**Session No. 518**

# Ignorance Is No Excuse – Combustion Systems Standards and Codes 101

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Many safety professionals responsible for facilities with fuel-fired equipment exist within a culture of ignorance, misunderstandings and/or denial about the impact of an explosion or fire caused by the operation of equipment such as boilers, furnaces, ovens, dryers, etc.

The National Fire Protection Association (NFPA) Journal reports that hundreds of explosions happen 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, but are often deemed to be culturally accepted as a general business practice.

Unfortunately, society and individual companies usually act only when some very large and tragic event occurs. Combustion equipment safety is critical to the daily operation of many facilities and the safety of employees. This presentation will help you understand how to protect your organization from combustion-related incidents involving fuel-fired equipment before you end up a headline.

This paper uses statistics from over 10,000 fuel-fired equipment inspections and tests to help readers weave through the basics of four combustion standards (NFPA 54, 85, 86 and ASME CSD-1) needed to dramatically reduce and/or eliminate fuel-fired factors and make safety, efficiency, reliability and continued competitiveness part of the corporate culture.

## Just a Few Numbers

Many people believe that explosions, fires or outages from fuel-fired equipment only happen to others, as if they are immune (Exhibit 1). Only loss of life seems to make the 11 o'clock news. Any headlines soon fade or rarely garner the follow-up attention required to highlight the pitfalls of poorly maintained and operated equipment. Today's corporate public relations departments are also very good at shutting down the flow of information that may leak to media. Our experiences has been that little "poofs", "pops", bulging furnace walls or "pregnant boilers" are more prevalent than not and imply that incident headlines are only the tip of the iceberg.

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

**Exhibit 1: Boiler Explosion**

Actually, between 1991 and 2002, 23,338 boiler and pressure vessel accidents have killed 127 people and injured 720.[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 just boilers and pressure vessels, major explosions and fires in the US between 1990 and 2002 have cost over $13.7 billion in property damage alone.[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. It is quite staggering to think about the true impact society absorbs with these safety and financial issues.

## Broken Risk Radar?

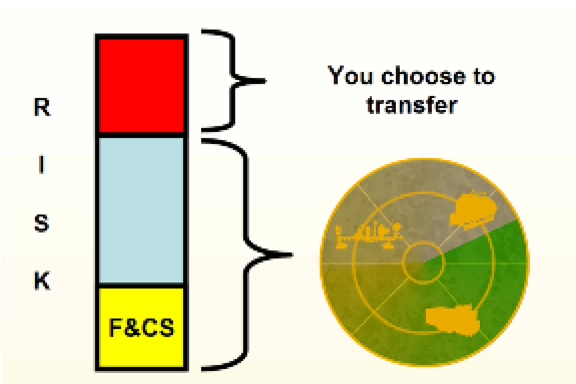


**Exhibit 2. Risk Transfer**

Every day, we all use "risk radar" (Exhibit 2) 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 maybe 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 proactive corporations such as Ford Motor Company, Alcoa, General Motors, Wyeth Pharmaceuticals and numerous others are successfully managing F&CS safety by creating programs at a minimum that 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 is found in 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, in September 2004, CEC teamed up with the Association of Facility Engineers (AFE) to survey readers about their knowledge of key combustion codes. The results were very 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 paper 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: 2006**

This code is a safety code that applies to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories (Exhibit 3). 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.

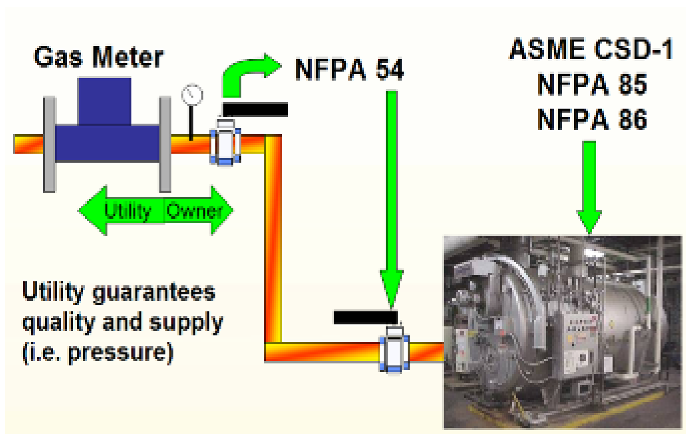


**Exhibit 3. Code & Equipment Applications**

**2. NFPA 85 – Boiler & Combustion Systems Hazards Code. Current Edition: 2007**

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: 2007**
   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.

4. **ASME CSD-1 – Boilers up to 12.5 MMBtu/hr. Current Edition: 2006**
   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**

**Table 1: Combustion Code Requirements and Frequencies**

Almost everyone using combustion equipment at one time or another either has had a narrow escape or had an 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 to 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 or all equipment, is safe. It is as if this sticker made all other fuel-fired risks within a ¼ mile go away. Typical insurance policies are broken into two separate policies, a boiler & 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 FM Global or IRI (currently Swiss Re) trained and required risk engineers to test safety devices. In many cases, it has been 20 years since many 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 doing large property inspections and plan reviews leaving little time to screen every fuel train.

Lastly, all of these reviews are visual only. 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

CEC's teams use checklists with hundreds of 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

All inspection wrap-up meetings become very focused during the "critical' issue discussion. This is especially true when a company or personnel have experienced a near miss. Code deficiencies are a close second.

A failed safety interlock or leaking valve causes 99% of all "criticals" issues. For the most part, only hands-on testing of the safety devices identifies these issues. For example, using sample data from CEC's testing database of over 10,000 combustion systems, we compared first time inspection sites that have had only visual inspections vs. 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.

| | 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 |

**Table 2: Sample of Visual only Inspections vs. Complete Visual and Testing**

<u>The Billion-Dollar Tip: First Time Inspections vs. Regular Programs</u>

All of fuel-fired equipment is to be checked on a regular basis by law (at least annually), 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 like observing flames (assuming you know what to look for), to annually for some block and bleed valve tightness testing requirements. The uneasy struggle for clients is always applying limited resources to balance production and safety.

Table 2 shows that industry samples have had at least 1.1 to 6.9 criticals per combustion system. In contrast, Exhibit 4 shows the results of multi-year programs that have driven critical findings down to .2 and .18 criticals per system. The findings become asymptotical and are typically

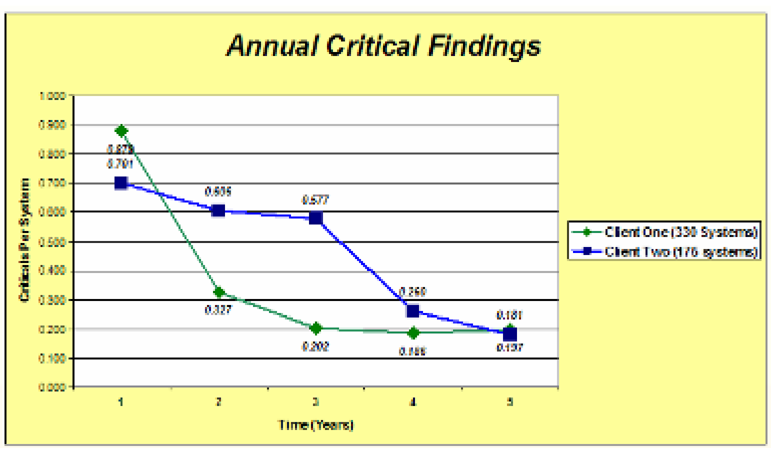


**Exhibit 4: Multi-Year Program Results**

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. This event became a catalyst for a multiyear program. This client enjoys results and return on investment similar to those in Exhibit 4.

## 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 very 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.

**Exhibit 5: Technician Performing**

This test is also called a "Bubble Test" since a tube is inserted into water and based upon pipe size the technician counts bubbles (Exhibit 5). Other considerations include the length and diameter of pipe to determine a timeframe when "counting bubbles".

A large percentage of manual valves are plug valves requiring 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 special sealant must be injected into the valve with a special 10,000-PSI injection gun. Additionally, the location of many valves are unknown or inaccessible since are in ceiling joists.

<u>Industry Trend #3: Lack of Training and Procedures</u>
By far, 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[v]. Other leading causes include, but are not limited to:

- Human Error – improper installation, operator error, poor maintenance
- Human Nature – somewhat lazy and wants to get done faster [vi]
- 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 some very large industrial accidents (Table 3) identifies numerous causal factors that contributed to the incident. All have some human element, which is all tied to proper training and procedures

**Table 3: Large Loss Incidents**

| Facility | Loss | Dead / Injured | Human Error | Equip. Failure | Lack of Training | Poor Maint | Improper Procedures | High Risk Culture |
|---|---|---|---|---|---|---|---|---|
| **Michigan Automotive/Steal Complex** | $1 Billion | 6 / 14 | X | | X | | X | X |
| **Algerian LNG** | $800 MM | 31 / 74 | ? | X | X | | X | X |
| **Kaiser Aluminum** | $300+ MM | 0 / 23 | X | X | X | X | | X |
| **Kansas City P&L** | $196 MM | 0 / 2 | | X | | X | | X |
| **Tosco Refinery** | $71 MM | 1 / 46 | X | | X | | X | X |
| **New River Casting** | $30 MM | 3 / 7 | | X | | X | | X |
| **GM Lordstown** | N/A | 1 / 0 | X | X | | X | X | X |
| **Crown Cork & Seal** | $20 MM | 0 / 1 | X | X | | X | X | X |


Once again, the very valuable and well thought out codes highlight recommended training areas 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 very 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 (CSB) is a government appointed, non-profit organization that investigates large industrial accidents**.** Most of their final reports include companies who paid a big price by allowing ignorance of codes and truly understanding their culture. This cultural complacency has been at the root of various and repeated 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 (incident) has been administered. They have personnel who 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 costs lives and the competitiveness of our country. They have lost their way but national standards and codes stand ready to help lead the way. With a lot of education, resources, tools and open minds, personnel can proactively live by the motto of: "You will never have to explain why you shut it down, but you will have to explain why you blew it up".

## References


[i] *National Board*, www.nationalboard.org/Incidents/incidents.htm, 11/30/2000.

[ii] NFPA Journal, *1999 Large-Loss Fires and Explosions*, Nov/Dec 2000

[iii] National Fire Protection Association, Inc., Quincy, MA
*NFPA 86 Standard for Ovens and Furnaces. 2007 Edition.*
*NFPA 85 Boiler and Combustion Systems Hazards Code. 2007 Edition*
*NFPA 54: National Fuel Gas Code. 2006 Edition*

[iv] American Society of Mechanical Engineers, New York, NY
ASME *CSD-1 – 2006 Controls and Safety Devices for Automatically Fired Boilers*

[v] National Board, *Ten years of Incident Reports Underscore Human Error,2000*

[vi] Process Safety Beacon, American Institute of Chemical Engineers,
www.aiche.org/ccps/safetybascon.htm, AIChe, June 2003

[vii] Murphy, Todd, Portland Tribune, *Shivering Students Become Hot Issue: Boiler Know-how Goes the Way of Laid-off School Janitors*, www.portlandtribune.com, January 17, 2003

[viii] Kletz, Trevor, *Lessons From Disaster: How Organziations Have No Memory and Accidents Recur*, Gulf Publishing Company, Houston, Texas, 1993

[ix] Reinert, Patty, Houston Chronicle, *NASA Fixing Broken Safety Culture*, Sunday, February 1, 2004

[x] Funk, John and Manges, John, The Plain Dealer, Executive Vows Strong Focus on Plant Safety; Davis-Besse Powering Back, March 9, 2004