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Process burner and combustion system hazards: 10 key issues that save lives

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Abstract

Burner and combustion safety is crucial for the safe operation of fuel-fired heaters and boilers at process industry facilities. This paper discusses 10 of the most common burner and combustion system hazards that impact the safe operation of combustion equipment. The paper includes a discussion of three burner related explosion incidents that occurred at plants and how to avoid them. Strategies are also presented for training of maintenance and operations personnel on hazard recognition and avoidance. A protocol for walking down equipment prior to light offs is also presented as an extra safety step.

Keywords: Boilers; Process heaters; Drying ovens; Thermal oxidizers

An LNG plant explosion kills 23 in Algeria and causes over $800 million in losses, another explosion at a Texas chemical plant costs $30,000,000 and the list goes on. These are only two very tragic, recent headlines. The National Fire Protection Association Journal (NFPA), reports that catastrophic fires and explosions cost billions annually. These statistics say nothing of the thousands of smaller events that occur and go unrecorded such as boiler fires, process heater failures, and the burns and injuries from these events. Unfortunately, society and individual companies usually act on these issues only when some very large and tragic event occurs. This paper hopes to provide a means of encouraging combustion equipment safety actions at your facility before it's too late. I hope to raise your awareness about this area of safety that few people know about simply because it is complicated and misunderstood. Combustion equipment safety is critical to the daily operation of all facilities and the safety of every employee. This paper will help you understand how to protect your employees from combustion-related incidents involving fuel-fired equipment (boilers, process heaters, drying ovens, thermal oxidizers), before you end up a headline.

This paper reviews three incidents that demonstrate how easy it is for a tragedy to occur. It also reviews 10 of the most common combustion equipment related issues that we find inspecting and testing fuel systems and safety interlocks on fuel fired equipment all over the world.

Before we discuss hazards let's review some of the basics of combustion equipment fuel trains and safety interlocks.

1. What keeps combustion equipment safe?

Burning fuels can be useful to humankind as long as it's with a controlled process. Control means that combustion takes place where we want it, when we want it, and at the rate we want it (Exhibit 1).

The complicated looking series of valves, wires, sensors and switches that comprise the fuel train installed on fuel-fired equipment is what attempts to do this.

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 certain possible danger conditions occur. Many systems use dual valves in series and some also have a vent between these valves 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.

Fuel trains also have a number of components that try and make sure that safe light-offs take place and that shutdowns occur immediately if anything goes wrong during the operation of the equipment. They do this with a series of pressure switches that look for too high or too low of fuel pressures being sent to the burner. They typically also have switches to make sure that airflows are correct for purging residual combustibles

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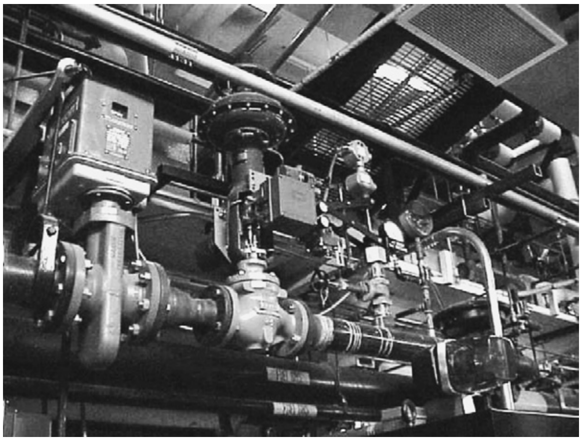


Exhibit 1. Typical fuel train with safety interlock components.

prior to light-off and that airflow is correct during operation (Exhibit 2).

Flame-sensing components also usually exist to make sure that flames are present when they are supposed to be present and not there at a wrong time (Exhibit 3).

Other components for sensing that the fuel valve is at low fire position prior to light-off may be present along with furnace pressure switches, high temperature limits, and/or water level cut-outs (depending on the type of equipment).

Exhibit 2. Typical high/low fuel pressure switches to verify fuel pressures are in the proper range.

Exhibit 3. Typical optical flame detector that monitors flame conditions.

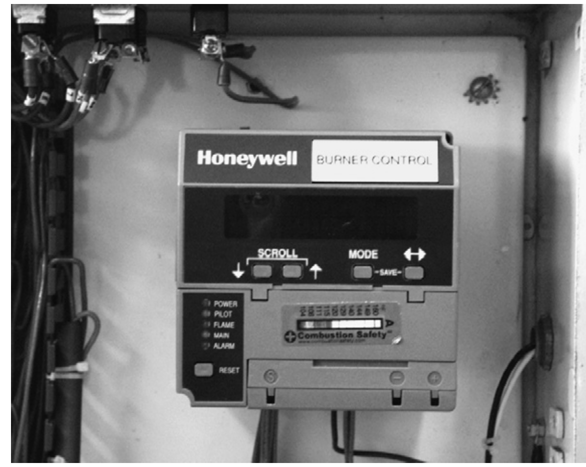


Exhibit 4. The BMS or burner management system is the brain that monitors/directs safe firing and operations.

All of these components are logically linked or interlocked to a burner management system controller, or BMS. The BMS is the brain that supervises and sequences all of the light-off efforts and sits and watches as the combustion processes take place. BMS systems can also manage the timing and adequacy of the purge prior to light-off and the time intervals allowed for getting pilots and main flames lit. The BMS systems may be a packaged single purpose device like the one shown below or it may be embedded as a part of a DCS system that controls many parameters of the units functioning (Exhibit 4).

All of this equipment is supposed 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.

Our typical circumstance is to find that no one is aware of regular testing requirements specified by codes. In most cases we find that sites do some level of testing semi-annually or annually. The level of comprehensiveness varies depending on who is in charge and that person's knowledge of the equipment or systems. It's rare to find a plant that tests everything properly.

Now that you understand something about the basics let's review three combustion related incidents and the type of havoc and destruction that can occur if even some very simple things go wrong.

1.1. Incident #1: it looks too rich? ($30,000,000 incident), but could have been much worse

This incident occurred when a fired heater unit was in operation for some time and chronically low flue gas oxygen levels were observed in a naturally drafted heater. In evaluating this, the operators decided that a field adjustment of burner dampers would be justified. A man was dispatched to attempt to manually operate dampers at each of the burners. In the course of making adjustments the control room operator also changed position on the main stack draft control damper. The result was an accumulation of fuel and combustibles in the heater that exploded when they got enough air from the damper adjustments. The explosion caused a feedstock line to break off which fed the fire in an uncontrollable manner. The fire burned for some time and finally weakened the unit's structure. The heater fell narrowly missing a major pipe rack and set of tanks.

The lessons:

1. Never add air to correct a fuel rich condition, only pull fuel.
2. Changes to any fuel air ratio problem should be done very slowly and incrementally.

1.2. Incident #2: oxygen sensor snafu!

This incident occurred while a unit was starting up. In this case a sampling line was accidentally left loose allowing air to be drawn in to an oxygen sensor instead of actual flue gas. The operators started the unit with the burner damper controls in manual. Once the unit was deemed to be successfully started they moved to put the oxygen trim system into automatic. When doing so the sampling line immediately sucked in air that had over 20% oxygen instead of the 2–6% expected. This made for the fuel valve to immediately go wide open thinking that the fuel air ratio was very lean.

The lessons:

1. Verify that critical lines are tight as part of a pre-start checklist.
2. Screen controls for a lack of features like cross tie limiting. Upgrade where necessary so that fuel and air settings can only go to predetermined values in a particular range.

1.3. The incident #3: purged, we think?

This incident occurred while starting up a unit that had been down. It was a natural draft unit that had a main fuel train along with burners for waste and auxiliary fuels. The unit had been purged for some time. However, there was then a 7 h delay before actually trying to light burners. All main fuel valves were verified to be leak free and holding. However, little attention was paid to one of the auxiliary fuel trains which allowed off gasses to be sent to the heater. In this case a manual auxiliary fuel valve was found to be leaking through while in the closed position. This valve put fuel into the firing chamber during the 7 h post-purge period. When an ignition source was finally introduced to try and light pilots a minor explosion occurred closest to the auxiliary fuel burners. Nothing was obviously damaged but a lot of nerves were frayed. This near miss was dealt with at the site as a very serious matter.

The lessons:

1. Never put considerable time between when a purge is completed and the introduction of ignition sources.
2. Always leak check all possible sources of fuel to a piece of equipment.

2. Fuel related explosions can be avoided. Here's how

These incidents are three of many. Almost everyone using combustion equipment at one time or another has either had a close call or had an incident involving injury or the destruction of equipment. We believe that many of these situations can be avoided and risks minimized by paying careful attention to 10 special combustion system areas of focus. We have developed this list through the course of inspecting and testing thousands of fuel trains on dozens of types of equipment. These issues/focus areas are as follows.

Combustion system hazards focus areas:

1. Verify that tightness testing of automatic fuel train valves is being done.
2. Verify that legally required safety interlock testing is being done annually.
3. Verify that if valves exist in instrument or level sensing lines they are not in a position to render controls ineffective.
4. Verify that safety interlock switch set points are not obviously wrong.
5. Verify that fuel system lubricated plug valves are not leaking through in the closed position and remain functional.
6. Verify that fuel train vent terminations are free and open.
7. Verify that a pre-start walk down of the equipment has occurred.
8. Verify that a proper purge has occurred and that adequate air for combustion is available.
9. Verify that no hot spots or new deformations exist.
10. Verify that personnel have been trained with mock hazard drills.

2.1. Verify that tightness testing of automatic fuel train valves is being done

(a) (b)

The photographs show evidence of valve tightness testing plugs that do not appear to have ever been removed. This is an obvious sign that the required gas train automatic valve tightness testing is not taking place.

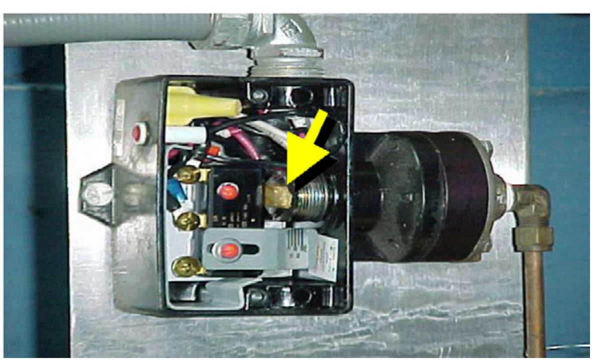
Fuel trains keep fuels out of the combustion chamber when no combustion is taking place through a series of tight closing, specially designed shut-off valves that are spring-loaded to close. These are the safety shut-off and blocking valves.

Equipment codes and laws require these valves to be tightness tested on a regular basis (at least annually according to NFPA 86).

Fuel leaking through these valves into a combustion chamber can enhance the chances of an explosion.

2.2. *Verify that legally required safety interlock testing is being done annually*

(a)



(b)

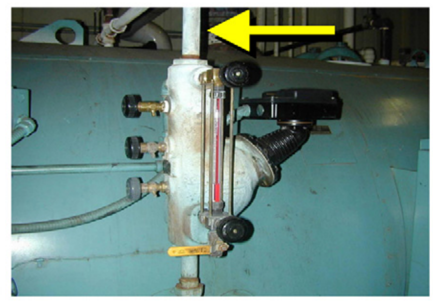
Safety interlocks include low and high gas pressure switches, air flow proving switches, flame detectors, low water cut offs, low fire position switches, low water cut offs, high steam pressure burner cut outs, and a number of other possible devices. We find about 5–10% of these to be failed every year for customers who have annual programs and 10–20% for those that may have had no regular testing program. Photograph (a) shows a typical fuel train with components that need annual testing.

In photo (b), a Popsicle stick is broken off and jammed into a failed air switch contact to hold it open. This is a very dangerous situation. Sometimes these kinds of practices can only be found through the testing of components.

If a site does not have obvious evidence of a comprehensive safety device testing program one should begin immediately. Make sure that only qualified and experienced personnel, with the proper training, attempt to do this work.

2.3. *Verify that if valves exist in instrument or level sensing lines they are not in a position to render controls ineffective*

(a)

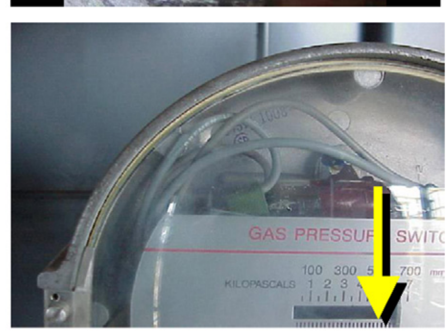


(b)

Valves in instrument or level sensing lines can be left in the closed position rendering safety related switches out of service and functionally incapable of operating. This could leave you and your equipment unprotected. If valves exist they should always be verified to be open, removed, or locked open. This especially applies to (a) high/low fuel pressure sensing lines, steam pressure switches, and water column connections.

2.4. *Verify that safety interlock switch set points are not obviously wrong*

(a)



(b)

Instruments and/or safety devices without correct set points provide little or no protection. Fuel pressure switches are shown that have set points pulled all the way to one side or the other.

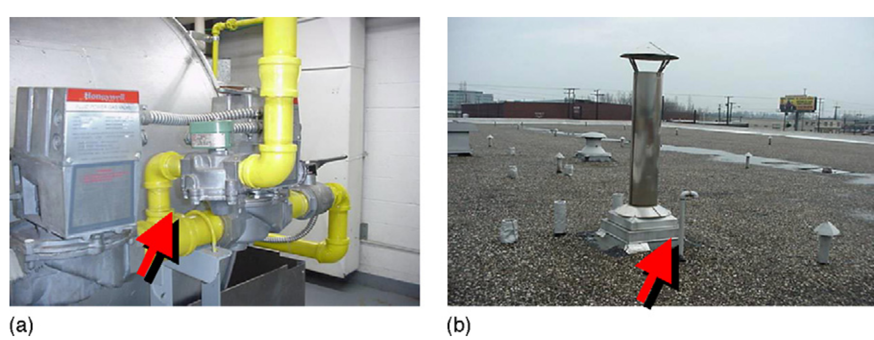
These are most likely not set correctly. Improper fuel pressures could cause flameouts and explosions.

2.5. *Verify that fuel system lubricated plug valves are not leaking through in the closed position and remain functional*

Lubricated plug valves fail a number of ways including leaking through when in the closed position and by being stuck in the open or closed positions. Inspections at hundreds of sites have found that more than 60% leaked through in the closed position. A typical plug valve showing the body, plug, and lubricant coating on the plug that makes the seal is shown (a). A seized valve that cannot be closed in an emergency is indicated in (b). Exterior stem corrosion is shown in (c). A valve that has been painted shut is shown in (e). A valve in the closed position that is leaking through the inside of the pipe downstream is indicated in (f).

Lubricated plug valves need to be properly maintained on a regular basis. This means installing the proper sealant material and making sure the valves are exercised. Servicing of these valves annually is required by NFPA 86.

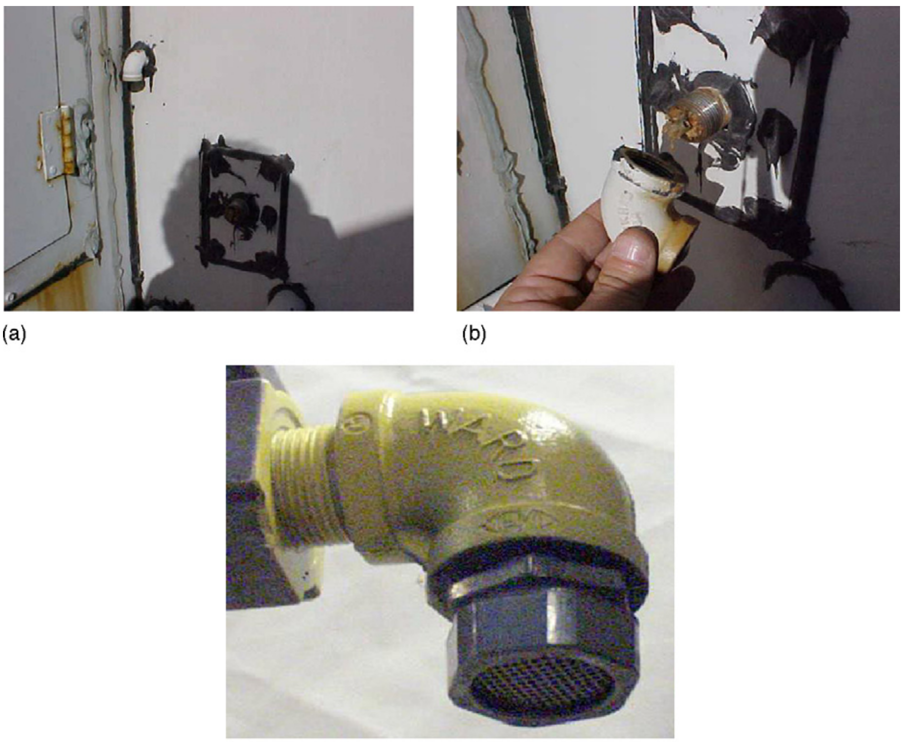
2.6. *Verify that fuel train vent terminations are free and open*



Normally open vent valves are installed in fuel trains to improve safety when equipment is off (a). They allow fuel leakage through the first automatic valve to get vented outside instead of into the firebox. When the burner tries to light they are supposed to close tight so all the fuel goes to the burner. If they are failed and leaking they can be venting fuel while the burner is trying to operate (b).

This venting can make for risks on the roof from ignition sources. It also makes for burners with unstable flames that cannot stay lit. If this happens back-up systems must recognize the loss of flame and be called upon to shut fuel off. If these fail an explosion is likely.

2.6.1. *Outside vent terminations can be blocked with insect nests*



(a) (b) (c)

Most instruments and switches are vented with pipes outside to safe locations (a) to allow for proper operation and for fuel to escape if a diaphragm failure occurs. Vent terminations are often found to be blocked with insect nests (b). A clogged vent can mean that there is no protection from leaking safety shut-off valves/blocking valves or for relieving failed components. Safety codes require protected vent terminations (c) with screening devices installed.

2.7. *Verify that a pre-start walk down of the equipment has occurred*

Many possibly dangerous issues can be identified by a walk down inspection of the equipment prior to its start up. This list of issues should be customized for every specific type of equipment. This checklist could include issues like reviewing combustion air intakes for obstructions, verifying that linkages are in place and secure, and checking fuel valves to be in the shut off position.

2.8. *Verify that a proper purge has occurred and that adequate air for combustion is available*

Combustion chambers need to have at least four fresh air changes passing though them before an ignition source is introduced. These air changes occur during each ignition sequence. This time for the purging to occur is called the purge period. In some equipment this is programmed into an automatic controller. In others an operator must initiate the purge and monitor its progress and success. It's important that air flow from fans be verified, calculations be performed for air flow volume and timing, and devices used to verify adequate flow be tested regularly. Many explosions have occurred from purge periods that are too short and or that haven't had enough flow.

2.9. *Verify that no hot spots or new deformations exist*

Hot spots on the outside of equipment mean that refractory or special panels secured for explosion relief have failed. Failed refractory and or seals could make for a burn through and structure failure. It could also mean that flue gasses are being released to the work area. Deformations such as bulges could mean that an explosion or poof had occurred. This could be evidence that a hard start has occurred and that the next start up could be tragic.

2.10. *Verify that personnel have been trained with mock hazard drills*

Training is almost always a major weakness with any client's staff. Many don't realize that training is required by most safety codes on an annual basis. Even when training is attempted it rarely contains an element of mock disaster or emergency drilling. This is an element that needs to be integrated into every operation. This kind of training means coming up with scenarios and then letting the staff describe what they would do while others listen and discuss the merits, pros and cons of the proposed actions. This is a healthy way to gain consensus and get to the right answers before an incident occurs.

3. It's a culture change!

Fuel and combustion equipment safety usually requires a major culture change. It's hard to force this kind of a change when most of the users haven't acquired a healthy respect for the awesome power of fuels. It's usually easy after a tragedy but it should never have to come to this for people to be motivated to change their ways.

In the beginning, you'll probably get a lot of the same old, "gee, we've been doing it this way for years" stories or comments like, "who says we have to do this". If you need back up for management to spend money direct them to NFPA 86 (National Fire Protection Associations) Standard for Ovens and Furnaces (NFPA 85 covers Boilers and NFPA 54 covers interconnecting fuel piping). These can all be purchased online at http://www.nfpa.org/. These are chock full of important combustion equipment safety guidelines.

The bottom line is that implementing comprehensive combustion equipment safety programs has saved lives. Our inspections and testing of over 1000 fuel trains annually usually identifies over 200 critical immediate life safety issues and thousands of code violations. The tides have now turned from aggravation and suspicion amongst some of our clients' plants to gratitude and thanks after they understand the risks and issues. Whatever the possible pain, this is one program that you need to find time for and implement before its too late.