined definition of what is needed to clean-up sites and when it is necessary, clean-up efforts will become more efficient and cost effective. This should leave tank-owning firms with
more money available to replace or upgrade their systems. Other ASTM standards of interest, including provisional standards (PS prefix), are:

E1526-93 "Practice for Evaluating the Performance of Release Detection Systems for USTs"
E1599-94 "Guide for Corrective Action for Petroleum Releases"
E1430-91 "Guide for Using Release Detection Devices with USTs"
PS 03-95 "Guide for Site Characterization for Confirmed of Suspected Petroleum Releases"
ES 40-94 "Practice for the Assessment of Buried Steel Tanks prior to the Addition of Cathodic Protection" (emergency standard up for final ballot in 1996)
E1527-94 "Practice for Environmental Site Assessments: Phase I"
PS11-95 "Practice for Environmental Compliance Audits"
"Provisional Standard Guide for Risk-Based Clean-up of Non-Petroleum Releases"

regulatory compliance

EPA published its requirements for underground storage tanks in 40 CFR Part 280 on September 23, 1988. Since that time, EPA has published a significant number of pamphlets in plain English to help tank owners better understand regulatory requirements. Contact EPA's Office of Underground Storage Tanks at 703-418-9700 or by mail at 401 M Street, S.W. (5401G, 5402G, 5403G), Washington D.C. 20460 for a copy or full list of informational pamphlets:

MUST for USTs: Summary of Federal Regulations for UST Systems
Don't Wait Until 1998: Spill, Overfill and Corrosion Protection for USTs
Dollars and Sense: Financial Responsibility Requirements for USTs
Manual Tank Gauging for Small USTs
Doing Inventory Control Right
Introduction to Statistical Inventory Reconciliation
Straight Talk on Tanks: Leak Detection Methods for Petroleum USTs and Piping
UST Program Facts: Implementing Federal Requirements for USTs

The Petroleum Equipment Institute's annual Convex trade show for underground storage tank equipment provides ample evidence of the tremendous worldwide interest in today's UST technologies. Some of this interest has been generated by new regulations in various nations that reflect expanding global concern for the environment.

Canada developed its latest requirements for underground storage tanks within the Federal Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products, CCME (Canadian Council of Ministers for the Environment), as published in March, 1993. All systems in Canada must provide secondary containment. Each province has its own set of requirements. Many of the equipment requirements are based upon Underwriters Laboratories of Canada standards. 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.

Mexico recently upgraded its requirements at service stations for USTs. PEMEX, Mexico's nationalized oil company, franchises all retail stations. In their 1992 "General Specification for Project & Construction of Service Stations," all tank systems must employ secondary containment. There was a tremendous demand for USTs in 1993-4, 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 May, 1995, the European Committee for Standardization, consisting of 18 countries' national standard bodies, drafted a European Standard entitled "Horizontal Single Skin and Double Skin Tanks for Underground Storage of Flammable and Non-Flammable Water Polluting Liquids." Compared to North American standards, the European document calls for a higher tank test pressure to verify integrity. Pressures of 9 to 30 pounds per square inch (0.6 to 2 bars) are used in Europe; 5 psi is common in North America.

Much of the global interest is being driven by environmental concerns. But keep in mind that fire codes continue to have significant influence over the operation of storage tank systems.

In Canada, 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.

In the United States, fire codes are well established to assure the safe storage and operation of potentially explosive liquids. The Flammable and Combustible Liquids Code, NFPA 30, developed by the National Fire Protection Association, is known worldwide for this purpose, as is the Automotive and Marine Service Station Code, 1993, NFPA 30A.

The United States has three model fire codes developed by its members, such as those authorities having jurisdiction over UST installations -- the International Fire Code Institute's Uniform Fire Code, the Building Officials and Code Administrators National Fire Prevention Code, and the Southern Building Congress Code's Standard Fire Prevention Code. Interesting enough is the fact that the code groups are planning to merge their safety requirements into a common fire code by the year 2000. The harmonizing movement of codes is being driven by the International Code Council, or ICC, an organization formed by the model code bodies for this very purpose.

**installation requirements**

An underground storage tank and piping system is only as good as its installation. Here
are some key elements of high quality installation:

Steel tanks can use a bedding and backfill of sand, crushed stone, or pea gravel. Large sharp rocks are not acceptable, particularly if they can damage a coating. Steel or FRP tanks require a 12-inch bedding, although a 6-inch depth is acceptable for steel tanks anchored to a concrete pad.

Tanks are normally buried approximately 4 feet below grade. One of the telling factors is with the pipe destination. The pipe is to be sloped 1 inch per 8 feet. Lengthy routed pipes to dispenser points might dictate a deeper burial.

The tank is to be handled using the designated lift lugs. When stored at the site, chocks should be installed at the tank sides to keep the tank from rolling.

Many double wall tanks come with a vacuum already in the interstice. The vacuum amount should be compared against the amount of vacuum within the interstice when the tank left the factory. A significant difference between the two readings will require further investigation. Contact the manufacturer for further directions, in such a situation.

Single wall tanks need to be pressurized with 5 psi pressure and a soap solution applied to all weld seams. Any large bubble formation is indicative of a pinhole. FRP tank surfaces need to be soap tested over the entire surface. Larger FRP tanks are tested at lower pressures.

Coatings of steel tanks should be visually inspected and repaired. Obviously, clad systems must be carefully repaired. Any repairs should be holiday tested in the field to assure a pinhole-free coating.

Most underground tanks should be anchored. Enormous buoyancy forces can develop in an empty tank where high groundwater conditions exist. In native clay soils, it is possible that an excavation will see an artificially high water level within the excavation itself, simply because the water cannot drain into the native clays as quickly as it gets into the backfill. Again, such systems should be anchored.

Straps are used to hold down a tank to either a concrete pad under the tank or a deadman bar of concrete laid along the side of the tank. The straps should have enough bearing surface to resist the anticipated buoyant forces. For a typical 10,000 gallon tank, this force can be as high as 100,000 pounds. Rods or cable should not be used as these can damage the coating or the structure. Straps must be installed in pre-designated places upon an FRP tank. With steel tanks, steel straps should be placed over rubber dielectric material to electrically isolate the strap and tank from each other.

Place any other appurtenances required for the cathodic protection system at the same level as the tank bottom, such as buried reference cells. STI mandates a PP4 test station with a buried reference cell upon all regulated P3 tanks.
Backfill with the same material as the bedding material. Placement of the backfill under the bottom quadrants or haunches is essential. This is good not only for the tank, but also to prevent long term consolidation of the backfill and breakage or cracking of the pavement above the tanks.

When piping connections are made, use a compatible sealant material to obtain a good seal. Pipe should be well inserted into the tank flange. Test stations for cathodic protection systems should be brought to grade.

Final integrity tests of tank and piping needs to be made. Cathodic protection tests should also be conducted, making sure the tank is electrically isolated from the other structures and a -850 millivolt reading is obtained. The FRP tank should be measured for deflection. To keep the FRP tank warranty, the tank diameter is only allowed to change from its original shape by an amount specified by the manufacturer. All checklists furnished by the installer should be filled out and kept in a permanent location -- along with any photos of the installation. Warranty records should be sent to the manufacturer; again, copies should be kept with permanent records. Appropriate labels should be recorded. Any product designations should be indicated with the tanks' fill pipes or manhole opening.

Specific, illustrated installation instructions are delivered with each tank. The Petroleum Equipment Institute and American Petroleum Institute have developed comprehensive standards for all phases of tank system installation, respectively, in PEI-RP100, "Recommended Practice for Installation of Underground Liquid Storage Systems", and API RP 1615, "Installation of Underground Petroleum Storage Systems". EPA has also developed some good resource material, including videos. At least 18 states require that installers be certified or licensed to qualify for regulated UST installations or services.

Contact the U.S. EPA, American Petroleum Institute, Petroleum Equipment Institute, Underwriters Laboratories, Fiberglass Pipe and Tank Institute, or the Steel Tank Institute for additional resource materials.