Steel Tanks: Past, Present and Future

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Past

Imagine the scene in Titusville, Pa. on that August day in 1859 when the first oil-well gusher erupted. Oil spewed into the sky and returned to earth as a grimy mess. But there were no corporate hazardous materials specialists on call. There were no carefully crafted procedure manuals to consult on how to actually capture and store the black gold. Daniel Yergin, author of The Prize , a book that chronicles the history of the oil industry, reports that the locals in Titusville rushed tubs, wash basins and whiskey barrels into use to contain the product that would change the world.

The growth in the use of petroleum forced oil companies to find the most effective ways to store the energy source. In the oil industry's earliest days, wooden barrels had to serve as storage vessels. But the capacity limitations of coopers and their products became apparent quickly, which eventually led petroleum producers and sellers to seek a reliable, long-term solution.

During the late 1800s, riveted steel tanks were developed for the specific purpose of storing petroleum - and, eventually, liquid chemical -- products. Whether employed aboveground or underground, the riveted tank became the standard for storage when the needed capacity was beyond a few barrels.

Starting to standardize tanks

The concept of standardizing tanks that held flammable and combustible liquids had great appeal to tank owners, manufacturers, fire officials and insurers. Several organizations concerned about the manufacture of tanks began a long association with oil-storage safety issues in the early 1900s.

An association of steel tank manufacturers -- which later would become Steel Tank Institute (STI) -- was formed in 1916. Around the same time, a third-party testing laboratory -- Underwriters Laboratories (UL) -- was developing its first safety standards for atmospheric steel storage tanks. UL is a testing agency specializing in certifying product safety through listing procedures.

In 1922, UL developed its first atmospheric aboveground steel storage tank standard, UL 142 (Steel Aboveground Tanks for Flammable and Combustible Liquids). In 1925, the agency published the first edition of its UL 58 document (Standard for Steel Underground Tanks for Flammable and Combustible Liquids) .

Another standard critical to the development of the storage tank industry preceded the UL developments. It was created by a group that developed and promoted industry consensus standards for protection of the public and firefighters from the hazards caused by fires.

The National Board of Fire Underwriters published NBFU 30 (circa 1904), which, as its title states, covered "Rules and Requirements for the Construction and Installation of Systems for Storing 250 Gallons or Less of Fluids Which at Ordinary Temperatures Give Off Inflammable Vapors, as Recommended by its Committee of Consulting Engineers."

Codes and standards developed by NBFU over time became the responsibility of the National Fire Protection Association (NFPA), which modified the storage system standard's code designation to NFPA 30L (published in 1913). Today that standard is known as NFPA 30 (Flammable and Combustible Liquids Code), which was first published in 1957. Many governmental bodies today reference the NFPA standard either by legislation, statutes or ordinances to give local or regional officials an enforceable code document. The NFPA code refers to various construction standards written by UL and STI, among other groups, as acceptable construction practices.

NFPA's work on storage tank issues has been essential, as most hydrocarbons are either flammable or combustible, requiring safe storage, handling and management.

As the use of petroleum products escalated, the producers of hydrocarbons and the companies that install tanks developed their own associations. The American Petroleum Institute (API), formed in 1919, has published several standards pertaining to the safe storage and operation of flammable and combustible liquids. The Petroleum Equipment Institute (PEI), founded in 1951, has developed several important guideline documents considered essential for the proper installation of underground and aboveground shop-fabricated storage tank facilities.

The impact of urbanization, industrialization

The first service stations required minimal storage tank capacity. In fact, it was common for product to be stored within the dispenser itself. As the need for hydrocarbons grew, the ability to store the product safely became an important growth factor for the petroleum, automotive and heating industries.

As the use of chemicals for industrial processes grew in prominence, tanks provided capacity and efficient handling that barrels in many cases could not match.

Some fuel tanks were installed aboveground at gas stations, but many were installed below ground, for aesthetic purposes, particularly at public retail service stations.

As urban areas became densely populated - leading to increased numbers of vehicles on the road - underground tanks became a more popular choice for fuel and chemical storage. The burial of USTs freed business owners to use real estate for other more-productive purposes. USTs also were more aesthetically pleasing than ASTs. From a public-safety perspective, USTs eliminated concerns about vehicle collisions or other forms of damage that could result in spilled fuel.

Welding replaces rivets

In the "early days" of steel tank production, the joining of steel by riveting was common. Most tanks were small by today's standards, under 1,100 gallons, but a few larger tanks were built.

During the 1920s and 1930s, arc welding replaced the riveting process for many steel fabricators, which led to higher quality tanks with fewer opportunities (rivet holes) to spring a leak.

Galvanized steel sheet was often used in producing the tank. However, World War II created a shortage of galvanized product. UL began to allow the manufacture of tanks from black carbon steel due to the scarcity of galvanized steel.

The basic cylindrical design remained virtually unchanged for decades. However, In the mid-1950s, the tank industry stirred slightly as improved manufacturing methods were discussed. STI advocated placing the product line on the bottom of a heating oil tank to prevent any accumulation of water. This design breakthrough carried the water with the heating oil to the burner, which led to evaporation. And in 1956, STI issued its Midwest 56 Standard, a widely recognized approach to designing the size and location of openings along the top of an underground storage tank.

Corrosion protection advances

Standards also have played a pivotal role in the control of corrosion on underground storage tanks.

Tanks installed during the 1950s were generally coated with red lead primer or a thin asphaltum-based paint. These coatings were fine in preventing atmospheric corrosion; however, they were nearly useless for protection against corrosion in many underground environments. Unfortunately, some tank buyers continued to install non-protected tanks underground until Congress in 1984 empowered the U.S. Environmental Protection Agency (EPA) to prohibit such tanks.

By the early 1960s, the average atmospheric-tank size had increased to nearly 4,000 gallons. And a new material was used to develop and test a different design of an underground flammable and combustible liquid tank. The tank was non-metallic. It was made from fiber-reinforced plastic (FRP). Tank buyers hoped to avoid the inevitable problem with steel underground storage tanks releasing product due to corrosion. At that time, environmental concerns did not drive the new product's development. Foremost on the mind of petroleum marketers were inventory conservation and the cost to replace lost product.

However, from the chemical industry's standpoint, the FRP matrix posed compatibility questions that in the vast majority of cases were resolved with the use of carbon steel, or stainless steel, designs.

The steel industry paid close attention to the efforts to produce a non-metallic tank, as did major oil producers. So steel tank makers responded with their own research efforts-focused on methods to make steel tanks corrosion resistant.

One effort was to install the steel tank in a plastic wrap or baggie. One major oil company had installed a number of these types of systems in Michigan as early as 1959. Steel tanks from this initiative were later uncovered about a dozen years later and found to be free of any corrosion. Preventing groundwater and corrosive-soil contact against the outer steel tank surface essentially eliminates a corrosion trigger.

During the next decade, the plastic baggie concept was commercialized for nationwide steel tank production. By 1970, more than 1,000 plastic-wrap tanks had been installed. Although this concept had merit, the plastic 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.

Given the limitations of the baggie approach, STI developed a new concept - a standard for coating a steel tank with a thick FRP coating. The concept was simple. If a non-metallic tank could be installed to eliminate corrosion, why not coat the steel tank with that very same material?

STI published the standard in 1968 and called it STI-LIFE. The standard actively existed for about five years. But fabricators stopped using it for the most part because of aesthetics and cost. The glass strands were not always lying flat and parallel to the steel. Equipment to produce the coating was relatively unsophisticated, unlike today's manufacturing processes in which the steel tank rotates while glass fibers and resin are sprayed onto the exterior.

Several fabricators continued to make FRP-coated steel tanks. A different standard was developed in 1987 to represent this type of composite product, which became known as the ACT-100 tank.

During the mid-1960s, the US Steel Company recognized the threat of new materials for tanks, which could undermine its interest in maintaining steel as the material of choice for storage applications. Faced with the non-metallic challenge, US Steel dedicated personnel from its research center to corrosion control for underground storage tanks.

The steel tank industry's greatest success followed the US Steel research, which led to development of a cathodically protected underground storage tank known as sti-P 3 ®. In 1969, the Steel Tank Institute unveiled the sti-P 3 ® design, which consisted of three major elements: good dielectric coating of the outer shell, galvanic anodes and electrical isolation of the tank from steel piping. The earliest coating was a coal-tar epoxy, which was significantly advanced from the industry's prior products of choice. In addition to US Steel, Dow Chemical helped to develop the sti-P 3 ® design with Kennedy Tank & Manufacturing Co., an STI member.

There were a number of improvements in the sti-P 3 ® design during the '70s and '80s - including the development of urethane coatings and enhanced methods of applying FRP as an external corrosion barrier. STI developed a national registration program and provided tank owners with a 20-year warranty against failure due to external corrosion. With the warranty came a strong quality assurance inspection program. The fabricator had to fill out a special inspection form for each tank produced. Eventually, STI hired UL to perform its inspections -- until early in the 1980s, when STI started its own quality program. Inspectors arrive at a tank shop unannounced and at random to verify that the fabricator is meeting STI's requirements. Today, the industry norm for the warranty period of underground storage tank products is 30 years.

Throughout the late 1970s, more and more media attention was focused on leaking underground storage tanks - heightening the tank industry's emphasis on environmental protection. Many efforts were focused on integrity testing of the tank. But tank-integrity testing was fairly new and had limited accuracy. Large leaks were easily noticed, but small microscopic leaks were difficult to spot. This resulted in record-keeping improvements for monitoring inventory. Many of the major oil companies began replacing their bare steel tanks with protected tank technology -cathodically protected steel and non-metallic FRP. In some cases, existing tanks were retrofitted with an internal lining, or a field-installed, impressed-current cathodic protection system. However, no national standards existed for either approach.

By 1977, most members of the industry had become aware of leaking underground storage tanks. Fire codes, such as NFPA 30 and the Uniform Fire Code, introduced language into their respective codes mandating corrosion protection. But by current standards, fire codes in the late 1970s were lax. For instance, the codes said steel tanks could be cathodically protected, simply well coated, or not protected from corrosion at all -- each of the three instances dictated by the soil corrosivity for the site at which the tank would be installed. By this time, NFPA had also produced a standard, NFPA 329, for investigating and locating releases from flammable and combustible liquid storage tanks. This recommended practice also covered tank integrity precision testing -- the only document of its kind at that time.

Secondary containment growth

Some steel tanks had been made with secondary containment during the early 1970s. In addition, some tanks were insulated with an outside weathering jacket placed over the insulation to form an additional barrier. But mass production of dual-walled steel tanks was rare during that decade.

In 1983, Steel Tank Institute formed a special strategic planning committee to address the new environmentally driven concerns with underground storage tanks. In addition to other critical strategic concerns, the association formed a committee to address secondary containment. The regulatory landscape was changing. In Florida and California during the early 1980s, government officials were starting to develop UST requirements for secondary containment.

At that time, most designs provided 110% containment of the primary tank. This required the tank to have channel or angle iron separating the primary and secondary tanks. Each tank was independent - capable structurally of standing by itself. STI discovered that German tank makers were already building to a double-wall design. STI members visited Europe and learned from the German experience, which led to America's first secondary containment standard, which was published in 1984 .

STI's standard is relatively simple. The outer wall of steel is intimately wrapped over the primary tank and can be a thinner gauge of steel. Due to the intimate wrap, the two walls act as a single structural unit, reducing the costs to build the tank. By adding a monitoring port, the owner can detect leaks in a number of ways, either manually or with special continuous monitoring equipment. This enabled new technology to evolve. Electronic and mechanical means to detect liquids followed. STI members verified that the intimate wrap did not inhibit product or water introduced into the interstice from finding its way to the monitoring port.

Federal and state regulations

Many local, state and county officials by 1982 were addressing the growing problem of leaking underground storage tanks through enactment of regulations. In 1984, Congress enacted a law to regulate underground storage tanks. By that time, media attention was reaching a peak

In 1985, EPA released the Interim Prohibition that required newly installed tanks to be corrosion resistant, compatible with the product stored and structurally sound. It provided guidance while the EPA developed technical requirements to meet the legislative initiative. By that time, several states had already promulgated their own regulations for USTs. For example, significant portions of Florida and California had already mandated secondary containment systems. Kansas had already required tank-overfill prevention. Connecticut and New York developed their own requirements for USTs. As a matter of fact, New York was one of the first states to publish a comprehensive technical manual on USTs.

By 1987 the federal agency was ready to issue a draft of the regulations. Key regulatory provisions emphasized corrosion protection for tanks and piping, structural integrity, release detection, proper installation, corrective action and secondary containment for the storage and handling of hazardous materials other than petroleum products. EPA also addressed existing tanks and the time frames by which tank owners had to comply. Though the regulations generally allowed tank owners 10 years to comply with the new rules (such as the corrosion protection mandates), some provisions required earlier action for existing tank systems.

After collecting comments for about a year, EPA published the regulation - somewhat modified from the original - in September 1988. The rule went into effect on December 22, 1988.

A key component of the regulation was EPA's creation of a means for new technology to become accepted, which was very important because new approaches to UST systems were surfacing rapidly. This coincided with the emergence of smaller, faster and more powerful computers that provided new automated solutions, especially in leak detection and inventory control.

The tank and pipe industry also witnessed an influx of new technological approaches, such as jacketed steel tanks and flexible piping.

A jacketed tank is an outer, non-metallic containment for a steel tank that also provides corrosion protection. The most notable materials developed for secondary containment have been high-density polyethylene, polyolefin and fiber-reinforced plastic. Typically, these systems were shipped from the factory with a vacuum between the walls of the tank. The jacketed steel tank offered several advantages - lighter weight than a tank with two walls of steel, and a lower cost .

Flexible piping attached to UST systems has eliminated leaks that traditionally occurred from loose elbows and fittings on steel pipe. The flex pipe is produced with a combination of chemically resistant plastic and elastomer.

One other notable construction feature emerged as the EPA regulations gained prominence. Sumps and boxes were placed above the tank and under the dispenser to catch releases from fittings and maintenance activities.

Steel Tank Institute in 1986 was the first organization to develop a national sump design standard, known simply enough as STI-86. Three decades after the introduction of the Midwest 56 standard, this concept was designed to allow all fittings and important tank appurtenances to be clustered in one spot with the protection of secondary containment. This included the submersible turbine pump, vapor-recovery equipment, gauges, and fill openings. The sump container was made from steel, and would "catch" any releases from the enclosed equipment. In addition, secondary containment pipe would terminate in the sump and sensors mounted to detect releases from piping as well. The STI-86 paved the way for a wave of tank-industry innovation. Within a few years, the STI-86 became obsolete - replaced by comparatively lightweight polyethylene sump containers.

Present

EPA UST deadline

During the last decade, the ermergence of new UST system technologies and trends has been commonplace. Manufacturers and system designers trotted out UST enhancements in advance of the December 22, 1998 EPA deadline for upgrading underground tank systems.

Some tank owners embraced the new designs because they were committed to the use of underground storage for the long haul. However, many small service station operators used the EPA deadline as a reason to sell or shutter their fueling facilities.

And, increasing numbers of tank owners revisited the question of why petroleum and chemicals had to be stored underground.

The final decade of the 20th century unexpectedly unveiled a completely new trend - extraordinary demand for aboveground storage tanks. Because of the negative headlines associated with expensive UST cleanups -- including contaminated soils and water resources -- tank owners began to think seriously about the advantages and disadvantages of owning an underground tank system. Many elected to close their tanks, and in the case of fueling vehicles, drive to the nearest public retail service station.

The AST phenomenon

Other tank-system owners began to study the advantages of an aboveground tank system. There were several characteristics that made an AST alluring.

First, the owner/operator could see all surfaces of the tank. There was no need to depend on other equipment or contractors to verify a tank system was free from releases. Visual release detection is simple, cheap, convenient, and trustworthy. Second, the owner/operator did not have to meet the financial responsibility requirements of regulated UST systems. Third, the owner/operator didn't have to worry about regulated, expensive soil clean-ups, which seemed to be constantly in the public eye via local and national headlines. Finally, many owner/operators felt that aboveground tank systems were cheaper to install and less regulated. The new era of aboveground tanks was about to begin.

On the other hand, many local jurisdictions did not allow aboveground fueling systems. They followed various national fire codes that carried either severe restrictions upon ASTs, or simply did not allow the aboveground storage of fuel. Despite that, fleet owners and small aviation fueling facilities saw tremendous benefit from owning ASTs, as described above. The typical owner of a public-accessible retail service station continued to prefer underground storage tanks (as did most fire inspectors) over potentially unsightly and potentially unsafe aboveground tanks.

Fire code revisions and harmonization during the '90s

With the suddenly strong demand for aboveground tanks, the codes needed to find a way to allow the safe siting of aboveground fueling facilities at service stations.

Major provisions were added to codes in the early 1990s. NFPA saw the need as so urgent that a Tentative Interim Amendment, or TIA, was issued in 1992 to allow an aboveground tank to be installed inside a concrete vault, whether that vault was located above or below grade.

By 1993, NFPA had added code language to allow other tanks to be installed aboveground, including traditional UL 142 tanks, and another new technology, fire-resistant tanks.

At the same time, the Uniform Fire Code was also modifying provisions that would lead to increased usage of aboveground tank storage. The UFC previously did not allow any AST fueling facilities, except special enclosures inside buildings. A special enclosure was defined as a 6-in. thick concrete enclosure over a steel tank; a fairly common application was in parking garages. The logic was that if a special enclosure was acceptable inside a building, why wouldn't it be acceptable outside?

The UFC developed a special code appendix to accommodate ASTs for motor vehicle fuel dispensing systems. The goal was to emulate the fire safety obtained from an underground storage tank, which was completely backfilled and free of risks from vehicles, vandals, and fires. An associated fire test procedure was developed to fulfill the safety needs. Tanks had to employ secondary containment and insulation.

This was the birth of "protected tanks". Several Uniform Fire Code criteria defined a protected AST:

- It had to prevent an internal tank temperature increase of more than 260 o F when the structure was exposed to a 2,000 o F two-hour fire
- The tank had to have features that resisted impacts from vehicle collisions and bullets

The appendix item gave local jurisdictions the option to adopt or disregard the new code language for aboveground fueling tanks.

As the fire codes proposed new language, environmental regulators also examined what would constitute safe operation of ASTs. In 1991, EPA proposed changes to the Clean Water Act, under the Spill Prevention Control and Countermeasures (SPCC) program. The regulatory changes strengthened the language in federal policy, changing "shoulds" to "shalls", while adding a proposal for integrity testing of tank and pipe systems. It also proposed that ASTs employ diking that would be impermeable for 72 hours.

The shop-fabricated AST market saw a major change in customer demand. Specifiers were asking for steel dikes (or tubs) within which a tank would be installed. Steel, an impermeable material, certainly met the requirements of the EPA proposal. But demand for integral double-wall ASTs also was growing.

But that was not the end of new standard development work.

- NFPA 30A in 1993 allowed UL 142 tanks to be installed, as well as fire-resistant tanks. The new criteria in NFPA 30A for fire-resistant tanks said the tank construction must prevent:
- Release of liquids
- Failure of the supporting structure
- Impairment of venting for a period of not less than two hours when tested using a fire exposure that simulates a high intensity pool fire, such as that described in UL 2085 (a draft of which was available for code officials' review during 1993)
- The UL 2085 standard was published in December, 1994. It provided two listings, a fire-resistant tank and a protected tank. The fire-resistant listing required exposure to a two-hour, 2,000 o F test. However, during that test, the internal tank temperature change could not exceed 1,000 o F. In addition, UL 2085 provided a listing for a protected tank, which prevents an internal tank temperature increase of more than 260 o F when exposed to a 2,000 o F pool fire. This listing essentially duplicated the requirements within the Uniform Fire Code Appendix II-F. UL called the standard Insulated Tank for Flammable and Combustible Liquids.

Code development work continued to accelerate at rapid pace. Revisions were made to the UFC Appendix II-F each year throughout the 1990s and to the NFPA 30A Code in its 1996 edition.

By 1997, STI had developed a statistically valid database of insulated protected tanks and double wall F921 tanks. The insulated tank was called Fireguard - the specification for which was published in 1994. STI's data showed that fewer than 3 percent of these ASTs were installed at public retail service station facilities. Private fleet facilities were the primary and dominant users of aboveground tanks for fueling vehicles. Nearly two-thirds of stored-product applications were for less flammable Class II or III liquids, such as diesel, kerosene or lube oils.

Because of the ongoing code changes, Underwriters Laboratories made further modifications to its UL 2085 standard. In December, 1997, UL removed the fire-resistant tank listing provisions from UL 2085 and moved it to a new standard, UL Subject 2080. Appropriate titles to reflect the type of tank were assigned to each standard.

UL also issued a standard for tanks installed in vaults. The UL 2245 standard covers below grade concrete vault construction, design and testing.

Future

Crystal balls can easily be clouded, but several recent developments clearly seem to hold influence for future storage tank systems.

Compartment tanks provide creative, cost-effective solution

Specifiers increasingly are calling for compartment tanks as a storage solution. In many cases, compartmentalized designs - whether double-wall or single-wall - can provide dramatic savings to the tank owner. If a tank system needs to hold 20,000 gals. with three different products, it's considerably less expensive to build and install one tank divided into three compartments than three USTs with the same capacity. This reduces costs by providing only one secondary containment and one interstitial monitoring device, while substantially decreasing excavation costs. In some states, tank owners can save on insurance by providing financial responsibility for one tank rather than three. However, savings are also possible by using compartmentalized secondary contained ASTs.

Air quality regulations

In major metropolitan areas where air quality is a significant and ongoing issue, AST owners may face questions about vent systems that are critical to the tank's operation, but enable the release of volatile organic compounds (VOC) as vapors.

New AST, UST system designs improving ease of installation, lowering costs

Authorities having jurisdiction (AHJ) continue to have concerns about important pipe fittings, such as emergency vents, that on occasion have been missing from ASTs upon installation. In 1997, UL introduced its AST system listing under a new standard, UL 2244. In this case, all important fittings and pipe attachments would be either shipped on or with the aboveground tank.

The shop-built tank market has changed so dramatically during the 1990s that even prefabricated tank system designs (vessels prefabricated with piping) had begun to appear in the underground tank market.

Maintenance remains critical

The proper installation of an underground storage tank or an AST to meet code and regulatory requirements has been clearly defined by industry groups and manufacturers. However, to assure efficient and safe long-term operations, a proper maintenance program is essential. Tank operators must remove water from dikes (when applicable) and tanks on a regular basis. Storage systems will work best if subjected to a regular inspection plan for each component. Repaint steel structures and repair concrete components to assure containment. Expect that local authorities will closely inspect venting and overfill devices to ensure their operation.

New materials providing corrosion protection and secondary containment for USTs

New options for coating steel tanks and creating secondary containment continue to surface. Fabricators have an eye on controlling costs while providing high quality and compatibility with anticipated alternative fuels, many of which are blended with alcohols.

Research has shown that some resins - in particular, those used in the manufacture of older FRP tanks -- are not compatible with ethanol and methanol when such fuels contain high concentrations of alcohol. It's recommended that specifiers contact tank manufacturers for more information about tank materials and coatings and alternative-fuel compatibility, especially for tanks that will be sited in regions designated as ozone non-attainment areas. In some cases, stainless steels and special linings will be required to provide adequate corrosion protection. Some linings are applied to prevent contamination of the liquid from steel oxidation. For example, jet fuels must be clean and pure.

Fewer USTs, but more secondary containment systems

From 1988 to 1998, the underground tank population in the United States fell by more than 55 percent. The number of retail service stations also dropped dramatically from over 207,000 in 1992 to less than 183,000 in 1998. The EPA regulation's impact has put many old single-wall tanks out of commission.

And it has opened the market's eyes to the need for aggressive action to prevent contamination of soil or drinking-water supplies. Underground or aboveground, specifiers increasingly are calling for storage systems that contain and control leaks.

Back-up power emergency generator systems

Ice storms, hurricanes, other natural disasters and fears about the inability of computer systems to perform adequately in the Year 2000 have led many businesses to explore options for back-up generator systems. Choosing the right tank and the right capacity to handle a business' fuel needs for an emergency electrical generator has become a prominent issue among managers responsible for assuring uninterrupted day-to-day operations.

Ongoing revisions of fire and building codes

Despite the many significant changes in prominent national codes, especially regarding ASTs, new proposals surface every year. Expect more revisions as regulators monitor the safety performance of AST systems within their communities. Given the level of regulatory activity among code groups, it's clear that the fire and building code groups will continue to surpass the influence of environmental regulations in shaping the direction of the shop-fabricated AST industry.

All of these trends are emerging today along with others such as development of international standards for tank fabrication, ongoing global consolidation among oil companies and the continuing increase in service station tank capacity.

We've come a long way from the whiskey barrels of Titusville, but improvements are still on the horizon.