SafetyInfo

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Safe Small Boilers Through Safety Engineering

Most buildings, including homes, have and use small boilers. Boilers used for heating homes operate around 15 psig. Commercial buildings operate around 100 psig, while small power plants operate around 250 psig. Boilers in large electric power stations may be over 100 feet tall and produce over one million pounds of steam an hour. Most boilers change water into steam. Steam can be used to heat buildings and power engines which drive steam locomotives, electric generators and propel ships. They also produce steam used for refining oil or drying paper.

A boiler is a closed vessel in which water is heated by the combustion of fuel such as gas, oil, or wood chips. The heat forms steam, hot water, or high temperature water under pressure.

Several common types of boilers found in buildings are the fire-tube Scotch marine and the water-tube cast-iron sectional boiler. They are an integral part of the building's internal utility system, providing heat and hot water. They serve industry in the generation of power and electricity. If safely designed, installed, and maintained, they provide a valuable service to society and mankind, but, on the other hand, could become a catastrophe should something go awry.

Boilers are fired pressure vessels which present a number of potential hazards. They can hold gases, vapors, liquids, and solids at various temperatures and pressures. Most furnace and boiler explosions are due to the ignition of excessive accumulation of fuel/air in the furnace combustion chambers (fire box) or ancillary areas.

Boilers, especially oil-fired ones, have caused fires in hotels, stores, apartments, and even churches. Boiler gas explosions are usually catastrophic and newsworthy. Many boilers operate unattended and are not maintained or checked regularly.

The design, fabrication, testing, and installation of boilers should be in compliance with the applicable sections of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. Section I of the code deals with power boilers, IV with heating boilers, VI with rules for care and operation of heating boilers, and VII with rules for the care of power boilers. The National Fire Protection Association's NFPA 8501 and 8502 deal with the safe design, installation, maintenance, and operation of high-pressure boilers. Boiler Inspectors-Loss Control/Safety Engineers inspect boilers to the National Board Inspection Code, which provides rules and guidelines for inspection, repair, and alteration.

Some common causes of boiler explosions are errors in design, construction, and installation; improper operation, human error, and improper operator training; corrosion or erosion of materials, mechanical breakdown, failure, or blocking of safety devices; and lack of inspections and preventive maintenance.

The pulp and paper processing industry is heavily dependent upon the use of boilers to process wood pulp into a variety of products such as paper. Large chemical and heat recovery boilers have the potential to explode, and without proper safeguards, production losses could be catastrophic. Black liquor recovery boilers present a major hazard. A violent reaction could result if water comes in contact with hot smelt. Shock waves from such a reaction could cause severe damage and injury. Fires can also occur in combustible residues in the flue gas circuit of the recovery boiler.

Power boilers used in the paper and pulp industry also have the hazards of fuel explosions and fires in the storage and handling of combustible dusts and combustible or flammable liquids.

Boiler-furnaces use controlled combustion to generate steam for power. The two basic types of boilers are water-tube and fire-tube. In water-tube boilers, water passes through tubes surrounded by hot combustion gases and is converted to steam. In fire-tube boilers, however, the hot combustion gases pass through tubes that are immersed in circulating water, which is converted to steam. Safety principles are applicable to both types of boilers.

It is essential that boiler-furnace fuels be as free as possible from contamination to ensure combustion safety. The design and reliability of fuel handling systems are very important factors in minimizing the risk of explosion and fire.

Many years ago, there occurred a boiler explosion which killed several children and injured a teacher and others. To remedy a faulty feed-water control valve and frequent low water shutoffs by the LWCO (Low Water Cutoff) switch, maintenance personnel by-passed the LWCO control. The feed-water control malfunctioned (shut off), causing a low-water condition which made the fire box red hot. The feed-water controls suddenly come on, injecting cold water into the hot fire box which turned it instantly to steam. The boiler exploded through a classroom wall killing and injuring students and the teacher.

Boilers should be inspected internally each year by a professional boiler safety engineer. The engineer should thoroughly examine metal parts for corrosion, pitting, cracking, and other defects. It is advantageous for the owner to administer a regular inspection and preventive maintenance program, as well as to keep boiler logs.

Sometimes hydrostatic tests are conducted to reveal leaks. These tests can be dangerous and should be conducted to ASME and NB Codes. The hydrostatic test pressure is 1 times the maximum allowable working pressure of the test boiler.

Boilers should be locked out or tagged out in accordance with the relevant standards when workers are inside. In one case a remote valve was inadvertently opened by another worker, resulting in a total body scalding of hot water and steam to the worker inside the boiler.

High-pressure systems can be very hazardous due to failure caused by leaks, pulsation, vibration, and overpressure. A blowout of a gauge or pipe is a potential source of severe injury and damage. These systems are subject to pulsating pressures. Internal pipe notches and scratches are stress raisers and can lead to cyclic stress fatigue failure. Leaks in these systems can also be hazardous. Usually these leaks occur around pipe welds. Pipe vibration can be reduced by installing dampeners near the bends to absorb this unwanted energy.

Boilers commonly use natural gas, LPG, and fuel oil grades 2, 4, 5, or 6 as fuel. Boiler-related safety concerns involve proper operation and maintenance, combustion controls, and safety interlocks, alarms, trips, and other features.

The basic cause of furnace explosions is the ignition of accumulated combustible gases or fuel within the boiler fire box or furnace, or its associated flue.

If there is sufficient quantity of the combustible mixture and the proportion of air to fuel is in the explosive range, ignition could generate an explosive force within the boiler. Some explosions called “furnace puff” are the result of improper procedures by operators, improper design, or malfunctioning equipment.

Some of the more common causes of boiler explosions are:

1. Loss of flame from an interruption in fuel, air, or ignition, followed by a delayed reigning of accumulated fuel;
2. Fuel leak into an idle furnace, and then ignition of this accumulated fuel;
3. Repeated unsuccessful light-offs without purging the furnace of an explosive accumulation of fuel;
4. Fuel accumulation in the furnace due to flameout, and then ignition when attempting to relight the burner.

Better instrumentation, safety interlocks and protective devices and proper operating sequences can greatly reduce the risk of furnace explosions. Any dead pockets with fuel that might exist in a boiler-furnace enclosure could explode when ignition occurs. Safe lighting and maintaining a stable flame is important to boiler safety.

When steam escapes through a break in a pipe, its energy increases 16 times due to its expansion. Cast-iron valves and fittings have fractured and been propelled due to the explosive force of steam. Sometimes piping fails due to such forces as water hammer, thermal expansion, thermal shock, or faulty material.

A boiler system design should be neat and simple with all the required safety features. Too many automatic controls could introduce more hazards.

If a boiler cuts off due to a flame failure, do not restart it until it is thoroughly purged of all fuel gases. The operator should check the boiler water level and test the low-water fuel cutoff (LWCO) daily. Safety valves and LWCOs should be tested weekly for low-pressure steam boilers, and monthly for low-pressure hot water boilers. The LWCO should be disassembled and inspected yearly. The failure of this safety control could be disastrous should it fail during a low water condition.

Fuel systems are designed for clean fuel by trapping foreign substances.

The optimum integration of manual and automatic safety features is evaluated with the consideration of each trip function.

Human error is a contributing factor in the majority of furnace explosions. Furnace explosions have also occurred due to poor functional design. The design must integrate the overall system and its controls.

Most boilers now use microprocessor-based systems which make logic decisions for the burner management system.

The combustion control system is important as it maintains pre-established air/fuel mixtures during the firing and operation.

The interlock system determines the safe operating state of the boiler within certain prescribed limits. Interlocks must be designed to withstand anticipated adverse environmental conditions of temperature, humidity, vibration, and corrosion.

The flame-safety shutdown system will stop the burner fuel flow with a four second minimum loss of flame.

The main burner gas safety shutoff valves should be periodically tested for tightness.

A safety shutdown in a gas-fuel system should occur with any of the following:

1. High or low gas pressure.
2. Loss of combustion air.
3. Loss of or failure to establish flame.
4. Loss of control system energy.
5. A power failure.
6. Low water level.
7. Excessive steam pressure.
8. Excessive water temperature.

When a safety shutdown occurs, the gas between the safety shutdown valves is vented to the atmosphere by a control signal to a reverse-acting vent pipe between the two valves. This vents any trapped gas to the outside, rather than into the fire box should any of the safety valves leak.

When a gas-fired water-tube boiler is started, the gas safety shutoff valves are closed. The fan motor comes on and dampers open to purge the furnace or firebox of any unwanted accumulated gases or fuel. When the purge is completed, the damper and fuel control valves go to the light off position. The igniter flame is proven within 10 seconds. The main flame is proven within 10 seconds. There is proper sequencing for gas and oil boilers that must be followed to assure safety. Detectors are used to supervise the igniter flame and gas or oil firing.

Inspection and maintenance is important for an effective operation of all safety and control devices. All devices should be verified by periodic testing.

Gas is colorless and can be especially hazardous where gas piping is routed through confined spaces in a building. Adequate ventilation should be provided.

Fuel oil leaks can create potential fire hazards. Fuel oils may contain abrasive, corrosive, or waxy contaminants which may clog filters, produce wear, or damage the oil-burning equipment. Strainers, fillers, traps, and pumps are used to remove harmful contaminant from oil-burning systems.

It is good practice to route piping and locate valves to minimize their exposure to physical damage and temperature extremes that may alter fuel viscosity or pressure.

Burner shutoff valves should be located as close to the burner as possible to minimize oil left in the line after a trip-out or shutdown from draining into the furnace. Positive means must be provided to prevent oil from leaking into an idle furnace or fire box. Fuel oil must be delivered to the burners at a specific temperature and pressure to ensure proper atomization and combustion. The oil-fuel train to the burner(s) usually consists of a strainer, a low fuel pressure switch, a fuel pressure gauge, main fuel and by-pass control valves, a main safety shutoff valve, a burner header low fuel pressure switch, another fuel pressure gauge, a thermometer, a check valve, and manual burner shutoff valves. The atomizing medium train has a manual shutoff valve, a strainer, a trap, a pressure regulator, a pressure gauge, check valve, and a manual burner shutoff valve.

Some other safety shutdown interlocks are U-V flame detectors, an excessive steam or hot water pressure interlock, excessive water temperature, low water cut-offs, and a combustion air interlock.

Preventive maintenance is of the utmost importance in keeping a safe boiler. This would require scheduled checks, logs, internal and external inspections, the testing of the controls (including the low water cutoff switch [LWCO] by draining the boiler down to an actual low water condition), testing the safety relief valves, checking internal corrosion of the tubes, checking for proper purging, firing, and combustion, doing frequent water analysis and chemical treatment of boiler water for proper pH, corrosion and scale inhibitors, and all other safety interlocks.

Your boiler manufacturer should be consulted for proper maintenance and inspection procedures. Some states require their own safety engineers to do periodic inspections of boilers and hot water heaters of a certain minimum capacity. Boiler operators should be properly trained in safe operation and maintenance procedures. Some states require operators to be licensed by taking an examination.

Good housekeeping is essential for safe operation and prevention of fires and explosions. Boiler and machinery rooms should be cut off from the rest of the building by code required fire-rated construction, be free of combustibles and any storage, and be clean.

Boiler water treatment is important in maintaining a safe and long boiler lifetime. The treatment should remove dissolved O_2 and CO_2 and maintain a pH basic enough to minimize corrosion. A maximum pH of 11 is usually recommended. Frequent boiler blow downs are also important in that they remove sludge and other impurities that could seriously reduce boiler efficiency and safety. This is done by using the low point boiler blow down pipe and valve. Safety valves should be kept in good working order at all times. Safety valve selection, fabrication, installation, and testing should always conform to the ASME Boiler Code.

Steam lines should be installed to facilitate maintenance which helps prevent accidents. The design, materials, fabrication, erection, testing, and inspection of piping systems should conform to the ANSI/ASME B31 series codes.

When boilers are taken out of service for any period of time, they should be properly cleaned with trisodium phosphate or equivalent and flushed to remove soot and ash which can contribute to its deterioration.

Confined space and tagout procedures should be used when entering boilers for inspections.

Post boiler operation emergency procedures in the boiler room. Someone on duty should always be trained to handle a boiler emergency.

In summary, boiler hazards can be controlled by safety devices and safe work practices. Boiler design, fabrication, testing, and installation should be in conformance with ASME Codes. Good piping practices can prevent and reduce injuries. There should be a routine schedule for boiler inspection, testing, cleaning, and maintenance. Boiler operators should be properly trained and licensed. Boiler checks and logs should be maintained. Safety devices should be properly; installed and maintained in good repair. All boiler parts should be in good working order, kept clean, and frequently inspected.

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