

# Ignorance is no Excuse: Combustion Systems Standards and Codes 101

## Safety Note

Many professionals responsible for facilities with fuel-fired equipment are ignorant about national codes and standards for combustion equipment or about the impact an explosion or fire caused by the operation of equipment such as boilers, furnaces, ovens or dryers can have.

The National Fire Protection Association (NFPA) Journal reports that hundreds of explosions occur every year, resulting in millions of dollars in business interruption, facility damage, lawsuits, fines, litigation and lost market share. Conversely, smaller but more frequent production outages also cost millions in business interruption, supply chain delays, lost orders and competitiveness, yet are often accepted as a general business practice.

Combustion equipment safety should be a top priority. Safe operation of equipment is not only critical to the overall daily operation of facilities, but it's imperative for the safety of employees. Unfortunately, society and corporations tend to act only when a very large and tragic event occurs.

### A Few Numbers

Many people believe that explosions, fires or outages from fuel-fired equipment only happen to others. Only loss of life seems to make news. These stories often neglect to tell the story of poorly maintained and operated equipment. Our experience has been that little "poofs," "pops," bulging furnace walls or "pregnant boilers" are more common than many think.

The American Society of Mechanical Engineers (ASME) states that the major perils in operating automatically fired boilers are loss of water

(low water), furnace explosions, overpressure, and over temperature. The principal causes of accidents to automatically fired boilers are lack of proper controls and safety devices, lack of adequate maintenance and complacency on the part of the operator due to long periods of trouble-free operation.

Between 2002 and 2009, boiler and pressure vessel accidents killed 85 people and injured over 150.(i) This statistic does not include unreported incidents or non-boiler/pressure vessel explosion and fire statistics (i.e. ovens, furnaces, parts washers, etc.).

Moving beyond boilers and pressure vessels, major explosions and fires in the U.S. between 2009 and 2013 resulted in over \$11 billion in property damage.(ii) These figures do not include the costs of lawsuits, fines, litigation, supply chain delays, lost market share, stock devaluation and probably the most expensive: low morale.

### Broken Risk Radar?

Every day, we use a "risk radar" to evaluate life's challenges such as crossing the street or driving a car. For example, there are tremendous risks when driving a car. Not only do we have to negotiate a couple of thousand pounds of stamped steel and molded plastic from point A to point B without incident, we must make sure we stay out of the way of others. Since we cannot control all aspects, we transfer some of the unknown risks to our insurance company. The remaining risk portions are kept in our control, minimized and managed by driving at the speed limit, wearing seat belts and possibly taking a defensive driving course.

Fuels and combustion system (F&CS) risks are managed the same way. A plant will transfer some responsibility to the insurance company's boiler inspectors and property risk engineers. The remaining facility risks are managed by a culture of engineering, maintenance, safety, and training programs.

### Combustion Standards & Codes: Your Safety Guidebooks

Many corporations such as Ford Motor Company, Alcoa, General Motors, ConAgra and Johnson & Johnson are successfully managing F&CS safety by creating programs that, at a minimum, address people, equipment and policies. They have and will continue to spend millions of dollars to develop, implement and update ongoing programs.

The good news is that the heart of these People, Equipment & Policy programs are based on national combustion standards and codes. The bad news is these valuable tools, which are developed from lessons learned and even loss of life, are largely ignored. For example, when Honeywell Combustion Safety teamed up with the Association of Facility Engineers (AFE) to survey readers about their knowledge of key combustion codes, the results were alarming:

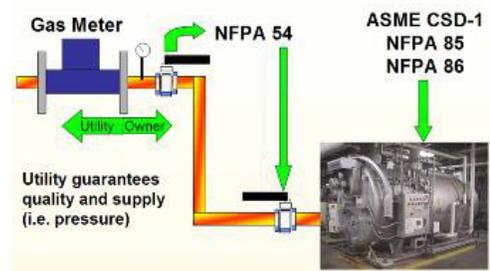
- 42% had no knowledge of codes
- 26% did not perform annually required gas valve leak testing
- 17% did not perform annually require safety interlock testing

This article addresses four key combustion standards/codes that cover boilers, furnaces and ovens or about 90% of fuel-fired equipment throughout the world. Many others address alternate fuels, electricity and fabrication requirements.

Each code is managed by an association (i.e. NFPA or ASME) and has dedicated committees with members from industry, end-users, insurance, manufacturers and trade associations. These committees are responsible for maintaining, updating and eventually gaining consensus for the final published standard. Standards are typically updated every three years. Some are adopted into law by various states and become legally enforceable codes.

#### 1. NFPA 54: National Fuel Gas Code (Current Edition: 2015)

This is a safety code that applies to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories (Exhibit 1). Coverage of piping systems extends from the point of delivery to the connections with each gas utilization device. For other than undiluted liquid propane gas (LPG) systems, the point of delivery is considered the outlet of the service meter assembly or the outlet of the service regulator or service shutoff valve where no meter is provided.



Code & Equipment Applications

#### 2. NFPA 85 : Boiler & Combustion Systems Hazards Code (Current Edition: 2015)

This code applies to single burner boilers, multiple burner boilers, stokers and atmospheric fluidized-bed boilers with a fuel input rating of 3.7 MW (12.5 million Btu/hr) or greater, to pulverized fuel systems, and to fired or unfired steam generators used to recover heat from combustion turbines. This code also covers strength of the structure, operation and maintenance procedures, combustion and draft control equipment, safety interlocks, alarms, trips, and other related controls that are essential to safe equipment operation.

#### 3. NFPA 86: Ovens and Furnaces (Current Edition: 2015)

This code applies to Class A, B, C, and D ovens, dryers and furnaces, thermal oxidizers, and any other heated enclosure used for processing of materials and related equipment.

## ABOUT US

Honeywell Combustion Safety is a part of Honeywell Thermal Solutions, an industry leader in commercial and industrial combustion solutions. Honeywell Combustion Safety, formerly known as CEC Combustion Safety, has been in business since 1984. With engineers and staff members that sit on Code committees such as NFPA 56, NFPA 85, NFPA 86, and NFPA 87, our inside expertise is integrated within all of our practices, and our global reach ensures that customers around the world are kept safe. Honeywell offers testing and inspections, engineering & upgrades/retrofits, gas hazards management, training, and field services for all industrial facilities and different types of fuel fired equipment. By assisting organizations and their personnel with the safe maintenance and operation of their combustion equipment, Honeywell aims to save lives and prevent explosions while increasing efficiency and reliability of combustion equipment.

#### 4. ASME CSD-1: Boilers up to 12.5 MMBtu/hr (Current Edition: 2015)

This code applies to single burner boilers, multiple burner boilers, stokers and atmospheric fluidized-bed boilers with a fuel input rating of below 12.5 million Btu/hr, to pulverized fuel systems, and to fired or unfired steam generators used to recover heat from combustion turbines.

The rules of this standard includes the requirements for the assembly, installation, maintenance, and operation of controls and safety devices on automatically operated boilers directly fired with gas, oil, gas-oil or electricity.

### Give Me the Cliff Notes

Each code has hundreds of pages covering the requirements for safe design, installation, operations, and maintenance of the respective equipment. The global economy, downsizing or right sizing has eliminated many engineering and maintenance personnel who could have stayed current with current codes. Table 1 highlights the basic requirements and frequencies. (iii) (iv)

Code	Equip	MMBTUH Rating	Interlock Testing	Leak Testing	Training	Maint.	Procedures
ASME CSD-1	Boilers	<12.5	A	A	R	A	R
NFPA 85	Boilers	>12.5	A	A	R	A	R
NFPA 86	Furnaces & Ovens	All	A	A	R	A	R
NFPA 54	Natural Gas Piping	N/A	R	A	N/A	A	R

A = Annually  
R = Required

Combustion Code Requirements and Frequencies

Almost everyone using combustion equipment at one time or another either has either experienced or has heard of a narrow escape or incident involving injury or the destruction of equipment. The following sections identify key milestones for each code as well as assumptions that are giving managers a false sense of security.

### Safety Interlock and Leak Testing

Fuel-fired equipment interlocks are designed for safe light-offs, operation, and shutdowns. Regular safety interlock testing and valve leak testing is required by NFPA and ASME, all insurance companies and recommended by equipment manufacturers. This performance testing evaluates the mechanical and electrical

functionality of almost 50 safety devices/interlocks on a typical natural gas and fuel oil boiler and about 35 on a typical natural gas furnace, oven or boiler. This annual testing ensures that the safety interlocks are performing as intended, have not failed or been defeated.

The codes go a long way in helping companies start or enhance testing programs by providing very specific recommendations for what constitutes a program. These items include, but are not limited to, frequencies, documentation of “as found” and “as left” conditions, repair options and documentation requirements. The rub is always finding funding and trained personnel to complete the tasks.

### Industry Trend #1: Boiler Transparency

Most organizations feel that since they have insurance and there is a current insurance sticker on their boiler, everything on the boiler – even the fuel train and other equipment components – is safe. Typical insurance policies are broken into two separate policies, a boiler and machinery policy and a fire protection policy. A boiler inspection only covers the “water side” or the pressure retaining components, effectiveness of the water treatment programs, and internals. This inspection has very little or nothing to do with reviewing or testing the functionality of the fuel train or burner components.

### Industry Trend #2: Visual Property Inspections Validate the Component Safety

The fuel train and combustion components typically fall under the property coverage. Fire protection risk engineers are charged with visually screening components. Gone are the days when insurance companies required risk engineers to test safety devices. In many cases, it has been 20 years since staff have had F&CS training. Over the years, we have heard “if it isn’t painted red” or “if it isn’t under water (i.e. sprinkler system), I don’t look at it.” These factors have produced a very small core of key combustion experts within each company who are spread very thin conducting property inspections and plan reviews, and who have little time to screen every fuel train.

Lastly, all of these reviews are visual. The engineer can identify that the component exists and is in the correct configuration but cannot tell what is really happening “under the hood.” Only safety interlock and valve leak testing can diagnose existing problems.

### It is a Critical Issue

Our teams use equipment specific checklists with over 140 points to perform consistent inspections and testing of fuel-fired equipment. The results are ranked into three major categories.

1. **Critical** – Pose immediate life safety and explosion risk
2. **Mandatory** – Required by national combustion standards and state codes
3. **Best Practice** – Good engineering practices and rules of thumb

Inspection exit meetings focus on the “critical” issue discussion. This is especially true when a company or personnel have experienced a near miss. Code deficiencies are a close second.

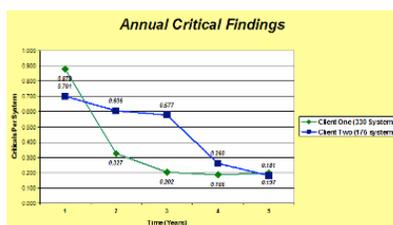
	Equip	Critical	Criticals / Equip	Service
Aluminum	379	171	0.5	Visual
Foods	43	33	1.7	Visual
Consumer Products	66	73	1.1	Testing
Packaging	35	59	1.6	Testing
Building Products	22	66	3.0	Testing
Auto Supplier	63	189	3.0	Testing
Chemical	23	96	6.9	Testing

Sample of Visual only Inspections vs. Complete Visual and Testing

A failed safety interlock or leaking valve causes 99% of all “critical” issues. For the most part, only hands-on testing of the safety devices identifies these issues. For example, using sample data from Honeywell Combustion Safety’s testing database of over 10,000 combustion systems, we compared first time inspection sites that have had only visual inspections with sites that have had complete visual inspections and interlock/leak testing. Table 2 shows that at a minimum, first time inspection sites had at least at least 1.1 failed safety devices or critical items per system. We have experienced increased critical findings as high as 150% with clients who have had our teams come back to perform interlock testing beyond a visual inspection.

### The Billion-Dollar Tip: First Time Inspections vs. Regular Programs

All fuel-fired equipment is to be checked annually by law, but with maintenance budgets among the first to be cut, proper checkouts and testing are seldom performed. Codes and manufacturers define what these frequencies are for different types of equipment. Frequencies of required testing range from daily for some items, such as observing flames, to annually for block and bleed valve tightness testing. The uneasy struggle for clients is applying limited resources to balance production and safety.



Multi-Year Program Results

Table 2 shows that industry samples have had at least 1.1 to 6.9 “criticals” per combustion system. In contrast, Exhibit 2 shows the results of multi-year programs that have driven critical findings down to .2 and .18 critical items per system. The findings are typically driven by standard lifecycle failures of components. Therefore, clients that invest in regular programs enjoy a minimum of at least 500% less combustion system risk exposure than the 1.1 first time sites. Actually, many years ago, a client experienced a catastrophic explosion with numerous deaths and injuries. This event cost them over \$1 billion dollars in lawsuits, fines, litigation, lost production and market share and became the catalyst for a multiyear program.

## Valve Leak Testing

Fuel trains help us to keep fuel out of the combustion chamber when no combustion is taking place through a series of tight, specially designed shut-off valves that are spring-loaded to close. These valves are directed to close when certain possible dangerous conditions occur. Many systems use dual valves in series and some also have a vent between them for added safety. These are the safety shut-off and blocking valves. The specific configuration that you have depends on your insurance and local code requirements.

One of the leading factors that contribute to “criticals” is leaking gas valves. These are leaks inside of the pipe and not around pipe threads or unions. Valve leak testing evaluates each manual and automatic gas valve in the closed position to determine if there is leakage and whether the leakage rate meets established performance guidelines. Yes, valves do leak.

Actually, each valve is built to a leak tightness standard and there are different standards. It is vitally important to understand the design standard used to prevent throwing away a good valve. Some valve manufacturer’s literature includes generic steps for the testing but may not include the acceptable leakage rates.

This test is commonly referred to as a “Bubble Test” as a tube is inserted into water, and based upon pipe size, the technician counts the bubbles. Other considerations include the length and diameter of a pipe to determine a timeframe when “counting bubbles.”

A large percentage of manual valves are plug valves and require a special sealant to prevent gas passage. Manual plug valves are in 65% of all facilities. Our research has identified that 60% leak through in the closed position and 10% are frozen in place. The standards/codes require annual servicing of these sealant-filled plug valves. Most facilities do not know that a specific sealant must be injected into the valve with a 10,000-PSI injection gun. Additionally, the location of many valves are unknown or inaccessible since they remain in ceiling joists.

## Industry Trend #3: Lack of Training and Procedures

Human error is the largest cause of combustion accidents, explosions, fires and outages. In the past decade, The National Board of Pressure Vessel Inspectors and NFPA have identified that 83% of boiler/pressure vessel accidents, 69% of injuries and 60% of recorded deaths were a direct result of human oversight or lack of knowledge (iii). Other leading causes include, but are not limited to:

- Human Error – improper installation, operator error, poor maintenance
- Human Nature – occasional laziness and tendency to rush tasksvi
- Reduced levels of expertise/experience vii (Portland City Schools)
- Lack of Training – this includes the basics of combustion and the equipment/components used to control combustion
- Lack of operating procedures
- Faulty, recalled, or obsolete components
- Lack of inspection and testing
- Lack of historical perspective (viii)

Reviewing high-loss industrial accidents identifies numerous causal factors that contributed to the incident. All have a human element, which can be linked to training and proper procedures.

The codes highlight recommendations for how all operating, maintenance, and supervisory personnel are trained, what should be covered (i.e. combustion, explosions hazards, sources of ignition, functions of controls, handling of fuels, operating instructions, confined space entry and lockout/tagout procedures), frequencies, record keeping and skills/knowledge validation. Additionally, codes identify the requirement for specific equipment operating instructions and information such as schematic piping and wiring diagrams, start-up/shutdown/emergency shutdown procedures and maintenance procedures, including interlock and valve tightness testing.

## Conclusion: Culture Change is Possible

The Chemical Safety Board is a government appointed, non-profit organization that investigates large industrial accidents. Most of their reports highlight companies who paid a big price by harboring ignorance of codes. This cultural complacency has been at the root of space shuttle disasters (ix), oil-refining incidents, nuclear (x), boiler and furnace explosions.

The problem with explosions, fires and near misses is that so many organizations learn hard lessons of poor combustion system and personnel management after the test has been administered. Their people are not empowered to announce a potential hazard and become paralyzed with unwarranted fears about worst-case scenarios.

Many corporations are breaking the laws of their cultures and fuel-fired equipment codes. Fuel-fired incidents continue to cost lives and reduce competitiveness. Thankfully, however, national standards and codes stand ready to lead the way.

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## For more information

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