# 1

# *What You Don't Know Can Kill You*



## How the Book Is Structured and What This Chapter Is About

Most chapters in this book begin with a small introduction and then a story that provides the flavor of an experience related to the topics in that chapter. These stories introduce real concepts that under certain conditions can lead to devastation.

The book also features a number of emphasis boxes that give key concepts special attention. In many cases the boxes describe seemingly obvious and simple, but nonetheless vital, issues. In this chapter we give you a flavor of some high-level concepts involved in the fuels and combustion systems safety world. We form a basis for an understanding of the more technical issues presented in later chapters.

There's something in this book for everyone: from operators of equipment and hands-on maintenance personnel to corporate risk managers and global safety directors. The book's perspective switches frequently and addresses issues of concern for all these groups. This chapter will mean more to corporate staff, managers, and those in charge of fuel and combustion equipment safety and risk management programs. It is my hope that many of you will read the chapter and realize the importance of this topic. This will give you the perspective to be supportive of, and wanting to implement, the concepts and strategies presented in subsequent chapters.

## Real-Life Story 1: Innocent Lives Lost from a Hot Water Heater Explosion

A lot can be learned from reviewing a terrible disaster that left five children and one teacher dead at an elementary school in Spencer, Oklahoma, in 1982.[1] A hot water heater explosion changed the town, and many families, forever. Shedding light on the

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underlying causes behind the explosion at Star Spencer Elementary School provides an opportunity to review your own combustion equipment testing, repair, and preventive maintenance schedules and to reframe your thinking about which of your combustion systems may be important.

It was shortly after noon in a busy school cafeteria on an average day. Children were seated at tables enjoying lunch when their secure little world was torn from them. Suddenly, a concrete wall that separated the lunchroom from the kitchen blew in as an 80-gallon water heater exploded and launched itself skyward. The children seated nearest the wall were crushed and killed as concrete and steel were propelled from the epicenter of the blast. In all, seven people died and 36 were injured.

Tragic warning signs at Star Spencer screamed out loudly to those trained to listen. Sadly, most building managers and facility staff would never have heard them. For example, would you know that when people complain that the water is too hot in the sinks, it could be a sign that you are about to have an explosion in your building? What about that safety relief valve that keeps dripping, or the little gas leak? It was a combination of issues as subtle as these that contributed to the deaths and injuries that day.

The first employees arrived at the school at 7:00 A.M. The cafeteria workers noticed that the domestic hot water was much hotter than normal. The custodian was called, and the gas water heater was shut down to await the arrival of a maintenance technician. The technician's fix was to replace the gas valve and relight the water heater. He replaced the valve with the only valve immediately available, a used valve that had been sitting on the shelf in the maintenance shop. The technician returned within the hour and noted that the water heater seemed to be working normally.

The cafeteria workers soon noticed that the water temperature was again much too hot, and getting hotter. They placed another call for service, which tragically went unanswered. At 12:13 P.M., the explosion ripped through the school.

Investigators found that the hot water heater's burner would not shut off. The used replacement gas valve was defective. These have been the subject of safety recalls. It is recommended that you check the Consumer Products Safety Commission website (www.cpsc.gov) to see if you might have one of these at your facility or even at home.

Hot water heaters are also required to have safety relief valves, which are supposed to relieve water if an excess temperature or pressure condition occurs. The safety relief valve on the water heater was found to be altered and could not function as designed. Someone had cut off the temperature probe part of the device, rendering this part of the protection ineffective.

Because the water had no place to go, it continued to increase in temperature and pressure as the heater continued to fire and store the energy input. At some point the limits of the strength of the steel and its connections were reached and the tank tore itself apart. At failure, when the tank gave way, all the water inside expanded at 1600 times its volume in an instant. This created a pressure pulse that blew out walls and moved anything in its path, sending debris flying in all directions.

Had the proper procedures and inspections been put in place, this accident could have been prevented. If there was a preventive maintenance schedule in this case, it was ineffective. The safety relief valve was installed incorrectly, the high-temperature-limit shutoff did not function, and the gas valve was defective. These problems were all avoidable.

Oklahoma's boiler inspection law at the time covered high-pressure steam boilers but not smaller equipment such as water heaters. This situation was not unique to Oklahoma. Most states do not provide much in the way of inspections for certain classes of combustion equipment, even in educational facilities or places of public assembly. The school system, then, had to determine what would constitute adequate inspection, maintenance, and repair of the water heater. This is an often-overlooked responsibility. Most facility managers do not understand that they are responsible for proper inspections and maintenance when it comes to fuel systems and combustion equipment. They often think that an insurance or state boiler inspector is providing some overall safety evaluation, but generally this is not the case. In most states, boiler inspection laws call for inspecting only the pressure vessel part of each boiler system, and not for looking at combustion issues.

Boiler inspectors (who are often hired by insurance companies or are employees of the state) have their hands tied when it comes to what they can ask someone to do. They have little enforcement authority. What they are inspecting for is often limited to exactly what is called for by the letter of the law. For example, in many cases they can only evaluate equipment for code compliance based on when it was installed even though important code changes occur almost annually because of advances in knowledge and experience.

Typically, there is no screening for how far away the "grandfathered" technology is from the most recent codes. This type of inspection sometimes means that archaic and antiquated equipment that has little in the way of modern safety features could "technically" be in compliance.

**Lessons Learned** You as a safety, risk, or maintenance professional and your facilities staff are responsible for all fuel lines, boilers, and hot water heaters, regardless of size and fuel source (even electric). You are responsible even if they are inspected annually by an outside entity and even if there are no local or state requirements to do so. Your guide must be that of standards and codes that exist relative to this equipment. This book gives you a chance to discover these requirements and apply them to your facilities and equipment before an incident occurs and lawyers tell you that you should have been fulfilling these requirements. Ignorance is not a defense.

Equipment does not have to be massive in size or Btu capacity to cause death and destruction. I began the chapter with this story to bring the reality of this type of "small" often overlooked equipment directly into view. It is my hope that at some point someone will go down to their basement and change out a safety relief valve or locate a problem on a hot water heater that will save a life.

The energy that can be stored in water is incredible. Check out the popular television show *Mythbusters's* video of blowing up a water heater[2] to see what can happen. This video shows a water heater launching through a simulated house roof hundreds of feet into the air when the tank ruptures. You must, on a regular basis, review these often ignored pieces of equipment and replace the safety relief valves. This is an inexpensive task that is simple to do. If you review the manufacturers' instructions for most small relief valves, you will see that they call for regular inspections. In most cases this inspection is supposed to include their removal to look inside. Rather, given their cost, you might as well replace them. Be careful lift-testing these; I have often found that they do not reseat effectively. Again, replacement on a schedule is your best option, whether or not they need to be serviced. Also make sure that the burners on hot water heaters are evaluated periodically. Their flames need to be reviewed to see that they are burning cleanly, and drafts need to be checked. It is also important to ensure that over-temperature shutoff safety devices are functional.

## 1.1 KNOWLEDGE GAPS IN OPERATING FUEL SYSTEMS AND COMBUSTION EQUIPMENT

Even though humankind has used fire for millions of years, a continuing pattern of accidents, deaths, and injuries tells us that there is still a long way to go when it comes to fuel systems and combustion equipment safety. You just read a story about how a simple hot water heater in a school cost six lives because of seemingly simple issues. And this equipment was not nearly as large or complex as that at most industrial sites.

My 30 years in the business has shown me that many incidents happen because personnel at industrial sites are often not trained adequately in the safe startup and shutdown of combustion equipment, daily operations, or proper testing of safety devices and maintenance of critical systems. Very few formal classes exist regarding burners, gas piping, safety systems, or fuel/air ratio controls. The fuel and combustion equipment industry itself is very fragmented. Although there are numerous technical books and articles on the subject and codes and standards provide safety information, much of the knowledge in use seems to be tribal, passed on from person to person from word of mouth among those who operate and maintain combustion equipment. Much of this information is wrong and misinterpreted.

To be sure, most companies attempt to maintain their equipment. However, the maintenance is usually done by someone with little formal training, and equipment is often far removed from its optimum configuration after years of being cobbled together so as to "just run." Over the years, while inspecting thousands of pieces of equipment, I've experienced my share of horror stories—and not just the kind that end in explosions. I've witnessed alarms ignored and safety devices turned off. I've even seen wooden sticks and cardboard shoved into relays and safety devices to keep the safety interlocks from shutting equipment down—a potentially deadly fix.

There seem to be two worlds out there: one where large organizations have enough of this equipment to have very good staff members and practices and another where there are just a few pieces of this equipment and no one with much knowledge of it. The more common situation is that fuel systems and combustion equipment are some small ancillary part of the operation and no one is really fully trained or completely understands the equipment or the hazards. Many of the tragedies related to fuels and combustion equipment throughout history could have been prevented with the right PPE. In this case I'm not referring to personal protective equipment but to *people, policies, and equipment*. In my opinion, every fuel or combustion equipment incident

**TABLE 1.1 Fires That Caused $10 Million or More in Property Damage, 2000–2009**

| | | | Direct Property Damage (Millions) | |
|---|---|---|---|---|
| Year | Number of Fires | Fires More Than $10 Million Damage | As Reported | In 2000 Dollars |
| 2000 | 31 | 31 | $1814 | $1814 |
| 2001[a] | 19 | 15 | 762 | 702 |
| 2002 | 25 | 22 | 562 | 509 |
| 2003 | 21 | 17 | 2623 | 2417 |
| 2004 | 16 | 9 | 337 | 242 |
| 2005 | 16 | 6 | 217 | 101 |
| 2006 | 16 | 13 | 380 | 305 |
| 2007 | 45 | 33 | 3393 | 2709 |
| 2008 | 35 | 23 | 2372 | 1794 |
| 2009 | 24 | 17 | 940 | 693 |

*Source*: Stephen G. Badger, *Large-Loss Fires in the United States—2009*, Fire Analysis and Research Division, Copyright © 2010, National Fire Protection Association; reprinted with permission.
[a]Excluding the 9/11/01 World Trade Center attack from the loss totals but not from the fire incident totals.

begins as a people, policy, or equipment issue. My goal is to provide you with knowledge of these PPE tools that will dramatically reduce the risks of an incident.

From my contacts in industries that use fuels and combustion equipment, I have found that most owners of fuel-fired equipment do not understand the obligations that they have for the safety of their workers and plants. Many professionals responsible for facilities with fuel-fired equipment work within a culture of ignorance, misunderstandings, or denial about the impact of an explosion or fire caused by the operation of this equipment. I am aware of numerous disasters from gas piping or equipment that failed or had not been installed correctly. Many of the real-life stories presented in this book are from my personal experience and witness.

According to the National Fire Protection Association (NFPA), large-loss fires between 2000 and 2009[3] (the most recent statistics available at the time of publication) made for losses that averaged $1.1 billion per year during this 10 year period (Table 1.1). Most of these incidents occurred in manufacturing and industrial settings.

Furthermore, NFPA reports that U.S. fire departments responded to an estimated annual average of 10,500 structural fires in industrial and manufacturing properties in 2005–2009. These fires caused annual averages of 11 civilian deaths, 254 civilian fire injuries, and $726 million in direct property damage. These types of losses have been experienced in the United States for many years, often resulting from fuel systems and combustion equipment issues that could easily have been prevented. These losses don't count the hundreds of other significant business interruptions, facilities damage, lawsuits, fines, litigation, and lost-market-share issues that have also occurred. Smaller but more frequent production outages also cost millions in business interruptions, supply chain delays, lost orders, and decreased competitiveness. These losses are often deemed to be culturally accepted as a general cost of doing business. It doesn't have to be this way.

Fuel systems and combustion equipment safety is critical to the daily operation of many facilities and their employees. Unfortunately, many companies act only when a very large and tragic event occurs. Many companies believe that explosions, fires, or outages from fuel-fired equipment only happen to others—that their company is immune. Only loss of life seems to make the 11 o'clock news. Headlines soon fade or rarely get the follow-up attention required to highlight the pitfalls of equipment that has been poorly maintained and operated. Today's corporate public relations departments are also very good at shutting down the flow of information that may leak to the media. My experience has been that little "poofs," "pops," bulging furnace walls, and "pregnant boilers" are more prevalent than not and imply that incident headlines are only the tip of the iceberg. For each incident reported there are undoubtedly many left unreported because they did not result in death, injury, or significant loss of production. Hence, they are never clearly researched and the lessons are not adequately learned.

## 1.2 MANAGING FUEL SYSTEMS AND COMBUSTION EQUIPMENT RISKS

OK, so by now you accept that there is risk and possibly danger associated with fuel systems and combustion equipment. If you wanted to better understand how that applies specifically to your facilities and equipment, how would you know what *safe* is? In the fuel and combustion systems world, *safe* is not necessarily a destination but a journey. The state of the art is constantly evolving in the codes and standards world. These are documents and sources of information that are out there to help you better understand what level of safety your organization is at and the type of journey you should be considering. Many proactive corporations manage their fuel and combustion system risks successfully by creating programs that address people, policy, and equipment issues. They spend millions of dollars to develop, implement, and update ongoing programs.

The journey will also depend somewhat on your organization's culture. *Culture* can be described as the subconscious knowledge that is embedded in people without them even knowing. Culture is slowly absorbed through habits and regular reinforcement. It becomes the emotional guiding light in the presence of confusion, stress, and dangerous situations. It's what's there when subconscious thought must take over because things are happening too fast. Combustion equipment culture is no different.

In some organizations the culture is such that there are willing and eager minds open to learning. Information is shared openly and there is little fear of retribution for making honest mistakes. These can be characterized as *rapid acceptance cultures*. In other cases, where someone will be harmed if even a slight mistake is perceived, acceptance and new thinking will be difficult. The following story demonstrates how culture might influence your experience in managing these risks.

### Real-Life Story 2: The Bulge in the Boiler Firebox

I walked into the boiler room, took one look down the side of the boiler, and said to the boiler operator on duty: "Excuse me, can you tell me anything about what happened here in the past to make that bulge?" When looking down the side of what used to be a flat surface, it was clear that the side of the boiler bulged outward. Obviously, sometime in the past there was an explosion. It's not clear that anyone reported it. It's also not clear that there was damage beyond the outer boiler skin being deformed, but then how would anyone know? Remember, sometimes staff, even those who might be managing the boiler house facilities, might not want to report something like this and attract a lot of scrutiny. The culture may be that it's not a good career move for anyone to do so. When you review facilities, make sure to ask about anything you see, even if it's old or very obvious, as it may be the first time that it has really been brought to anyone's attention and been acted on.

The operator responded: "Oh, that, that was a small poof we had. It just happened once at light-off but it went away." It was clear that this investigation now needed to focus on a few key issues, such as low-fire gas flow control valve positioning for light-off, malfunctioning gas pressure regulators, the possibility of leaking valves, faulty purge timing, and incorrect fuel/air ratios.

The investigation was begun using a combustion analyzer to check the flue products. This identified an excess of 1500 ppm carbon monoxide (CO) at a low fire level. The maximum CO expected for a well-tuned burner of this type for this application should have been less than 100 ppm. It got worse as the boiler moved off low fire and pegged the meter at over 2000 ppm CO. Significant levels of CO are an indicator of poor fuel/air mixing and incomplete combustion. No one could remember reviewing or adjusting the fuel/air ratio since the boiler was installed and commissioned over 10 years ago.

Many combustion analyzers can only read CO to about 2000 ppm. The generally accepted lower flammable limit of carbon monoxide is 12,500 ppm,[4] or 12.5%. It would be rare to have an explosion due to accumulating this much CO. However, because CO can be read by an analyzer, it serves as a surrogate indicator of other additional combustibles present, including unburned fuels. Partially burned fuels represent things that come from the cracking of some of the hydrocarbon molecules when they are partially burned. The elevated temperatures and mixtures of fuels and fuel derivatives can have a wide range of ignition temperatures. It's these other combinations of things, not the CO, that usually end up being what ignites and makes for explosions.

**Lessons Learned** Cultures must be such that personnel are not afraid to report issues. An unreported minor issue can easily degrade quickly and cost someone his or her life. Always question any damage you see to a firebox or fuel train. Never assume that since it looks old, everyone is aware of what happened and that the actual cause has been identified and the problem abated properly. Best-practice organizations conduct daily flame observations and logging of findings. They also conduct fuel/air ratio adjustments (burner tuning) at least annually.

Incomplete combustion can make for flammable mixtures in the firebox and flue passages of combustion equipment. If flue gas oxygen metering and reporting are part of the equipment instrumentation, be aware of the limitations of meters being used, exactly what they measure, and all of the implications of the meter readings. Train the staff and drill them about what levels of oxygen should be a cause for concern and what actions should be taken.

## 1.3 THE CREATION OF FUEL SYSTEMS AND COMBUSTION EQUIPMENT CODES AND STANDARDS

Because of numerous tragedies and the continuing human desire to use heat processes to advance society, many smart people have gotten together over the years to learn from past mistakes and to create definitions and examples of what safe fuel and combustion systems should look like. Some of the most important of these documents are called codes and standards. Today's many codes and standards organizations consist primarily of volunteer experts working under well-defined protocols to assemble informative documents that include much hard-learned wisdom. It's your challenge to read and incorporate the knowledge and experiences contained in the applicable standards and codes and apply this information to enhance the level of fuel and combustion equipment safety within your organization.

To learn why these documents and organizations came into existence let's look at the history of combustion equipment in industry. During the nineteenth century, boilers and steam engines became the heart and soul of the industrial revolution. At the same time, accidents related to boilers and pressure vessels became commonplace. From 1870 to 1910 there were more than 10,000 recorded boiler explosions in North America[5] (an average of 250 per year). By 1901, the rate had climbed to between 1300 and 1400 recorded boiler explosions per year. When these incidents occurred, they were often horrific and involved many people. There were public outcries for remedial action. It soon became clear that this technology needed to be made safer if it was to proliferate. The American Society of Mechanical Engineers (ASME), answered the call with groups of volunteer mechanical engineers coming together to create the first boiler code committee in 1911.[6] The first ASME boiler code was published in 1914–1915. The code documents produced by ASME identified safe practices for the construction of boilers and pressure vessels and for pressure piping systems. These documents provided specifications for steels required, their thicknesses, welding practices, and many other fabrication and installation issues that enhance safety. ASME codes, standards, and more information about the group may be found at www.asme.org.

Once these documents were developed, industry experts realized that there needed to be another group that actually enforced the rules. This group would need to consist of paid professionals who could be on the job every day acting as code enforcers or inspectors. They would need to visit fabrication shops, review welds, and measure and verify thicknesses of pipes when boilers were being fabricated. Identifying this need gave birth to the National Board of Boiler and Pressure Vessel Inspectors (NBBI) in 1919.[7] Headquartered in Columbus, Ohio, this group was created to promote greater safety to life and property through uniformity in the construction, installation, repair, maintenance, and inspection of pressure equipment, most of it boilers.

The National Board membership oversees adherence to laws, rules, and regulations relating to boilers and pressure vessels. The National Board members are chief boiler inspectors, representing most states and all provinces in North America, as well as many major cities in the United States. More information about the NBBI is available at www.nationalboard.org.

NBBI functions include the following:

- Promoting safety and educating the public and government officials on the need for manufacturing, maintenance, and repair standards.
- Offering comprehensive training programs in the form of continuing education for both inspectors and pressure equipment professionals.
- Enabling a qualified inspection process by commissioning inspectors through a comprehensive examination administered by the National Board.
- Setting worldwide industry standards for pressure relief devices and other appurtenances through operation of an international pressure relief testing laboratory.
- Providing a repository of manufacturers' data reports through a registration process.
- Accrediting qualified repair and alteration companies, in-service authorized inspection agencies, and owner–user inspection organizations.
- Investigating pressure equipment accidents and issues involving code compliance.
- Developing installation, inspection, repair, and alteration standards (the National Board Inspection Code).

As additional emphasis was put on having safe standards for the use of fuels such as natural gas, which led to a group called the National Fire Protection Association (NFPA) being created.[8] The organization was formed by a group of sprinkler manufacturers, installers, insurance, and enforcement officials, who developed the first code for the installation of fire sprinklers, issued in 1896. NFPA's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA publishes more than 300 codes and standards. Among them are codes and standards regarding the safe design and installation of fuel train controls and combustion systems. These include specific codes and standards for boilers and for devices other than boilers. The NFPA's website is www.nfpa.org.

Before describing some of the codes and standards developed by these organizations and others, it's important that you understand the difference between a standard and a code. A *standard* is prepared and presented by a recognized national organization that collaborates on technical issues and identifies state-of-the-art best practices for safety. A *code*, on the other hand, is intended to be adopted as a law. Standards usually say how to do something for safety, whereas codes require when and where to do something for safety.

Each code and standard is managed by a combination of staff and dedicated volunteer committees with members from among end users, insurance companies, manufacturers, testing laboratories, special experts, and trade associations. These groups usually meet several times a year and are responsible for maintaining, updating, and eventually gaining consensus for the final published standard. Codes and standards are typically updated regularly, usually every three to five years. Some are reaffirmed where the technology has not changed. Codes and standards are often adopted into law by federal government departments, states, provinces, and other jurisdictions to become legally enforceable.

### 1.3.1 How Codes and Standards Are Structured

There are several parts to a code or standard. Much of what is described here is from the perspective of NFPA documents. These documents normally include a table of contents, definitions, the body of the document, and appendixes (often called an annex). In most cases, only the body of the code is enforceable—not the appendices, which contain explanatory materials. When NFPA codes are revised, there are vertical markings on the sides of pages to indicate what has changed. Asterisks indicate that there is appendix material.

Remember, codes and standards are typically not prepared only by scientists and testing agencies. Consensus code and standard developers have rules that ensure adequate representation and balance of the participants in the process: people on committees from a wide variety of backgrounds and perspectives. Recommendations for revisions can be submitted by anyone (even the general public) and are to be considered, debated, and voted on. Most standards developers have forms and guidelines available on their websites to assist those wanting to submit proposals for revisions.

Following the letter of the code does not guarantee safety in all cases. Each document has many pages covering the requirements for safe design, installation, operations, and maintenance of the respective equipment, but sound engineering judgment in applying this information is still required. It must also be remembered that these codes and standards are minimum requirements. Best-practice organizations understand this and often try to do more.

In Sections 1.4 and 1.5 we provide brief overviews of the most applicable codes for common combustion equipment, highlighting NFPA and ASME codes. (All NFPA codes can be purchased at www.nfpa.org and ASME codes are available at www.asme.org.)

### 1.3.2 Applying Codes and Standards

In most cases, codes are not retroactive. Most are meant to be applied when the equipment is installed. Most plants have equipment that is "grandfathered" in: that is, it is exempt from certain current requirements as long as the equipment was installed in compliance with the codes and standards in effect at the time of installation, continues to be used for the same purposes, and is not changed significantly. Almost no one has equipment for very long that meets all current codes. Some proactive organizations conduct gap analyses to learn where they do not meet current codes and then do something about it. Keeping up with codes and standards after equipment is installed is recommended. It allows an organization to remain current with newly discovered risks and changes to technologies that can make for reduced risks.

When codes and standards are changed, or new code and standards documents are added, it is usually for very good reasons. An example of a code change is the requirement in NFPA 86, the Standard for Ovens and Furnaces, that there be two automatic pilot valves in series. In many older ovens and furnaces, only one such valve exists. The code committee learned after a number of incidents that it's safer to have two of these to prevent gas leakage when a system is in a closed or off state. These two valves in series minimize the chances of fuel leaking past a defective valve and accumulating in the combustion chamber, thus posing an explosion risk. Adding another valve in series to minimize this risk usually costs less than $500. Even though the equipment may be grandfathered in with one valve, why would you not want to add this additional protection when considering the low cost and reduced risk?

## 1.4 FUEL SYSTEM CODES AND STANDARDS

NFPA publishes codes and standards in many areas of fire protection. The following are publications are related directly to fuels.

- *NFPA 54, the National Fuel Gas Code* NFPA 54 is a safety code that applies to the installation of fuel gas piping systems, fuel gas appliances, and related accessories. It covers pipe materials, pipe joining methods, pressure testing, purging, and certain other gas piping installation issues. Don't be fooled by the word *appliances* here if you are an industrial user. This code is somewhat general, and elements of it can be applied to many systems. It covers both natural gas piping systems from the point of the utility's delivery to the appliance shutoff valve on individual appliances and to some propane piping systems from the final-stage pressure regulator to the appliance shutoff valve. In the case of most utility connections for natural gas, the point of service to a customer starts with the discharge flange of the natural gas meter or at the service shutoff valve where a meter is not installed.
- *NFPA 31, the Standard for the Installation of Oil-Burning Equipment* NFPA 31 applies to the installation of stationary liquid fuel–burning appliances. It also covers the storage and supply piping for liquid fuels. As many appliances (i.e., boilers and furnaces) can use liquid fuel as well as other fuels, the language for this standard is similar to that of NFPA 54, although NFPA 31 deals specifically with fuel oil.
- *NFPA 58, the Liquefied Petroleum Gas Code* NFPA 58 covers the storage and use of liquefied petroleum (LP) gases. The LP gases included in NFPA 58 include propane and butane. Propane is a gas at normal temperature and pressure (72°F and atmospheric pressure) but is often compressed to be liquefied for ease

of storage and distribution. NFPA 58 applies to the storage of liquid LP's, their piping, and use in a facility of liquid and vapor at over 20 psig. Because the fuel is often transported by truck and rail, the U.S. Department of Transportation (DOT) regulations are also to be consulted for truck unloading operations at a receiving facility.

## 1.5 COMBUSTION EQUIPMENT CODES AND STANDARDS

In this section we discuss popular combustion equipment–related codes and standards. The ones discussed below are published by ASME and NFPA. ASME codes cover primarily boilers, while NFPA codes cover many other types of combustion equipment as well as boiler combustion systems.

Most codes and standards related to combustion equipment call for the testing of safety devices, training, and the existence of startup and shutdown procedures. A lot of ASME codes and standards deal with such subjects as the type of materials to be used, their thickness, and information on installations and repairs.

### ASME Boiler and Pressure Vessel Codes

ASME distributes over 600 codes and standards all over the world. The Boiler and Pressure Vessel Code originated in 1914. It has been adopted in whole or in part by all 50 states, many municipalities, and in all Canadian provinces. The Boiler and Pressure Vessel Code is organized in 12 sections:

Section I: Power boilers
Section II: Materials
Section III: Rules for the construction of nuclear power plant components
Section IV: Heating boilers
Section V: Nondestructive examination
Section VI: Recommended rules for the care and operation of boilers
Section VII: Recommended guidelines for the care of power boilers
Section VIII: Pressure vessels
Section IX: Welding and brazing qualifications
Section X: Fiber-reinforced plastic pressure vessels
Section XI: Rules for in-service inspection of nuclear power plant components
Section XII: Rules for the construction and continued service of transport tanks

### ASMECSD-1: Boilers Up to 12.5 Million Btu/h

ASME CSD-1 (CSD, Controls and Safety Devices) is a code that applies to boilers that have a fuel input rating of less than 12.5 million Btu/h. This code is applied and enforced in at least 26 states and some major municipalities. It is unique in that it is the only code that actually covers the fire or combustion equipment safety side of smaller boilers. In most cases where it is applicable, jurisdictional inspectors will ask to see evidence that annual testing of safety interlocks is taking place correctly. This code's jurisdiction includes requirements for the assembly, installation, maintenance, and operation of controls and safety devices on boilers operated automatically and fired directly with gas, oil, gas–oil, or electricity.

### NFPA 85, the Boiler and Combustion Systems Hazards Code

NFPA 85 applies to single- and multiple-burner boilers, waste heat or heat recovery steam generators (HRSGs), stokers, and atmospheric fluidized-bed boilers with a fuel input rating of greater than 12.5 million Btu/h. It also applies to unfired steam generators used to recover heat from combustion turbines. NFPA 85 covers fabrication issues, operation and maintenance procedures, combustion and draft control equipment, safety interlocks, alarms, trips, and related controls that are essential to safe equipment operation.

### NFPA 86, the Standard for Ovens and Furnaces

NFPA 86 includes extensive information about categories of ovens and furnaces, their installation, design issues, required safety devices, testing of safety devices, and issues related to training of operators and maintenance staff. There is also information about the safe operation of the various types of ovens and furnaces and any other heated enclosure used for processing of materials and it's related equipment.

### NFPA 87, the Recommended Practice for Fluid Heaters

NFPA 87 is a 2011 edition document that identifies safety issues related to fluid heaters. These fluids would include heat transfer fluids but not petrochemical process-related fluids. This document excludes certain petrochemical process heaters and refers the reader to American Petroleum Institute materials.

### NFPA 70, the National Electrical Code

The National Electrical Code is the bible of the electrical installation industry. It is a very comprehensive document and covers all issues related to residential, commercial, and industrial wiring and electrical device installation. This code is not specific to combustion equipment. It covers electrical panels, devices, switches, conduits, grounding, arc flash, and other installation issues that interface with combustion equipment.

## 1.6 OTHER WIDELY RECOGNIZED CODE- AND STANDARDS-RELATED ORGANIZATIONS

There are a number of other organizations that play an important role in fuel systems and combustion equipment safety. Those most common in North America are described in this section. In Chapter 11 we discuss those most popular in Europe and the developing world.

### Factory Mutual (www.fmglobal.com)

Factory Mutual (FM) is an insurer well known in the industry for its very high standards, well-trained staff, and extensive risk management guidelines for just about every issue and type of occupancy or process in existence. Many of Factory Mutual's data sheets and other materials are available on the Web. FM's loss prevention data sheets are well written, based on a great deal of experience, and full of very practical information.

FM also has a testing laboratory that "approves" components and devices. Their Approval Guide is widely distributed and used throughout the industry. FM's approval logo is a key to look for when codes require that a component in a fuel train must be approved by a nationally recognized testing agency for the service for which it is intended.

### Underwriters' Laboratories (www.UL.com)

Underwriters' Laboratories (UL) is a nationally recognized testing agency that has been in existence for over 50 years. One of the most respected names in the history of electrical and fire protection safety, UL reviews and tests hundreds of components to certify them for safe use and applicability.

When working with fuel trains, devices, or equipment that is "listed" and "approved," be very careful when making modifications other than direct replacement of components. If you change something that is listed and labeled and there's a problem later, the insurer may have a reason to fight a claim. Make sure that your insurer is involved in approving changes made to fuel trains or control systems and that you receive written authorizations from them before proceeding.

## 1.6.1 Other Standards Developers and Related Industry Organizations

In addition to the agencies listed above, there are other organizations that publish or enforce codes and standards for the safe operation of combustion devices. You may see tags on equipment that reference these groups:

1. American Gas Association (AGA), www.aga.org.
2. CSA International (Canadian Standards Association), www.csa-international .org.
3. Industrial Risk Insurers (IRI); no longer exists, purchased by GE Gaps.
4. American National Standards Institute (ANSI), www.ansi.org. ANSI is the "umbrella" organization for all American national standards and is the U.S. representative to the International Standards Organization (ISO). ANSI does not develop standards, but oversees the creation, promulgation, and use of thousands of American national codes and standards.
5. Technical Safety Standards Authority (TSSA), www.tssa.org. TSSA is a not-for-profit, self-funded delegated administrative authority that administers and enforces public safety laws for pressure vessels, fuels, and other areas in the

province of Ontario, Canada. TSSA, established under Ontario's Technical Standards and Safety Act, does not develop standards but provides guidance on complying with the government standards established in Ontario, Canada.

6. American Petroleum Institute (API), www.api.org. The API is the only national trade association that represents all aspects of America's oil and natural gas industry. The API has extensive standards available related to refining and petrochemical process equipment and combustion systems.
7. PHMSA (Pipelines and Hazardous Materials Administration) is the section of the U.S. Department of Transportation that deals with issues related to hazardous pipelines, www.phmsa.dot.gov. DOT is a cabinet-level branch of the U.S. government that was established by an act of Congress in October 1966. It ensures a fast, safe, efficient, accessible, and convenient transportation system that meets the nation's interests. DOT regulates air, rail, pipeline, and road transportation in the United States.
8. International Society of Automation (ISA), www.isa.org. Founded in 1945, ISA is a leading global nonprofit organization that is setting the standard for automation by helping over 30,000 worldwide members and other professionals solve difficult technical problems while enhancing their leadership and personal career capabilities. Based in Research Triangle Park, North Carolina, ISA develops standards, certifies industry professionals, provides education and training, publishes books and technical articles, and hosts conferences and exhibitions for automation professionals. Many ISA standards address combustion equipment-related issues.

## 1.7 SAFETY INSTRUMENTED SYSTEMS AND SAFETY INTEGRITY LEVELS

In addition to complying with the most current fuel and combustion system codes and standards, risks can also be minimized by applying safety instrumented systems and safety integrity levels. Safety instrumented systems (SISs) and safety integrity levels (SILs) are becoming ever more important methods of describing the overall safety level and risk associated with combustion systems. These terms are used regularly in the process combustion equipment industry. There seem to be two different worlds when it comes to fuel systems and combustion equipment safety. One world consists of those involved with industrial manufacturing and large commercial and institutional venues; the other is the entire process and petrochemical refining world. The interesting thing is that these two worlds don't seem to talk much and don't seem to share many requirements.

The process and refining worlds have valuable information, including many standards and papers that have been created and maintained by organizations such as ISA, API, and the American Institute of Chemical Engineers (AIChE; www.AIChE.org). The chemical process and petrochemical industries use an approach to safety that differs from that of much of the commercial and manufacturing industrial combustion industry.

In the process industry, many systems, including combustion systems, are designed according to the SIS/SIF/SIL approach. A great explanation of this topic exists at the General Monitors website.[9] An SIS is a combination of inputs (sensors) with a logic solver (hardwire or computer-based, PLC device), outputs, and final elements (e.g., valve actuators).

In the process and petrochemical-fired equipment world, small dedicated computers called programmable logic controllers (PLCs) have replaced many hardwired relay-based logic solvers. PLCs, in combination with sensors, instruments, and components such as control valves, can make up an SIS. Each SIS may have a number of SIFs, safety instrumented functions. Every SIF within a SIS will have a SIL, a measure of a SIS's probability of failure on demand. SIL 1 is the highest level (most risk of failure on demand). The scale generally runs from 1 to 4, with 4 being the highest achievable level of risk reduction, the lowest probability of failure on demand. As stated at the website:

> If something needs to be a SIL 4 system it is likely very complex and costly and probably not usually economical to implement. For the process industries, if a process has so much risk that a SIL 4 system is required to bring it to a safe state, there is a fundamental problem in the process design that needs to be addressed by a process change or other method.

The hierarchy is this: SIS is the overall system; it may contain several SIFs; each SIF has an SIL. The SIL describes the SIF's probability of failure.

> It is a very common misconception that individual products or components have SIL ratings. SIL levels apply to the entire instrument safety function and safety instrumented system (SIF and SIS). The logic solvers, sensors, and final elements are only defined as suitable for use in a specific SIL environment, but only the end user can ensure that the safety system is implemented correctly. The equipment or system must be used in the manner for which it was intended to successfully obtain the desired risk reduction level. Just buying SIL 2 or SIL 3 suitable components does not ensure a SIL 2 or SIL 3 system in service.

Although ratings can be identified, depending on where the boundaries of the system are defined, ratings do not usually take into account an actual "in service" probability of failure on demand that takes into account human factors such as the maintenance of final elements or the possibility that someone can leave a safety system in a bypassed mode.[10]

The identification of risk tolerance is subjective and site-specific. The owner or operator must determine the acceptable level of risk to personnel and capital assets based on company philosophy, insurance requirements, budgets, and a variety of other factors. A risk level that one owner determines is tolerable may be unacceptable to another owner. When determining whether a SIL 1, SIL 2, or SIL 3 system is needed, the first step may be to conduct a process hazard analysis to determine the functional safety need and identify the tolerable risk level.

Mike Scott and Bud Adler of AESolutions posted an article[11] on reviewing SIL levels for boiler burner management systems in light of NFPA 85 requirements. In their evaluation of the requirements of both prescriptive and performance approaches, they indicated that the NFPA 85 requirements are very prescriptive;

that is, specific types of components and approaches were required. The SIS approach is more performance based. Note that NFPA 85 allows alternative approaches to safety with the approval of local authorities.

A SIS approach means that concepts are given and the designer of a performance-based system is freer to address the specific hazards and situations than in the prescriptive approach. The performance-based approach requires that process hazards be evaluated and risk analysis be performed. The risk analysis effort should consider many factors, including hazards associated with the process, the sequence of events that could lead to a hazardous event, human factors, opportunities to mitigate risks through design and layers of protection, and the organization's overall risk tolerance level. Following the risk analysis, a SIL level can be assigned. The ANSI/ISA 84.00.01-2004 standard provides extensive information on this approach.

## 1.8 THE WORLD OF INSURANCE AND COMBUSTION EQUIPMENT

Every day, whether or not we think about it consciously, we all use a kind of "risk radar" to evaluate life's challenges. This means that we need to accept that something is a risk and that we have to plan for how much of this risk we may want to try to control and how much of it we may want to transfer to an outside vendor or an insurer. For example, tremendous risks exist when we drive a car. Not only do we have to guide thousands of pounds of stamped steel and molded plastic from point A to point B without incident but we must make sure that we stay out of the way of others. There are many driving risks that we choose to control and manage on our own, such as driving at the speed limit, wearing seat belts, and perhaps taking a defensive driving course. However, since so many other things about driving, like the weather, are not under our direct control, most of us transfer some of the unknown risks to an insurance company.

Fuels and combustion system risks can be thought of and managed in the same way. For example, an owner or plant may transfer some liability to a boiler insurer, which will try to manage some of the risk with boiler inspectors and property risk engineers. The remaining facility risks might be managed by an organization's internal engineering, maintenance, safety, and training staffs through specifications for equipment, maintenance programs, and training to address the culture related to operating fuel systems and combustion equipment.

Before we take on this topic more fully, let's cover a few basic definitions related to this world. There are many different types of insurance, four of which might be related to fuel systems and combustion equipment coverage:

1. *Property:* protects structures and equipment and is usually related to fires. This would also typically cover fire-side explosions in a boiler firebox.
2. *Boiler and machinery:* also often called *breakdown insurance*. In this case it offers coverage, usually, for issues related to the water side of the boiler (i.e., the pressure vessel itself). This would typically not be for failed maintenance issues such as poor water treatment. This would not typically cover fire-side explosions related to fuels in a boiler firebox.

3. *Business interruption:* covers the loss of profits if an incident were to occur and the facility were to be out of service.
4. *Casualty:* can have many meanings but usually covers disability and/or accidents to people.

The four types of insurance identified above represent four different types of risk that organizations may want to manage. Managing these risks means accepting some of them and taking steps to mitigate them or to transfer them to someone else in exchange for payments. Let's look at how the management and transfer of this risk works on an enterprise level. As a first step, many large organizations have to decide how much risk to self-insure or accept and how much risk they want to pay to transfer. They can also transfer some to a "captive," their own insurance entity set up to fund some part of a possible loss.

The insurance industry is a unique world. It has differing amounts of capacity each year. Unlike a normal purchase such as buying a car, where the consumer wants a product and picks from several offerings, when you purchase insurance, you have to put together a package of what you want in terms of boiler insurance, property insurance, casualty insurance, business interruption insurance, and so on. This package is then presented to a number of insurance organizations to see if they have the financial capacity for the risk and want to assume it. Financial capacity depends on such things as how many disasters occurred during a year for the insurance industry and the specific potential provider.

If an insurer wants to provide a price quote, it passes the information on to one of its underwriters. The underwriter works at an insurance company and has the job of reviewing statistics and using formulas to come up with a price and with qualifying conditions. There are detailed databases on each potential customer or related industry, with historical data on losses and previous coverage providers, which they use for reference. The underwriter considers the limits of liability sought, deductibles, and loss histories and presents an offer for your consideration.

The process can be complex; that's why most large companies work through a broker. A company seeking insurance coverage can have a dozen different entities somehow involved in providing the overall levels of coverage. For example, one entity might handle the first $100 million in losses, another the next $300 million, and so on, a process called *layering*. In some cases the insurers sell off some of these risks to reinsurers, which would reinsure all or part of a package that a particular insurer might have just signed up to provide.

Once a company decides on an amount for property insurance and a vendor, it may engage a risk engineering service. This could be to help mitigate self-insured risks or it could be required by the underwriter as part of the coverage. These types of services may be furnished by the property insurance provider or an outside organization such as AXA Matrix Risk Consultants[12] or Factory Mutual.[13] One of the qualifying conditions for the coverage may be that there are loss prevention inspections at the customer's highest-risk and or most valuable sites. These are usually identified by the maximum foreseeable loss value at a site. *Maximum foreseeable loss value* (MFLV) is an insurance term that quantifies the overall impact of a site being completely destroyed. It is unlikely that every site will be visited for inspections, so MFLV provides a means to prioritize sites.

When it comes to focus on fuel systems and combustion equipment, most industrial organizations experience periodic visits by a property insurance inspector for at least their major facilities. These reviews are often completed within a single annual visit and can be rather broad in scope, covering a range of insurance concerns, such as fire, wind, earthquake, flood, fleet, and business interruption. Considering the property loss inspectors' short duration at a site and broad scope, these visits cannot be relied on to verify that fuel systems and combustion equipment are properly designed, maintained, and operated. In fact, it is not their intent to give you general overall approval of the way you operate, or maintain what you have. Instead, it is at best usually an overview of some key risk reduction points related to the equipment.

When industrial facilities have some type of boiler or pressure vessel, these may require periodic inspections by a state or provincial certified boiler or pressure vessel inspector. For these objects (called *jurisdictional objects* by the inspectors), the intent of the state and provincial inspection is often limited to the pressure vessel portion of the object. Considering the specific focus of the inspection (i.e. pressure vessels and not fuel and combustion systems) the state and provincial certified boiler and machinery inspectors cannot be relied on to verify that the combustion equipment is properly designed, maintained, and operated. Even in those jurisdictions where the inspector is required to inspect the fuel train, more often than not, the inspection will consist of verifying that the installation meets originally installed code requirements from what can readily be seen without touching, opening, or testing anything. In most cases the inspector will not be verifying that the equipment is properly designed and maintained. In the end, in almost all cases, state, provincial, and local codes will stipulate that the overall responsibility for the safe operation and maintenance of the equipment always lies with its owner or user.

Another way that insurers try to control risk is by requiring customers to submit plans for new or substantially modified combustion equipment for review and approval before they are installed or retrofit work starts. Always remember to make sure to ask whether your insurer needs this information if you are involved with a new project or a retrofit. You don't want to create situations in which there is reason to fight or deny a claim. This could happen if an unapproved system later has a problem.

### Real-Life Story 3: But It Was Inspected Recently!

Relying on jurisdictional boiler inspectors to manage your risks is not enough. You must do your own inspections and preventive maintenance safety testing as well. You must also address gas piping systems in your inspection and testing program. The following is an account from a local newspaper about a tragic incident in the U.S. Midwest that occurred at a nursing home, killing five people in 1999.

A blast centered in the nursing home's boiler room blew out the walls and caused the ceiling to collapse. More than 90 residents and about 20 other people were in the building at the time of the incident. Even as emergency crews were searching for survivors and evacuating the elderly residents, the incident was being attributed to a boiler failure. Press reports[14] indicated that the facility manager had recently had the boilers inspected and that the inspection found them to be in good working condition. Most people would have thought the equipment to be safe. Litigation followed, indicating that the incident may have been due to a gas piping leak. Gas piping leaks or corrosion of gas piping systems are not typically within the jurisdiction of state boiler inspectors.

The facility manager probably thought that everything was covered, including the gas piping, when the state issued an annual boiler inspection certificate. Like many others, he probably did not completely understand what the inspection did and did not cover. This is an issue within the boiler inspection world that no one seems to want to address. There is an ongoing culture of letting owners think that the state certificate is a completely protective all-encompassing shield against any and all concerns.

**Lessons Learned** Most official "boiler inspections" are jurisdictional and cover only the "water side" or the pressure-retaining components, water-level controls, and boiler internals. This incident occurred in a state that had adopted ASME CSD-1 as law, meaning that this code was enforced by jurisdictional inspectors. The code requires fuel train safety components to be tested but does not have jurisdiction for gas piping feeding the boiler.

As often happens, once an incident occurs, there is an important legal scramble by every insurer to try to define the perceived liability. Because of this, owners need to understand very clearly that jurisdictional and state-mandated inspections are *very* limited. They absolutely do not guarantee that fuel piping and every boiler safety system have been inspected or tested and that everything is safe. If you don't understand this and you manage a facility, you can lull yourself into a false sense of security and end up very disappointed! It is recommended that in addition to a satisfactory inspection by a state or jurisdictional boiler inspector, facility managers should contract with a capable service provider for an inspection of gas piping and controls and boiler fuel train safety device testing on at least an annual basis.

**IMPORTANT**

Insurers, including their inspectors and equipment review team, need to be part of your overall efforts toward fuel and combustion system safety. However, you need to understand the limitations of their approvals and what their scope really is. It is often much more limited than you think!

## 1.9 PERSONAL CRIMINAL LIABILITY

Ever been to jail? No? Neither have I, so far. However, I can cite numerous examples of situations where criminal prosecution for workplace accidents has occurred, and it's a growing trend. Most people think that if something happens, perhaps the company will be involved in a worker's compensation claim or even a civil action.

Rarely is thought given to being criminally liable for one's actions at work. The following should give you food for thought. Whenever there is a serious injury or death, it's always a prosecutor's prerogative to conduct an investigation and submit information to a grand jury for an indictment. It could be a supervisor telling employees to ignore obvious safety issues with a boiler or furnace, to bypass safety controls, or even not to respond to an obvious gas leak. In our world today, your actions may be second-guessed by a grand jury that lacks a technical background but, instead, is simply considering the probability of a successful conviction by a jury of your peers, who also lack technical know-how. If this does not cause you to err on the side of safety, nothing will.

### Real-Life Story 4: Personal Criminal Liability at Work?

Take, for example, the case of a construction equipment company owner on the U.S. east coast who was charged with manslaughter, assault, criminally negligent homicide, and reckless endangerment for his perceived role in a 2008 accident that killed a crane operator and caused major financial losses to a project. According to press reports,[15–17] the criminal action happened even though the owner was never cited by the Occupational Safety and Health Administration (OSHA) for anything at the job site. The owner of the company plead not guilty to the charges.

This case and others like it could have serious implications for high-level executives who are never involved in the day-to-day details of running a business. Just because your plant is compliant with OSHA standards does not mean that you and the company are off the hook if something bad happens.

This incident involved a crane that was made in the early 1980s. This equipment was somewhat high tech and needed very specialized maintenance, periodic testing, and training—kind of like a boiler, an industrial furnace, or an oven. Press reports indicated that the crane manufacturer was out of business and that many replacement parts were no longer available. This can happen with older burner management systems and combustion controls on boilers and furnaces. My guess is that at least 25% of all burner or furnace controls in use today throughout industry are obsolete and no longer supported by manufacturers. When a major gear needed to be replaced, the crane owner tried to buy one from alternate suppliers and found three bidders. One Chinese company offered to provide a gear at less cost than that proposed by the other two bidders and offered a four-month faster delivery time. The company owner did what most others would do and chose the lowest bidder with the best delivery schedule.

Forensic evidence showed that a structural weld made by the successful bidder failed catastrophically. Prosecutors stated that the owner did not conduct due diligence on this company and that the vendor was supplied with grossly inadequate welding specifications. They went on to state that the owner did not follow generally accepted engineering and workplace standards to ensure that the weld was safe.

The owner said that he had the weld inspected properly and that city officials even signed off on it. The owner was eventually found not guilty. There is no doubt that he suffered greatly through the entire legal process.

**Lessons Learned** This case is an important lesson to upper management everywhere. The message is that if negligent actions are found, or even perceived, an individual can be prosecuted and held criminally liable. Prosecutors are under tremendous pressure, especially in very public incidents, to hold someone accountable. They can be very aggressive about this. It all starts with an OSHA report. Lots of times, if there's an OSHA citation, there's presumed guilt and presumed civil negligence. The best defense is not to have an incident in the first place. If you take advantage of what is presented in subsequent chapters, your chances of an incident will be greatly diminished. Much of what is presented was learned the hard way. The more than 50 real life stories in this book reflect what can happen if things go wrong.

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