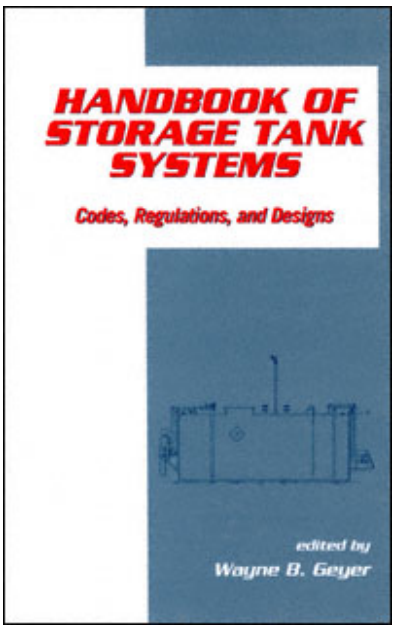
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HANDBOOK OF STORAGE TANK SYSTEMS

Codes, Regulations, and Designs

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Preface

The storage of hazardous liquids has never been more reliable. This assertion reflects the tremendous progress over the last two decades in developing tanks and appurtenances (in response to regulations and standards) that incorporate the best thinking that leads to safe, long-term performance. However, that does not mean there will never be another release from an underground or aboveground storage tank system. New products and services will continue to surface as the industry defines even higher standards of performance.

The *Handbook of Storage Tank Systems* reflects the invaluable contributions of experts in standards, manufacturing, installation, and specification of storage tank systems. Each author deserves our thanks for shedding light on the best equipment and methods for storing or handling petroleum or chemicals.

Behind the scenes, a number of organizations and individuals merit recognition for enabling this book's publication. The American Iron and Steel Institute and the Steel Tank Institute helped to fund the project. Jeanne McFadden and Ann Pulido served as the production editors who guided the book to completion. Significant out-of-the-limelight contributions were provided by Arlene Barnhart, Athena Bolton, Charles Frey, Jr., John Hartmann, Julie Hoffmann, Diane Lekovish, Vicky Lekovish, Jack Quigley, Bob Renkes, Dana Schmidt, Rick Sharpe, and Lorraine Waller.

A special note of appreciation goes to Wayne Stellmach, who, in addition to authoring two important chapters, provided invaluable contributions in developing the overall content, making arrangements with authors, and managing the book's progress.

Jim Wisuri

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Disclaimer

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The rules and regulations governing storage tank systems vary widely from one jurisdiction to the next, and they change—sometimes from one year to the next. In some jurisdictions, a fire-code inspector may require the owner of a storage tank system to address issues that seemingly contradict the mandates of a building-code official or an environmental regulator. The most prudent course of action, in all cases, is to check with regulators first before finalizing a specification, purchasing storage-system equipment, or installing tanks, piping, and other appurtenances.

In addition, it is recommended that all applicable standards be checked for details that may affect an individual project. For best results, development of tank-systems design and installation should rely on the assistance of professionals who have proven experience with storage tank and liquid handling systems.

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1
Introduction: A History of Storage Tank Systems

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I. BACKGROUND

In August 1859, the first oil well was constructed in Titusville, PA. The visionaries who financed and developed the primitive derrick and drill believed that ‘‘rock oil” would provide an excellent source of energy for illuminating buildings [1]. And for a few years, it did—until Thomas Edison found a way during the early 1880s to harness electricity. Luckily for the oil industry, other world-changing inventors in Europe and the United States had already begun the first steps toward redefining transportation—through development of a four-stroke engine and adaptation of the motor to power a buggy. The seeds of an automotive industry had been sown. And, from that point on, a need for storing petroleum products grew.

The first service stations required minimal tank storage 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 and automotive industries. The storage tank industry traces its start to these events that have altered society.

II. FORMATION OF IMPORTANT ASSOCIATIONS AND STANDARDS

In 1916, a group of Midwestern tank and boiler fabricators established a trade group, known as the National Steel Tank Association. Today this group is known as the Steel Tank Institute (STI), an international trade association enhancing the

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There were some early attempts to protect underground tanks from corrosion in the 1950s. One PEI member developed a special kit of galvanic magnesium anodes designed for cathodic protection of the tank via connection in the field to a steel tank or steel pipe. However, there were few takers in that era, and the business eventually pursued other profit-making activities.

In the early 1960s, the average atmospheric tank size had increased to nearly 4000 gal, and a new material was being used to develop and test a different design of an underground flammable and combustible liquid tank. The tank was nonmetallic. 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 conservation and the cost to replace lost product.

V. CORROSION CONTROL OF UNDERGROUND STEEL STORAGE TANKS

It took several years to make the FRP tank design acceptable enough for use at service stations. The first prototypes lacked structural integrity. Reinforcing ribs were later added to the design to enhance the tank's stiffness. By the latter half of the 1960s, UL had issued its first listing of a nonmetallic underground storage tank for flammable and combustible liquids. Within a year or two, NFPA 30 accepted the nonmetallic tank as an alternative. Up until that time, all tanks had to be steel, usually built to the UL 58 standard. More than a decade later, UL published the first edition of a new standard, UL 1316—(Glass-Fiber-Reinforced Plastic Underground Storage Tank for Petroleum Products).

The steel industry paid close attention to the efforts to produce a nonmetallic 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 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 one of the necessary ingredients for corrosion to take place.

By the early 1970s, the plastic baggie concept was commercialized for nationwide steel tank production. More than 1000 plastic-wrap tanks had been installed by 1970. Although this concept had merit, the plastic was quite thin and prone to tearing. Pieces of plastic were often "sealed" together with tape. Of course, if one did not keep the steel surface completely free from contact with moisture or

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leases. By the mid-1990s, several flexible pipe systems were available and capturing a considerable share of the UST system piping market. 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. It 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, gages, 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 where sensors were mounted to detect releases from piping as well [12]. The STI-86 paved the way for a wave of technological innovation. Within a few years, the STI-86 became obsolete—replaced by lightweight plastic sump containers.

By the time 1990 rolled around, new technology and new trends with storage tank systems were commonplace. But the final decade of the 20th century unexpectedly unveiled a completely new trend—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.

VII. REGULATION OF ASTS

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. Secondly, the owner/operator did not have to meet the financial responsibility requirements of regulated UST systems. And third, the owner/operator didn't have to worry about expensive soil cleanups, 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 ben-

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efit with 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.

As the compliance difficulties of UST owners became evident, some states began to express sympathy through legislation to ease restrictions upon the use of aboveground tanks. Thus, lawmakers in several states completely bypassed the fire prevention safeguards built into local and national fire codes.

In some cases, such as the Uniform Fire Code, no fueling of motor vehicles from ASTs was allowed. Others, such as NFPA, did provide some exceptions for tanks with capacity smaller than 6000 gal and often used in rural applications at commercial, industrial, and governmental facilities (also known as private fueling systems). 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 additions 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 room, whether that room 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. 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 [13].

This was the birth of "protected tanks." Several Uniform Fire Code criteria defined a protected AST: (1) It had to prevent an internal tank temperature increase of more than 260°F when the structure was exposed to a 2000°F two hour fire, and (2) 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 [13].

In addition to activity among code-making bodies, there were new environmental-protection interpretations that would allow ASTs without normal dikes typ-

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ically associated with aboveground tanks. The EPA also had a rule that covered ASTs, which was developed in 1972 as part of the Clean Water Act. According to the Act, all aboveground storage tanks that contained fuels and chemicals had to provide diking as a means of containment in case of a release, and to prevent the flow of hazardous liquids into navigable waterways.

In 1992, EPA issued an interpretation that allowed secondary containment double-wall tanks to be installed without diking under certain conditions, which included a tank capacity below 12,000 gal and the use of overfill prevention equipment [14]. In 1993, the NFPA 30 code issued a similar change. The fire codes required diking or remote impounding to assure a release would not fuel a fire at another location. The revision allowed secondary containment tanks as an exception to the spill control requirements. Again, a number of requirements to satisfy this exception were established, such as a maximum 12,000-gal capacity, openings at the top of the tank, emergency venting of the interstice, overfill shutoff devices, overfill prevention alarms, and gages for transport driver use. The main goal was to prevent common causes of AST system releases. Some of the provisions included in the NFPA 30 code paralleled the UFC requirements [15]. For service station tanks, NFPA 30A (Automotive and Marine Service Station Code) took this further by mandating security in the form of fencing and gates to prevent vandalism of the tank. Also required were antisiphon devices [16].

All of these changes paved the way for more secondary containment tanks. By 1993, STI members were building more aboveground tanks than underground tanks, which reflected a dramatic change in the market. By the mid-1990s, STI members were building two or three ASTs for every UST. A survey of tank owners published by STI in 1993 verified this trend. The survey results indicated that most tank owners were concerned with overfills and vandalism as the two greatest threats for AST releases, and that fire codes had the most authority over such tanks [17].

The EPA was also active during this time span on aboveground tanks. A major spill in Pittsburgh from the failure of a large field-erected tank, which caused pollution of the Ohio River for hundreds of miles, brought national attention to ASTs in 1988. Further, a slow but constant release in Fairfax, VA, caused flammable fumes to migrate into an affluent neighborhood and grab the attention of the Congress. As a result, several U.S. senators and representatives began to pursue legislation that would increase regulation of ASTs. However, none of the law-making initiatives garnered much popular support.

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. This proposal, if it had been adopted, essentially would have eliminated most earthen dikes from

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regulatory compliance. As of this publication, several other revisions and additions had been proposed to the SPCC regulations, but the final rules had not been released.

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.

So between the fire codes and the environmental regulation proposals, the demand for secondary containment tanks increased exponentially. Prior to 1990, a shop-built secondary containment AST was rare. By the mid-1990s, it became the norm—accounting for at least a third of STI members' AST sales.

National standard development work paralleled these significant changes. Underwriters Laboratories in 1993 nearly tripled the size of its UL 142 tank standard document by adding provisions for steel dikes, double wall tanks, and rectangular tanks. Rectangular tanks became very popular for ASTs smaller than 1,000 gal. Because of their flat-top design, the rectangular models made it easy to access the top of small tanks where fittings and fueling equipment could be located. STI also developed several standards that addressed changes in marketplace demand. In 1991, STI issued a standard for a single-wall AST contained in a steel dike. One year later, STI introduced its dual wall AST standard, F921. Both construction standards met UL 142 requirements.

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

1. 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, and 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) [16].
2. 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, 2000°F test. However, during that test, the internal tank temperature change could not exceed 1000°F. In addition, UL 2085 provided a listing for a protected tank, which prevents an internal tank temperature increase of more than 260°F when exposed to a 2000°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 [18].

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

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NFPA 30A Code in its 1996 edition. In addition, the Building and Code Administrators International (BOCA) and Southern Building Congress Code International (SBCCI) had fire codes that also brought forth changes to allow aboveground storage tank systems for motor vehicle fueling facilities. However, in the case of BOCA and SBCCI, an AST system could not be installed at retail service station facilities [19,20].

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 less 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 [21]. UL also issued a standard for tanks installed in vaults. The UL 2245 standard covers below grade vault construction, design, and testing.

Finally, authorities having jurisdiction continued to have concerns about important pipe fittings that were missing from ASTs upon installation, such as emergency vents. 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.

VIII. SAFER STORAGE 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 [22]. Consolidation among oil companies was continuing. Tanks were getting larger as the throughput of fuel at each service station increased. More compartment tanks were being installed. The market had changed so dramatically during the decade that even prefabricated tank system designs (tanks prefabricated with piping) had begun to appear in the underground tank market.

Petroleum and chemical storage was far advanced from the tubs, wash basins, and whiskey barrels rushed into use in Titusville when the first drill found rock oil [1]. Because of public safety and environmental concerns, the storage of flammable and combustible liquids is handled today with unprecedented attention to ensuring that product remains in reliable containment.

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2
Historical Perspective on Standards and Codes

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Industries that require the storage of flammable and combustible liquids face a complex array of codes and standards with which they must comply. Besides adhering to environmental regulations, underground and aboveground tank systems must be sited and operated in accordance with local building and fire codes.

Local codes, mostly, reflect the work done by national or regional code-making bodies. A city council or county board may adopt for their jurisdiction a nationally developed code—and add some local distinctions as well. This chapter will provide some historical background on the regulatory function of codes and standards, and cite some of the codes that most affect storage tank systems.

I. WHAT IS A STANDARD?

A standard is a series of requirements that tell you *how* to do something. A standard tends not to have any enforcement requirements. A standard becomes an enforceable document when it is adopted by reference in a code [1].

II. WHAT IS A CODE?

A code is a set of regulations that tells you *when* to do something. A code will have requirements specifying the administration and enforcement of the document.

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A. What is a Building Code?

A building code is a set of regulations legally adopted by a community to ensure public safety, health and welfare insofar as they are affected by building construction.

B. What is a Fire Code?

A fire code is a set of regulations legally adopted by a community that define minimum requirements and controls to safeguard life, property, or public welfare from the hazards of fire and explosion. A fire code can address a wide range of issues related to the storage, handling or use of substances, materials or devices. It also can regulate conditions hazardous to life, property, or public welfare in the occupancy of structures or premises [1].

III. ORIGIN OF BUILDING AND FIRE CODES

The writing, adoption, and enforcement of codes have a centuries-old tradition. For at least 5000 years, man has exercised some limited controls over the construction and utilization of buildings and structures throughout the civilized world.

A. Historical Perspective of Codes

1. 2000 BC—Hammurabi

Hammurabi, founder of the Babylonian Empire and known as an effective leader, wrote the earliest known code of law. Portions of the Hammurabi Code of Law dealt with building construction. Here are some translated examples of Hammurabi's Code of Law on Building Construction:

> No. 229: If a builder has built a house for a man and his work is not strong, and if the house he has built falls in and kills the householder, that builder shall be slain.
>
> No. 230: If the child of the householder is killed, the child of that builder shall be slain.
>
> No. 231: If the slave of the householder is killed, he shall give slave for slave to the householder.
>
> No. 232: If goods have been destroyed, he shall replace all that has been destroyed; and because

the house was not made strong, and it has fallen in, he shall restore the fallen house out of his own material.

No. 233: If a builder has built a house for a man, and his work is not done properly and a wall shifts, then that builder shall make that wall good with his own silver.

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In Polynesia, an even sterner law than the Hammurabi Code of Law required builders to entomb a live slave under each corner post, which was meant to guarantee that the structure would be supported properly, in perpetuity.

2. 64 AD—Burning of Rome

In 64 AD, Emperor Nero had a master plan for construction of a new Rome prepared sometime prior to the fire that destroyed much of the city. Prior to Nero's ascent to power, Rome lavished its wealth and resources on the construction of public buildings, but ignored almost all other construction regulation. Many of these buildings collapsed even before they were completed, killing and maiming many of the workmen. Consequently, the charges that Nero deliberately ordered Rome's destruction seem to be well founded. The rebuilding of Rome was accomplished in accordance with sound principles of construction, sanitation, and utility. Until the downfall of the Roman Empire, construction, public and private, was closely monitored and controlled. In hindsight, it could be stated that Rome's burning might have been the world's first urban renewal program.

3. 798, 982, 1212, 1666—Fires in London

London had major conflagrations in 798, 982, and 1212. The fire in 1666 is singled out because it resulted in the British government's adoption of building controls.

London was destroyed in the great fire of 1666. Destruction may have been more of a blessing than a calamity because London was a crowded, filthy city of low, timber-framed warehouses, churches, and houses. Most of its thoroughfares had open drains that carried raw sewage. Housewives threw garbage into narrow cobblestone streets. London had been ravaged by the plague for nearly a year prior to the fire. Its people were dying at the rate of 1000 per week. The fire started in a rundown neighborhood near the Tower of London. The fire raged for five days and nights. Its toll was 15,000 buildings, including 84 churches. Miraculously, only six lives were lost in accidents directly attributable to the fire.

In its attempt to prevent another devastating fire, Parliament decided to write requirements to control building construction. However, it took Parliament two years to enact such controls for buildings. The regulations were called the ‘‘London Building Act," and it applied only to property within the boundaries of London. Unfortunately, during those two years, London was reconstructed almost in the same style that existed prior to the fire.

4. Major Fires in the United States

From 1800–1900, 11 major American cities were devastated by fire. The following two examples of conflagrations in cities in the United States show the importance of building regulations:

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a. 1871—Chicago Fire. The Chicago fire in 1871 was devastating, and the second most costly blaze in American history. Chicago at the time consisted of about 60,000 buildings, more than half of which were of wooden construction. Lloyds of London had warned its underwriters in Chicago of the city's conflagration potential, but the insurance companies continued to issue fire insurance coverage.

The initial fire, which by legend was blamed on Mrs. O'Leary's cow kicking a lantern, started on October 7, 1871. Local officials thought after a few hours that the fire posed no more danger. However, on the night of October 8, a new fire broke out and, fanned by winds whipping off Lake Michigan, was soon raging out of control. The fire grew to such large proportions that drastic measures were employed by the army, including the use of explosives to create firebreaks.

Before the fire was extinguished two days later, 17,000 buildings had been destroyed and 250 lives had been lost. Almost 100,000 persons were homeless. Fire damage was $168 million in 1871 dollars. In 1994 dollars, the fire damage would be more than $2 billion. Sixty insurance companies went into bankruptcy because of fire-related claims. The insurers that survived the financial disaster threatened to leave the city unless adequate laws regulating buildings were enacted. In 1875, a building code and a fire prevention ordinance became effective in Chicago.

b. 1906—San Francisco Earthquake and Fire. The San Francisco fire that started on April 18, 1906, was the largest loss fire in U.S. history. Fire damage was $350 million in 1906 dollars. In 1994 dollars, the fire damage would be $5.7 billion.

B. What is the Purpose of Controls, and Why do We Need Building and Fire Codes?

As can be seen, building regulations, as we know them today, are the result of an evolutionary process that has its roots deeply embedded in disaster and tragedy. The absence of controls, and the absence of enforcement, must share the responsibility for the needless loss of lives and property. It would be proper and safe to say that in the past 5000 years, millions of lives have been sacrificed for lack of such laws [1].

IV. MODEL BUILDING AND FIRE CODE GROUPS IN THE UNITED STATES

The following organizations publish model building and fire codes that jurisdictions in this country have adopted by reference.

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Building Officials and Code Administrators International, Inc. (BOCA)
Southern Building Code Congress International, Inc. (SBCCI)
Southeast Association of Fire Chiefs and Southwest Association of Fire Chiefs
International Conference of Building Officials (ICBO)
International Fire Code Institute (IFCI)
National Fire Protection Association (NFPA)

A. Brief History of the Model Building and Fire Code Groups in the United States

1. NFPA

Founded in 1896, NFPA published its first code, an edition of the sprinkler code, in the same year as the organization's inception. Other codes of interest to the storage tank industry are NFPA 30 (Flammable and Combustible Liquids Code), and NFPA 30A (Automotive and Marine Service Station Code). From 1913 to 1957, the NFPA 30 Code was known as the Suggested Ordinance for the Storage, Handling, & Use of Flammable Liquids. Prior to 1984, NFPA 30A originated as Chapter 7 of NFPA 30. NFPA's national fire codes and standards are developed and revised through the deliberations of 235 technical committees. These committees are composed of a balanced membership of technically competent individuals from industry, government and independent experts. One-third of these codes and standards are revised every year. All NFPA Codes and Standards are usually on a three-year revision cycle unless the committee for a code or standard requests an extension of a year or two.

All dues-paying members of NFPA can vote on the adoption of codes and standards at the association's fall and spring meetings.

2. BOCA

BOCA was founded in 1915. BOCA published its first building code in 1950; it was called the BOCA Basic Building Code. Today, the building code is called the BOCA National Building Code. BOCA published its first fire-prevention code in 1966, the BOCA Basic Fire Prevention Code. The fire prevention document today is known as the BOCA National Fire Prevention Code.

The BOCA code change cycle covers three years. Here's a typical sequence of events in the cycle: The 1996 editions of the BOCA national codes were issued during that year. (The year the full edition of the Code is published serves as a moratorium period for any code changes.) But in 1997 there were meetings to discuss code changes, which led to the 1998 Supplement to the BOCA National Building Code/1998 and BOCA National Fire Prevention Code/1996. In 1998, more

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code changes were proposed and voted upon, which resulted in publication of the revised 1999 BOCA national codes.

Only code-official members can vote on changes to the BOCA national codes.

3. SBCCI

Founded in 1940, SBCCI published in 1945 the first edition of the Standard Building Code. SBCCI published in 1974 the Standard Fire Prevention Code. Since 1991, the Standard Fire Code has been under the control of the Southeast Association of Fire Chiefs and Southwest Association of Fire Chiefs. The SBCCI code cycle covers three years. SBCCI issues code supplements for the first two years. A supplement is issued for each year; the second year's supplement is cumulative—including changes from the previous supplement. Then, in the third year, SBCCI issues completely revised editions of its codes.

Only code-official members can vote on changes to the standard codes.

4. ICBO

Founded in 1922, ICBO published in 1927 the Uniform Building Code. ICBO published its first fire code in 1971, the Uniform Fire Code. From 1971–1991, the Uniform Fire Code was under the control of the Western Fire Chiefs Association. In October 1991, the International Fire Code Institute (IFCI) was formed to manage the Uniform Fire Code.

The last edition of the Uniform Building Code was published in 1997. The new International Building Code (IBC), which is scheduled for publication in 2000, will not only replace the Uniform Building Code, but also the BOCA National Building Code and the Standard Building Code. The IFCI will continue to publish and maintain the Uniform Fire Code with supplements in 1997 and 1998, and a completely revised edition in 1999.

Only code-official members can vote on changes to the Uniform Building Code and the Uniform Fire Code.

a. Formation of the ICC. On December 9, 1994, the three model building code groups (BOCA, SBCCI, and ICBO) formed an umbrella organization to support common code development. They called it the International Code Council (ICC). Its mission is to promulgate a single model code system to meet global economic trends.

B. How Does a Code or Standard Become Enforceable?

A code or standard becomes enforceable when it is adopted by reference through local, state, or federal government legislative process, such as an ordinance, statute,

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or bill. The law must adopt a specific edition (year of publication) of a code or standard, and may include amendments to specific portions of the code or standard being adopted.

REFERENCE

. RL Sanderson. Codes and Code Administration: An Introduction to Building Regulations in the United States. Chicago: Building Officials Conference of America, 1969.

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3
History of the Uniform Fire Code

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I. THE LONG EVOLUTION

As noted in Chapter 2, fire codes in use in the United States have an interesting history. One of the most prominent codes in modern use is the Uniform Fire Code, which regulates underground storage tanks, aboveground storage tanks, and a vast array of products and services that could affect public safety. The Uniform Fire Code, which is cited within the ordinances of communities in 38 states, is like many other codes. The current version is the result of an evolutionary process.

Today's codes are essentially the refinement of work started during the mid-1800s by an organization—the National Board of Fire Underwriters (NBFU)—to serve the interests of fire insurance companies. That organization developed and first published in the early 1900s a model code called the National Fire Code.

In the early 1900s only a few large cities had comprehensive codes. Many of those codes were based upon the model National Fire Code. A few cities actually took it upon themselves to develop and adopt a code unique to their communities.

Some state governments created code enforcement agencies, usually as part of the state insurance commissioner's office, or an independent state fire marshal's office. There was a wide variance as to what each state adopted for a code. Many adopted, or simply used, some or all of the National Fire Protection Association (NFPA) pamphlets, which covered a broad spectrum of fire safety subjects.

II. INFLUENCE OF WORLD WAR II

The greatest early influence that shaped changes in fire codes was World War II. As industry rapidly ramped up for war production—and relatively large segments

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of the population migrated to provide labor for those industries—significant societal changes were unleashed. Public safety officials became concerned with how to manage population growth, urban density, new materials and processes of a hazardous nature, and transportation issues. That influence carried over to the post-war era, especially in states such as California, which experienced unprecedented growth that compounded the region's problems related to fire safety.

The postwar era led to a realization by officials in smaller cities of the value and necessity for adopting and enforcing a fire code. That necessity was emphasized to local decision-makers by the activities of the Insurance Rating Bureau, another organization whose function was primarily to look out for the interests of insurance companies. Communities were encouraged to adopt the National Fire Code. Around this time the code publishing organization's name also evolved—from the National Board of Fire Underwriters to the American Insurance Association.

As more communities adopted codes, enforcement personnel became more experienced, organized, and sophisticated. Recognition was growing that the National Fire Code was focused primarily on property protection. It was generally lacking in regulations aimed at the protection of life. Further, there was a generalist approach to the document. Communities that were home to industries with special hazards were forced to be creative in amending the code to provide for their unique needs.

NFPA offered a solution for some of those needs. They continued to expand the selection of fire safety pamphlets and standards, giving communities choices that were not earlier available. One of the NFPA documents that became widely used was the Safety to Life Code. It was focused on assuring that people were protected, not just property. Its earliest editions were generally referred to as the NFPA Exits code. The thrust was to assure that buildings were designed safely enough that occupants could exit in the event of a fire.

Meanwhile, building codes were evolving and becoming more widely adopted. Nevertheless, it is interesting to note that as recently as the 1950s a large number of cities and counties had no comprehensive building codes. Building code adoption at the state level was not common until even later. Even today, there are areas of the country that do not adopt or enforce building codes, which typically are written and dominated by code enforcement officials with input and support from architects and representatives of the building materials industry.

III. RESOLVING INEVITABLE CONFLICTS

With the confluence of the heavily amended National Fire Code, the NFPA Safety to Life code, locally created fire codes, and model building codes, a new set of problems surfaced. There were conflicts between the requirements of the building

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code and fire code adopted by individual communities. Those conflicts created problems of enforcement between building and fire code personnel. Architects, builders, building owners and operators, and many other stakeholders were constantly caught in the middle of turf battles.

A case in point, in the extreme! A large apartment building was constructed—allegedly in compliance with the building code—and given a certificate of occupancy by the building official. Once it was opened, the local fire official inspected it for compliance with a conflicting fire code, found it in noncompliance, and ordered the building demolished. When the case went to court, a judge upheld the fire official and a brand-new building was knocked down. While that was an unusual case, the problems of conflict persisted to an intolerable degree.

Determined to solve the problem, the California Fire Chiefs Association (CFCA) and the International Conference of Building Officials (ICBO), based in California, started a dialogue. Out of that came the recognition that a solution should be more broadly based than the concerns raised in just one state.

Around 1969 conversation started between the ICBO, writers of the Uniform Building Code, and the Western Fire Chiefs Association (WFCA) regarding ways in which code conflicts might be addressed and mitigated. Both of those organizations were based in the western states. Party to those conversations were CFCA representatives, who had already developed an expanded fire code based upon the National Fire Code. Out of those conversations came agreement to develop—jointly and contractually—a new Uniform Fire Code based upon the California Fire Chiefs code.

IV. THE NEW CODE

In 1970 the two organizations formed a work committee of eight officials—four from fire code enforcement, and four from building code enforcement. Their charge was to create a draft fire code, carefully reviewed and amended to eliminate, as nearly as possible, conflicts between the Uniform Building Code and the proposed fire code. Staffing for the effort was through the International Conference of Building Officials. By contract, the document copyright was to be owned on a 50/50 basis. The future development of the code would be by the WFCA. The document staffing and publication responsibilities would remain with the ICBO.

The development of the first 1971 Uniform Fire Code draft consumed the better part of the year. The WFCA at their annual meeting considered and voted to approve the document. The work committee was dissolved. The code was published. A new WFCA code development committee was appointed to assume the task of conducting code change hearings on an annual basis. The next code was published in 1973. Since then a new edition has been published every three years with supplements printed in the off-publication years.

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V. A NEW ORGANIZATION

Over time, recognition grew that activities associated with the Uniform Fire Code should be expanded. For example, the consensus was that training and inspector certification programs would be beneficial. There was also an increased desire to broaden the use and influence of the Uniform Fire Code from its original western states base to a national constituency. In 1991 the WFCA and the ICBO jointly created a new umbrella organization named the International Fire Code Institute. Its board was made up of persons from both organizations, as well as individuals from other code groups throughout the United States. Its purpose was to assume all of the responsibilities for administration, code development, training services, and other related activities previously carried out jointly by WFCA and ICBO. The Uniform Fire Code copyright remained with the originating organizations. Staffing remained with the ICBO.

The first Uniform Fire Code edition published by IFCI was 1991. The IFCI continues to operate today. The most recent Uniform Fire Code edition is 1997 with supplements issued after the annual meeting in the summer of 1998.

As the move toward an international fire code has gained momentum, the Uniform Fire Code's future has been a source of controversy. The IFCI intended to cease oversight and publication of the Uniform Fire Code by the year 2000. However, at the time of this book's publication, the Western Fire Chiefs Association had announced an intent to continue development of the Uniform Fire Code through annual code cycles into the next century.

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4
Quality Control on USTs and ASTs

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I. OBTAINING A QUALITY PRODUCT

Steel tanks fabricated in the 1950s and 1960s are not much different from the tanks of today. Yes, it's true that advancements in corrosion protection and secondary containment have remarkably changed products built to Underwriters Laboratories UL 58 standard for underground storage tanks (USTs). And it's true that extraordinary innovations in aboveground storage tank (AST) design have forever altered the concept of what a UL 142 tank would look like.

But for 98 percent of USTs and ASTs manufactured, when you strip away the latest product features, you still are working with a steel cylinder equipped with a few fittings that will be used for the storage and handling of petroleum or chemical products. In the remaining cases, you are likely to be working with a flat-top rectangular tank—most often storing less than 2000 gal.

Many companies are qualified to fabricate steel ASTs and USTs, but it's the quality of their effort that ultimately will make the biggest difference in how well the tank serves the end user. From a quality control perspective, tank buyers should be aware of essential fabrication requirements to ensure receipt of a quality tank that will provide many years of trouble-free service. These essentials would include quality control (QC), design, materials, tank suppliers, fabrication and welding, surface preparation, coatings, and inspection. Equally important are shipping, handling, and installation. Because of some key differences in the installation of ASTs and USTs, see Chapters 13 and 23 for more information. Each of these areas should be considered prior to ordering a tank.

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II. QUALITY CONTROL

It is imperative in today's litigious world to approach the specification and purchase of storage systems with quality in mind. Purchase orders should concisely identify materials, specifications, inspection/testing requirements and documentation. Buyers should evaluate a supplier's capabilities and examine the workmanship of existing orders. Does the supplier have a QC program with qualified inspectors and well-documented procedures? Even in the best QC programs mistakes will happen; however, a good manufacturer will identify the problem, make the necessary correction and try to prevent the situation from reoccurring on the next tank.

III. MATERIALS

Since tanks have relatively few components, materials are fairly easy to monitor—compared to a product such as an automobile. Most tanks are made from commercial-quality hot-rolled steel. Many tank fabricators will purchase steel meeting ASTM requirements, for example A36 or A569. More important to the steel, whether it be certified ASTM, or commercial quality, is the carbon or carbon equivalency content. The carbon content of the steel should not exceed 0.3 percent. In addition, the carbon equivalency should not exceed 0.53 percent. To calculate the carbon equivalency (CE) of steel, use the following formula:

$$CE = C + (Mn + Si)/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

Increased amounts of carbon reduce the weldability of the steel and increase the hardness and tensile strength, which can make the steel difficult to work with.

Other materials that are very important and will be discussed in greater depth are the welding electrode (or filler material) and the corrosion protection coatings. The welding electrode/filler material is critical, since many tank failures develop at the weld seams.

IV. FABRICATION AND WELDING

Tank fabrication is very labor intensive, which means the skill of a craftsman is very evident to a trained eye. The steel is usually purchased in coil form before it is flattened and cut to length. Many fabricators will purchase their steel from a supply house that will flatten and cut the steel to length prior to shipment.

At the tank plant, the steel is rolled into cylinders and tack welded before it's moved to a welding station. Typically, the long seam of the cylinder is either butt

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welded or lap welded. In many instances only the inside surface is welded prior to further assembly. Many fabricators will use what is called an offset (or joggle) joint to connect the cylinders or cans together. The joggle joint has a couple of advantages. Because there is an offset, the assembly and fit-up of one can—or course of steel—to another is relatively easy. Also, the resultant weld joint is relatively consistent, making it desirable for automatic welding processes.

Most fabricators will use a flat, flanged head on their tanks. Flanged heads are often purchased from outside suppliers, although just about every fabricator has a flanger on site for making heads. All flanged heads should have an inside knuckle radius of two times the thickness of the head. Because the knuckle is cold-worked—meaning it hasn't been heat-treated to relieve stresses—it is a natural stress point on the tank. Steel Tank Institute's quality inspectors, for example, closely monitor the knuckle radius for signs of proper fabrication.

Most fabricators will use a single piece of steel for making a head, whenever possible. However, because of the diameter required on larger tanks (12,000 gal capacity or greater), stock materials matching the diameter are often unavailable. When this happens, a fabricator will have to piece together two or sometimes three sheets of steel to meet the required dimensions. The fabricator will then weld the sheets together and cut them to match the radius required for the tank. Prior to flanging the head, the fabricator will grind the weld flush with the base metal in the areas that will come in contact with the flanger die. The stress created at the weld during the flanging operation can feasibly produce cracks.

Typically, most tank interior welding is completed prior to fitting the last head on the tank. Many tanks now have manways for interior access, but most fabricators will try to minimize their employees' exposure to working in confined spaces. After the final head is fit and tack welded into place the tank's exterior seams are welded. Then the openings are cut for placement of the fittings, or other attachments. Once the tank is complete, welds will be cleaned and prepared for leak testing.

Of course, not all facilities will follow this procedure. As a matter of fact, it is very rare to find any two fabricators building tanks in an identical manner because every production shop has found special success formulas that make them unique.

A. How Tanks Are Welded

Four basic welding processes are used in fabricating steel tanks and pressure vessels. Each of the four processes (whether manual or automated) will repeatedly produce quality weldments. But they each have strengths and weaknesses. Prospective tank buyers should be aware of the different processes. In general, the best fabricators focus intensely on assuring outstanding fit-up. Many combine that

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dedication with the use of automatic weld processes—which typically leads to high-quality welds.

SMAW (Shielded Metal Arc Welding)

Commonly referred to as stick welding, SMAW is the most commonly used welding process. Equipment and materials are inexpensive, portable, and relatively simple to operate, even outdoors.

However, the SMAW process is slow. Because it is a manual process, the operator must stop and replace the consumed electrode approximately every 18 in. In addition, the operator must remove slag from the weld surface. SMAW welds are readily identifiable by start/stop markings that lead to a greater number of surface irregularities than would be found with other processes.

The type of electrode used in the SMAW process has a significant impact on the mechanical strength created by the weld. For example, a jet rod (known for its speed) will not penetrate as easily into the base material; thus, the strength of the joint is not as great as other types of electrodes, such as pipe rod.

GMAW (Gas Metal Arc Welding)

Also known as metal inert gas (MIG) welding, the GMAW process uses a solid bare wire to create the arc between the work piece and the filler material. The wire is fed (usually automatically or semiautomatically) through a welding gun from a spool or reel. A shielding gas protects the weld from environmental contamination (principally oxygen). The gas flows through the welding gun/nozzle to the arc.

The GMAW process has a high deposition rate (i.e., the rate at which the electrode melts and gets deposited on the work piece) and can save time and labor costs. However, because the process uses shielding gas, it is very susceptible to drafts or wind that might blow the shielding gas away from the arc. Thus, it is not well suited for welding outside.

While GMAW welds generally have a good uniform profile, MIG welding is less forgiving than some of the other processes. A greater risk of lack of fusion exists because the arc doesn’t provide as much heat. Many fabricators will limit its use to thinner gauge steel. Undesirable weld spatter (metal particles expelled during welding that do not form a part of the weld) is generally greater with this process, but can be significantly reduced with the proper mixture of gas and the use of anti-spatter material on the tank surface.

FCAW (Flux Core Arc Welding)

The FCAW process is very similar to MIG welding, although it does not always need shielding gas. Also, instead of a bare wire, a tubular wire containing granular flux is used. When a self-shielding flux is used, no shielding gas is required.

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Some wires use a combination of both flux and shielding gas for improved weld metal properties.

The FCAW process is very popular because of the deep-penetrating arc that reduces fusion type discontinuities, and because it has a quick deposition rate. The self-shielding electrode is popular in field applications as well. Like the SMAW process, solidified slag must be removed from the surface of the weld.

The FCAW process is known for generating smoke, which often hangs in the air of a manufacturing plant. Although similar to MIG welding, the FCAW process often presents a different kind of problem: slag. Because the tubular wire has flux inside, there is greater opportunity for slag entrapment in the weld. Undercutting (melting away of the base material along the edge of the weld forming a groove) is very common with this process because the arc creates significant heat.

SAW (Submerged Arc Welding)

SAW is probably the most efficient welding process because it's automatic and uses a solid wire electrode submerged in a granular flux blanket. As with the FCAW process, SAW has a deep penetrating arc, and solidified slag must be removed from the surface of the weld. The deposition rate of the SAW process is excellent, especially on thicker materials requiring multiple passes.

The SAW process produces a very smooth and uniform weld, but it can also pose problems. With the automatic process the tank must be rotated at a constant speed, and the weld joint fit must be uniform. With other processes (manual and semiautomatic), the welder can make adjustments to conform to the joint geometry. With SAW, the welder cannot see the arc and is limited to only minor adjustments while the unit is in operation. Again, slag entrapment and fusion discontinuities are fairly common with this process. Also, because of the amount of heat at the arc, some caution is important—many SAW operators have burned right through the base metal.

When evaluating a tank supplier's welding program it's important to verify that the supplier has qualified procedures and operators. Good tank suppliers will have welding procedure specifications (WPS) for each process. The WPS will identify the volts and amperages, electrode/filler material, shielding gas, etc., to produce a quality weld. A fabricator will have visual, mechanical, and sometimes nondestructive tests performed on weld samples to qualify a WPS or a welding operator.

V. LEAK TESTING

Once a tank is completely welded, the tank will be visually inspected and checked for leaks. Most cylindrical atmospheric tanks are tested at 5 psi. Tank openings are

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sealed, and compressed air is applied to the tank until the necessary test pressure is achieved. It is important to consider the volume of air applied to the tank when pressurizing. While the test pressure is not that great, the volume of air is significant and, in the event of an accident, can cause severe injury to nearby personnel. Fabricators are required to have a safety relief device on the tank to prevent over-pressurization.

Once the test pressure is achieved, a soap solution is applied over the welds to identify leaks. Bubbles are created when air leaks through the weld and are readily identified by the tester. Leaks are then repaired before the welds are retested to ensure the tank's integrity.

Testing of tanks should be performed in a well-lit area. All gages, relief valves, and testing equipment should be in good working condition. Soap testing solution should be protected from contaminants. The tank welds should be free of slag, spatter, or foreign materials that prohibit testing.

Most double-wall tanks will, in addition to the bubble test, have a vacuum applied to the interstitial space. Comparing a vacuum to the bubble test is like comparing apples to oranges. The vacuum is much more sensitive to leaks than the bubble test, and is most effective at proving simultaneously that both the primary and secondary tanks are tight.

Some distinctions exist for testing on various UST and AST technologies:

All single-wall and double-wall steel tanks should be tested with an air test that includes soaping of the weld seams to look for pinhole leaks—some fabricators recommend an additional vacuum test on Type I (blanket wrap design) double wall tanks.

Jacketed tanks typically are shipped with vacuum, but if a leak develops in the jacket the external shell could be tested with an ultrasonic device or a helium leak detector.

Steel dikes on AST systems can be examined using a dye penetrant, or penetrating oil, on weld seams.

VI. SURFACE PREPARATION

Tanks that have coatings or laminates applied directly to the exterior steel shell should be prepared by abrasive blasting, which will remove mill scale and roughen the surface to improve adhesion of the paint or coating. Typically the resultant profile left on the steel is between 1.5 and 3.5 mils deep.

The blast medium used is often coal slag, silica sand, or recycled grit. The profile depth depends upon the size, type, and hardness of the blast media; particle velocity; angle of impact; surface hardness; and maintenance of the working mixture.

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The coal slag and grit tend to give a deeper profile versus the sand. However, the sand tends to remove mill scale easier from the surface. Under most circumstances shot or wet blast should not be used for surface preparation on steel tanks.

Prior to coating, the tank should be free of abrasives, oil, grease, or other contaminants. Most fabricators will apply the coating to the tank as soon as possible after blast. The longer a blasted, uncoated tank is exposed to the environment, the greater the chance that rust-back will occur, especially in locations subject to high relative humidity. Should rust-back occur, the entire tank should be reblasted.

VII. COATINGS

There are hundreds of different coatings on the market today designed to meet very specific applications. Years ago, many tank suppliers used a coal-tar coating on their USTs. The coal tar was an excellent coating, and was relatively trouble free. The problem with the coal tar was that it took roughly 24 hours to cure before you could move the tank. The long cure time didn't help tank manufacturers as it created a logjam at the coating application stage.

Coating manufacturers eventually introduced a polyurethane product that provided the necessary corrosion protection and reduced the cure time significantly—enabling the fabricator to move the tank within minutes on a hot day, or just a few hours in cooler weather. With the reduction in curing time most fabricators switched from the coal tar to the polyurethane coatings.

While the polyurethane is a very good coating, it is much more susceptible to application errors or defects. Since the coating is a two-part system, the coating actually mixes at or near the spray nozzle. The ratio by volume of a coating manufacturer's proprietary Part A to Part B in the mixture is critical. Many coating defects are directly attributed to the mixing ratio and may cause the urethane to blister if the ratio is off.

Many jacketed and composite tanks use an isophthalic fiberglass-reinforced polyester (FRP) laminate to provide a corrosion barrier. The fiberglass laminate is an excellent coating for corrosion protection. The application of the laminate requires a skilled operator and well-maintained equipment. The operator must ensure that the correct ratio of glass to resin is maintained at all times. A skilled operator will be able to work around attachments and manways and maintain a holiday-free coating. Most fiberglass-clad tanks require a holiday test—a high-voltage examination of the external tank surface that will discover any exposed metal.

All fabricators will use some kind of inhibitor to protect the tank from ultraviolet light while the tank is in storage. Many fabricators will use a color addi-

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tive in the final phase of coating for added UV protection. Prior to adding the gel coat color, fabricators can visually inspect the coating for flaws.

Many jacketed tank technologies also use FRP as a corrosion barrier. Because the jacketed tank design calls for the FRP to serve as an outer tank, there is always some spacer material between the steel tank and the FRP shell. This eliminates most of the need to blast the tank. Blasting only occurs where the laminate directly makes contact with the steel. This is usually around the fittings and manway.

Construction of the jacket is critical since it is considered a double-wall tank. The tank surface must be relatively smooth and free of abrupt changes that would create stress on the jacket. Many fabricators reinforce the flanged head and weld seams to reduce, or prevent, such stress. Most jacketed tanks are suspended at the heads during application. The heads are the final area of laminate application, and must be thoroughly inspected during the vacuum integrity test for leakage.

Aboveground tanks require exterior paint for protection from climatic conditions in a variety of areas. If the AST will be located in areas near saltwater, deserts, urban pollution or high humidity, a specifier should check with tank manufacturers and coating suppliers about the recommended application of AST paints.

VIII. INSPECTION

The best time to inspect a UL 58 or UL 142 steel tank is just prior to coating application. Once coated, evaluation of the fabrication and welding is often difficult, if not impossible.

By inspecting prior to coating, you have the opportunity to examine all weld profiles to ensure they meet specification. This also enables the removal of excess spatter. Prior to applying the corrosion barrier, it is important to ensure that no sharp edges are present to inhibit the coating process.

Once the coating has been applied, the inspector should determine if the urethane, FRP, or coal-tar epoxy has the minimum dry-film thickness required by the specification on the entire tank. Inspectors can measure dry-film thickness in a number of tank shell locations with a gage. The coating should be free of sags, runs, blisters, or other surface defects. Composite tanks require a 10,000 to 35,000 V holiday test to ensure that the laminate completely protects the steel from corrosive elements. Check with local officials on requirements. It is recommended that the ground wire lead from the holiday tester be connected directly to the tank for maximum detection of coating defects or flaws.

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5
UST and AST Fabrication

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I. CREATING WHAT THE END USER NEEDS

Tanks must be fabricated to match an end user's needs. It's true that underground storage tanks (USTs) and aboveground storage tanks (ASTs) are largely standardized to work in a wide range of environments, but many unique situations call for a customized design.

Tank design and fabrication can be influenced by economic factors, regulatory requirements, the liquid to be stored, internal pressures, external environmental forces, corrosion protection, leak detection, and welding needs.

II. ECONOMIC FACTORS

Economic considerations continue to play a major role in the final specification that meshes the tank owner's technical needs as balanced with budgetary limits and regulatory requirements.

A. Single Wall

The single-wall design, the oldest and most widely fabricated UST and AST, is primarily popular because of price. As its name implies, the single-wall tank is fabricated by welding together a shell and heads made of a single thickness of steel. The single-wall underground storage tank is primarily used by service stations and