

Part 1 b

Safety Risks & Recommendations of Prevention Measures

in

Boilers, Fired Systems & Associated Equipment

Safety Process Risks

Explosions

Fires

Implosions

Mechanical,

Chemical,

Electrical ...

Occupational Health & Safety Risks

Furnace Pressure



Critical parameter for monitoring

Pressure in a Balanced Draft Furnace



Negative (-)

Pressure in a Pressurized Furnace



Positive (+)

Examples

Causes of High Furnace Pressure

Tripping of induced Draft Fan

Incorrect operation of regulating vanes of the fans

Unstable flame

High excess air levels

Gradual buildup of fouling in air pre-heaters

Tripping of air pre-heater

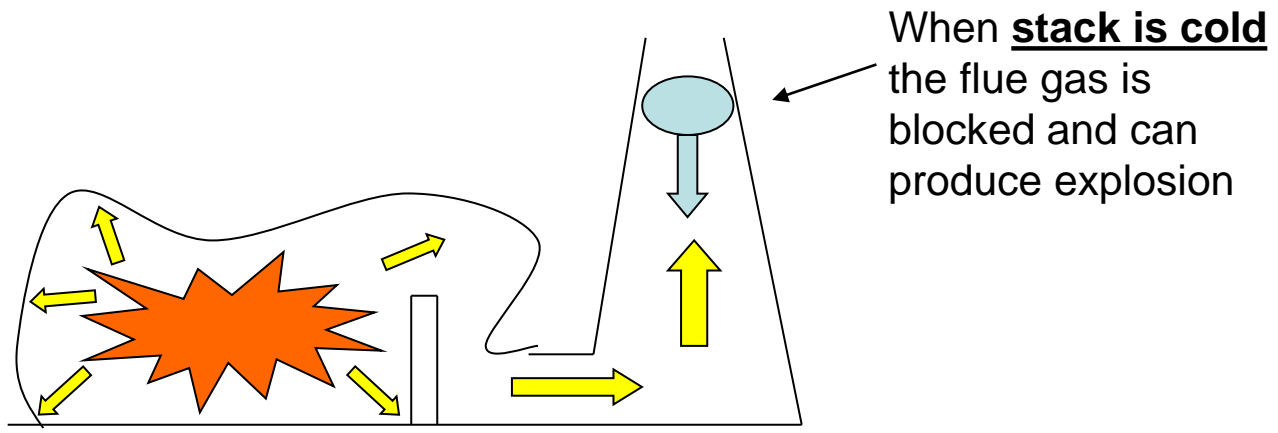
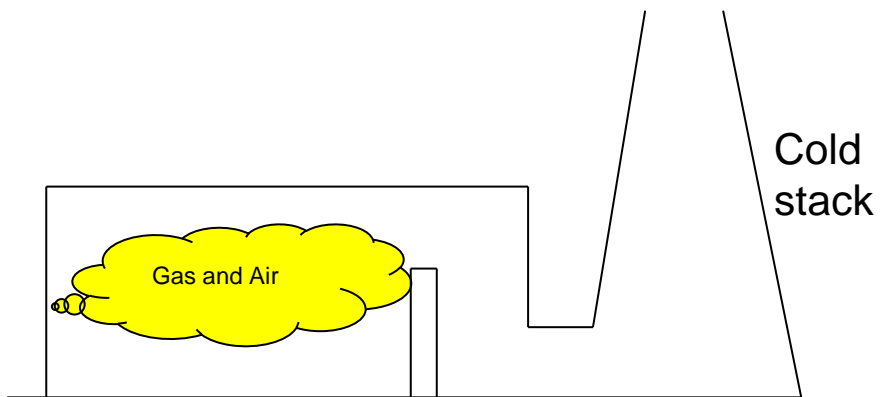
Furnace water seal is broken (Coal Fired Boilers)

Examples

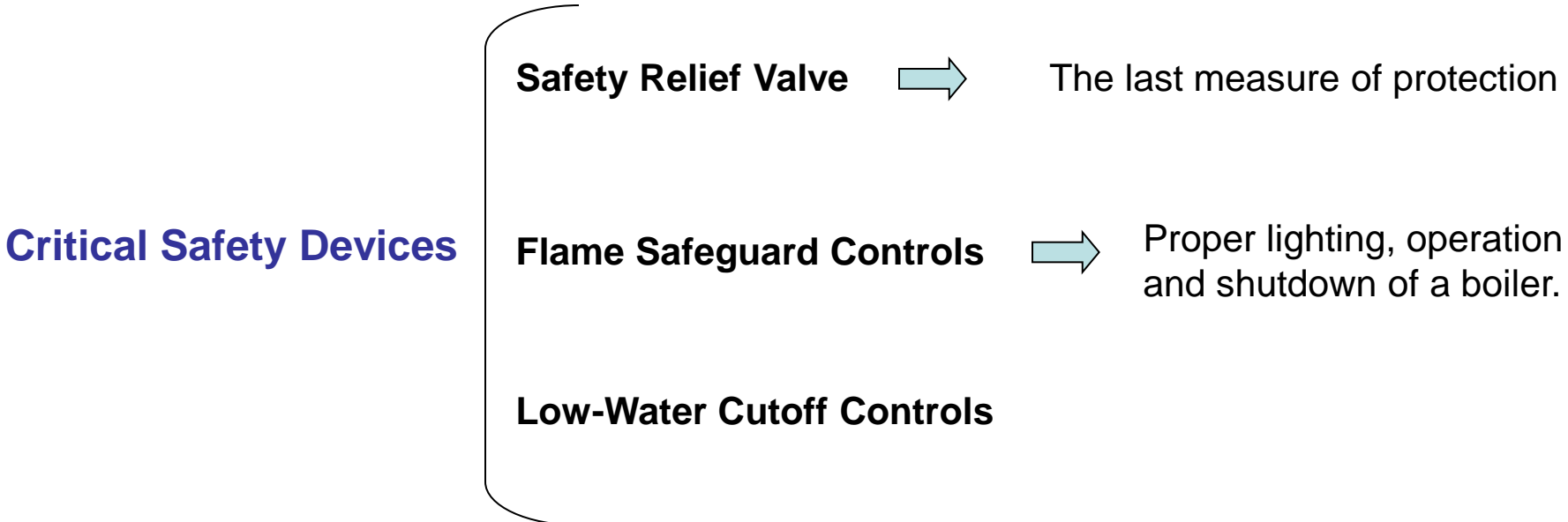
Causes of Fuel Explosions

- **Fuel-rich mixtures**
- **Operating the boiler with unstable flame**
- **Poor atomization of oil**
- **Improper purge**
- **Unsuccessful attempts to relight a burner**
- **Poor combustion and/or defective burners**
- **Unstable fuel control systems**
- **Incorrect fuel gas flow control valve settings**
- **Leaking fuel shut down valves and pipe connections**
- **Bypass safety devices with jumper wires to restart your boiler.**
- **Lack or poor of inspections and maintenance**

Lightning Burners when the Stack is Cold



Recommendations to avoid Fuel Explosions



The flame safeguard control is critical → **Its failure can be catastrophic**

Recommendations to avoid Fuel Explosions

- Automatic combustion control systems must be in good condition
- Automatic burner fuel control systems **should not** normally require manual intervention in order to avoid any type of problem
- Procedures should be in place for the start up and shut down and safe operation of boilers
- Procedures should include mitigating measures
- Always identify the cause of persistent flame failures before attempting to relight a burner
Investigating the cause of the trip before attempts to relight
- Ensure an extended purge cycle after repeated failed attempts to light up a burner so that unburned fuel vapor is dispersed from the furnace and gas passages
- Burners should be lit with oil/gas fuel at the minimum design flow rate
- A system for periodic checks of burners, fuel shut down valves, safeguarding devices and instruments should be in place

Steam Explosion

is a **violent boiling or flashing of water into steam**

Occurs when water is superheated, or rapidly heated

The water changes from a liquid to a gas with **extreme speed, increasing dramatically in volume.**

The dual liquid vapor transitional phase causes a **water hammer effect** on the internal surface of the vessel.

The combination of **rapid evaporation** and **internal shock** causes a vapor explosion of considerable magnitude.

Steam explosions are not normally chemical explosions, although a number of substances will react chemically with steam (for example, **zirconium reacts with steam** to give off **hydrogen**, which burns violently in air) so that chemical explosions and **fires may follow**

Examples

Steam Explosions

- **Low-Water Conditions**
- Poor build quality, poor of maintenance and inspection (e.g. Corrosion of critical parts of the boiler)
- Failure in safety valve
- Missing or Inoperative Controls and Safety Devices
- Ruptures, Cracks
- Fatigue (expansion and contraction very frequently)
- High stack temperatures (> 350 F)
- Constantly resetting of controllers and safety devices (Excessive pressure)
- Over pressure / Excessive Temperature
- Operators without training
- Defective steam pressure gauges.
- Bypass controls

Recommendations to avoid Steam Explosions

- Test & calibrates valves in accordance with codes and regulations
- Verify & Calibrate gauges regularly
- Replace defective gauges immediately
- Verification of water feed system periodically
- Making good maintenance practices
- Regular inspections (Internal and official)
- Verification the operation of controls periodically
- Replace or correct defective electrical wiring immediately
- Establish adequate and updated maintenance procedures
- Keep an adequate maintenance log.
- Eliminate restrictions in vent lines
- Assign maintenance responsibility
- Insist on performance of maintenance functions.

Fire Hazards

Main Fire Hazards

Flammable gases

Combustible liquids
(including lubrication oils and greases)

Main causes

Leakages around burners (Wind Box areas)

Failure of fuel lines contacting hot boiler surfaces

Other Causes of Fires

- Overheated boiler
- Boiler control malfunctions
- Boiler can cause a fire if flue pipes is near combustibles materials
- Proper clearance to combustible materials
- **Boiler rooms are often used as storage areas, increasing the risk of fire.**
- Electrical equipment (e.g. motors) / cable failures
- Electrical failure in wiring connected to furnace controls can initiate a fire
- Cable arcing / insulation failures / earth faults
- Electrical equipment that is misused or overloaded can cause fires
- **Sometimes unqualified individuals often modify electrical circuits**
- Poor housekeeping
- Fuel leaks at burner deck or fuel stations

Other Causes of Fires

- Steam line not insulated.
- Fuel oil leak on start up
- Pulverized coal (fuel) leak during in-service operations
- Hydraulic system failure
- Human Error (Failure to follow standard operating procedures, uncontrolled smoking)
- Environment (e.g. Lightning)
- Chemical (Hydrazine / chemical storages (leaks, tank failures))

Causes of Fires in Air Pre-Heaters

- Unburnt oil and soot deposits in surfaces of air pre-heater due to poor atomization of oil
- Worn-out oil burner tips produce to coarser particles of oil
- Low air flow through the burner leading to unburnt particles
 - Improper air distribution
 - Inadequate tip position with respect to diffuser or spinner
- Inadequate frequency of operation of APH Soot blowers
- Plugged Nozzles of APH Soot blowers
- Low blowing steam pressure in APH Soot blowers

Recommendations to avoid Fires

- **Appropriate Controls**

- Combustion
- Water level alarm
- Steam purity cont
- Temperature alarms
- Fuel / air mixture

- **Adequate routine inspections and good maintenance system**

- **Operating staff should**

- be trained in **first attack** fire fighting
- **work continuously (24 x 7)**
- Be trained and **competency** assessed

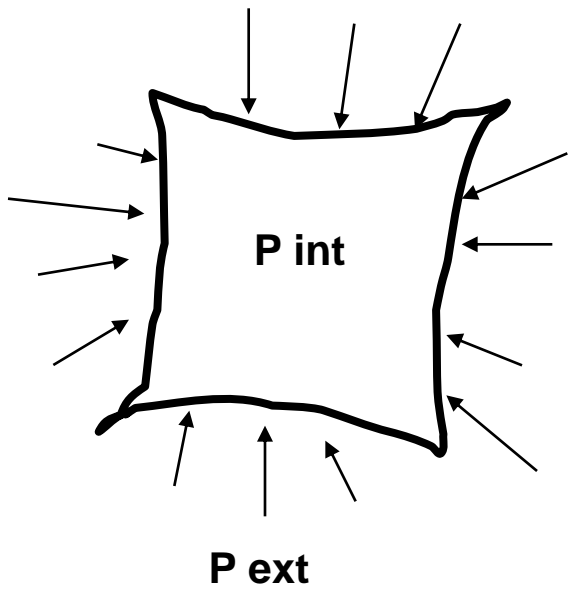
Recommendations to avoid Fires

- **Use non-sparking, explosion-proof equipment**
- **Keep all potential ignition sources away from an explosive or flammable environment.**
- **Have qualified personnel monitor** for explosive atmospheres and flammable vapors.
- **Emergency warning system** installed throughout all station areas (both audible and visual for high noise areas)
- **Portable and Permanent gas monitoring detectors**
- Remote controlled fire CCTV cameras around all Station high risk areas
- **Security plant** perimeter fencing and 24 hr security & patrols
- **Hot Work Permit System** in place
- **Automatic fire deluge** installed on all boilers/burners and hydraulic equipment (front and rear levels)
- **Adequate Fire Extinguishers, hydrants, hoses and foam making equipment**
- **Follow safe work practices** (e.g. when the operators are performing tasks associated to the agitation or release of chemicals.

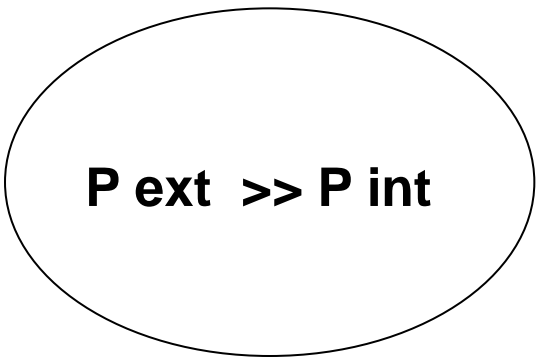
Implosions

Low Furnace Pressure can cause similar damage like furnace pressurization.

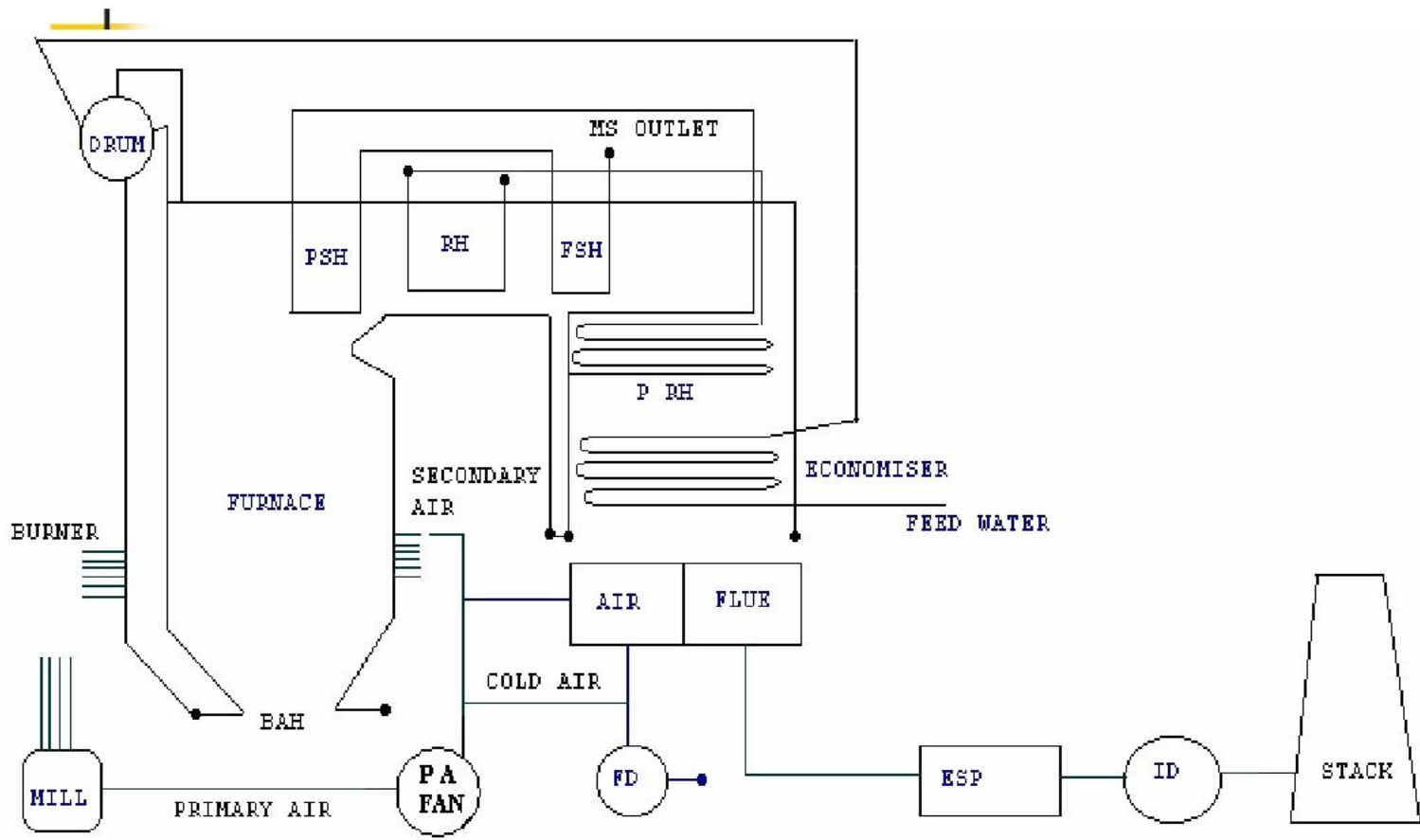
Furnace implosion  Is not a problem with the small boilers



Low pressure prevailing inside the furnace.



A risk of furnace implosion exists whenever a fan is located between the furnace and stack



Source <http://www.scribd.com/doc/48175772/boiler-fundamentals>

Causes of Implosions

- **When we have a trip (lack of fuel), the flame is extinguished and we have a rapid decrease of temperature**
- **When the flow of water is not entering to the boiler, can produce excessive overheating and then a collapse of material**
- **When is added cold water to the boiler when the water level of boiler is low (below of 50% of total volume of water)**
- **Rapid decay of furnace pressure due to sudden loss of fuel supply**
- **Induced draft fan control failure.**
- **Improper operation of dampers on unit with high static pressure induced draft fans**
- **Sudden reduction in air flow**
- **Sudden tripping of one forced draft fan, leading to a large reduction in air flow**

Recommendations to avoid Implosions

- Control of Negative Furnace Pressure is critical
- The operator should have a rapid access to see the furnace pressure to evaluate the movements of flow rates changes between the air and combustion gases
- It is recommendable to use three transmitters (to measure in independent points of in order to compare the signals)
- If there is a failure (leading to low furnace pressure) the control system should switch the induced draft fan control from auto mode to manual mode and give necessary time the operator to take the corrective action
- Check the air flow condition and ensure the correct air flow to the boiler as per the load condition.
it is very important to monitor anticipatory changes in air flow demand
- Check the induced draft fan vane control system for proper functioning by changing the set point and finding the response
- Damper regulation (Starting up and inverse situation)
- **Good Burner Management System (BMS) (Master Fuel Trip)**

Mechanical Failures & Risks

- **Welding cracks**
 - could lead to the rupture of pressure components
 - possibly death, serious injury and/or substantial property damage.

- **Abnormal operating conditions**

If the pressure of the boiler can rise beyond the control, the parts can become weak and the chance for a failure is very high

- **Safety Valves failures**

- **Tubes failures**

- Stress rupture (Stress Corrosion Cracking)
- Fatigue (Vibration)
- Water or Fire side corrosion
- Erosion
- **Lack of quality control.**

Mechanical Failures & Risks

- **Failure of structural components** due to metal fatigue
- **Escape of steam**
- **Thermal fatigue. Corrosion fatigue**
- **High-velocity water and especially water/steam mixtures cause erosion in feed water systems**
- **Over temperature**
- **Ruptures** due to poor design, defective materials, or bad welds
- **Hydrogen embrittlement**
- **Failures of Pipelines**
- **Failures in Rotating Equipment** (Feed water pump, Centrifugal Pumps,,,,,,,,)
- **Damages caused by maintenance works**
- **Mechanical Failures due to acid dew point Corrosion**
- **Failures in Ventilation System**

Recommendations to prevent Mechanical Failures & Risks

Water or Steam Leaks.

- Look for water on the floor.
- Check for water or steam escaping from any part of a pressurized system including the boiler, valves or piping.

Flue gas leaks (Fugitive Emissions)

- Look for around sheet-metal joints.
- Check any part of boiler enclosure and breaching, especially in the connection to the stack, and check the boiler exhaust system integrity

Safety Devices (inspected, tested and calibrated)

- Test all operating controls and safety devices for proper operation

Safety valves

- Ensure that a safety valve is installed with full-sized discharge piping properly supported and directed to a point of safe discharge.
- Safety valve set pressure must be equal to or less than boiler maximum allowable working pressure.
- Safety valve relieving capacity must be equal to or greater than boiler output.

Recommendations to prevent Mechanical Failures & Risks

Proper piping supports

- Check for proper supports and allowance for expansion and contraction

Regular inspection of exterior side and insulation (including refractory materials for cracks and other signs of deterioration)

Relief Safety testing and servicing program

- Relief valves should be tested and maintained at regular intervals

Adequate Maintenance Program

Wet fluorescent magnetic particle testing is recommended for identification of cracks.

Keep an efficient boiler log

- This log is useful to ensure all necessary tests, maintenance, and services are performed and that records are available.
- The records must be maintained because the information provide a historical profile of the boiler

The application of a coordinated pH/phosphate control will lessen the possibility of hydrogen embrittlement

Recommendations to prevent Mechanical Failures & Risks

Adequate training of operators

(Good integrating of operation, maintenance, quality control and safety)

Adequate Standard Operation Procedures integrated with The Occupational Health & Safety Management System

Updated and adequate Management of Change procedure

Perform regularly is inspecting and cleaning both the fire and water sides of the boiler to remove soot and scale

Appropriate Water-Treatment Program

- Important: Water contains impurities that can cause fouling of heat-transfer surfaces spot overheating of steel, corrosion, and damage to other boiler components

Boiler Blow Down

- This blow down helps maintain the concentration of chemicals in the system at the desired level.

Chemical Risks

- **Water-treating chemicals** such as hydrazine and its derivatives
- Chemicals used in the **regeneration of ion exchange columns**
- Dust in the environment containing **Refractory Oxides** , **Vanadium** or **Asbestos** from insulation repairs or maintenance works
- **Water additives**
- **Corrosion inhibitors** (various organic or metal-organic compounds)
- **Cleaning products**, derusting and descaling products and solvents
- Presence of gases such as **carbon monoxide; carbon dioxide; nitrogen oxides; sulfur dioxide; and vanadium oxide**
- **Gas welding in a confined space**, especially when heating or straightening, can cause an accumulation of nitric gases, containing dangerous nitric oxides
- **Chemical fumes**
- The boiler environment can contains **ash, dust and silica particles**

Recommendations to prevent Chemical Risks

- **The Boiler Room should have a Correct Ventilation**
- **Chemical spills response plan & procedures**
- **PPE for emergency situations**
- **PPE for normal operation & maintenance works**
- **MSDS (Updated). Easy access (Not only access by PC)**
- **Adequate portable and permanent gas detectors for gases**

Electrical Risks

Two main types

Direct contact with electricity

Formation of an electric arc

- **Exposed energized electrical wiring**

Damaged insulation
or
Lack of protective covering.

- **Open electrical boxes** (failure to cover electrical boxes)
- **Working on energized electrical equipment**
- **Improper use of tools and lights**
- **Lack of grounding**

Electrical Risks

- **Combustible dust entering the electrical equipment**
- **Wire extension cords damaged** in bad condition with abrasions, cuts, splits
- **Lightning**
- **Plug connections altered or damaged**
- **Electrical control panels front area obstructed**
- **Electrical panels breakers are not properly labeled**
- **Extension cords are used improperly** (Extension cords should be used only with portable equipment)

Recommendations to prevent Electrical Risks

**Good Lockout and
Tag out procedures**



to prevent



- Accidental start-up
- Electrical shock

- Maintain all equipment associated with electrical energy in good condition
- Use safety features like three-prong plugs, double-insulated tools, and safety switches
- Install or repair only with qualified and authorized persons
- Keep electric cables and cords in good condition and clean
- Never carry equipment by its cords
- Use extension cords only when is necessary
- Do not touch water, damp surfaces, ungrounded metal, or any bare wires if you are not protected
- Do not wear metal objects when working with electricity
- Ensure that covers are installed on over-limit switches, temperature sensors, and controls,,,,.

Occupational Health & Safety Risks

Examples of Tasks of Boiler Operators

- Operating
- Changes burners, pipes and fittings.
- Observes control panel
- Activating pumps
- Adjusting
- Measuring
- Monitoring
- Cleaning (valves, equipment, fuel tanks)
- Removing (ash, wastes...)
- Checking
- Assisting maintenance crews (Repairing / Fixing)
- Wrenching
- Sealing (leaks)
- Screwing
- Regulating (flow, temperatures, pressure, draft and other parameters)

Examples of Tasks of Boiler Operators (Cont)

- Assembling and Disassembling
- Lighting
- Regenerating (ion exchanger resins)
- Loading and Unloading (fuel, chemical products,...)
- Remove fly ash from hoppers
- Remove contaminated water from boiler systems
- Removing accumulated debris such as used rags, chemical pails and bags
- Keeps chemical lines free of residue build up
- Maintaining (insulation, etc.)
- Testing and Treating (feed water, valves, control systems equipment....)
- Assisting to Maintenance Crews in Installing equipment, instruments, etc...
- Detecting (malfunctions)

Examples of Occupational Health & Safety Risks

- Falls from ladders, stairs and elevated platforms
- Slips and falls due to presence of water and oil on floors
- Falling objects
- Burns from hot surfaces, hot water and escaping steam
- Electrocution or Electrical shocks
- Carbon monoxide Inhalation and other gases
- Asphyxia
- Splashes of chemical substances
- Contact with material in motion
- Drawing or trapping in between

Examples of Occupational Health & Safety Risks

- Punctures, cuts and amputations
- Exposure to fuels and to corrosion inhibitors can cause dermatoses
- Excessive continuous noise levels
- Vibrations
- Hot and Humid Environment
- Stress causes due to monotony, dissatisfaction at work, low salary , etc
- Heat stress caused by prolonged work at high temperatures and relative humidities
- Potential exposition to radiation (radon, etc)

Examples of Occupational Health & Safety Risks

- Exposure to specific dust, and asbestos or fly ash from the insulation can cause pneumoconiosis mainly during maintenance activities
- Exposures to asbestos may cause cancer; smoking strongly increases the risk
- General tiredness as a result of physical work in a noisy, warm and humid environment
- Cumulative trauma disorders as a result of continuous repetitive movements or big efforts
- Back pains and other musculoskeletal problems (including lesions of intervertebral discs) resulting from overexertion and wrong postures, during lifting and moving of sacks and heavy loads
- Impacts
- Struck by ejected parts of equipment
- Entanglement with equipment

Examples of Occupational Health & Safety Risks

- Burn injury due to handling cleaning of burners in furnaces
- Burn injury accident due to attending electrical faults
- Burn injury accidents due to handling of acids / alkalis
- Workers have not enough illumination at different worksites of Boiler Room
- Development of fungi and growth of bacteria in the boiler room, due to the elevated temperature and humidity
- Rodents and insects (may result in infectious diseases)
- Irritation of eyes, respiratory tract and skin as a result of exposure to chemicals, steam, hot water additives. severe exposure may cause temporary blindness
- Irritation and respiratory tract problem due to inhalation gases such as CO, CO₂, chemicals, etc.

Standards, Acts, Codes & Regulations

NFPA 8502

Standard for the Prevention of Furnace Explosions / Implosions in Multiple Burner Boilers

NFPA 8502 provides vital safety requirements for boilers firing more than one burner and with a minimum fuel input of 12.5 million BTU/hr.

It covers boilers that use pulverized coal, gas, and fuel--and is newly revised to address single fuels as well as simultaneous firing of multiple fuels.

NFPA 85

Boilers & Combustion Systems Hazard Code

Standards, Acts, Codes & Regulations

- NFPA 58** Storage and Handling of Liquefied Petroleum Gases (LPG).
- NFPA 59** Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plant.
- NFPA 59A** Production, Storage and Handling of Liquid Natural Gas (LNG).
- NFPA 69** Explosion Prevention Systems.
- NFPA 70** National Electrical Code (NEC).
- NFPA 72** National Fire Alarm Code.
- ISA S.84** Application of Safety Instrumented Systems for the Process Industries.
- IEC 61508** Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems.

Standards, Acts, Codes & Regulations

Occupational Health and Safety Code 2009 Alberta

Safety Codes Act Revised Statutes of Alberta 2000 Chapter S-1

Boilers and Pressure Vessels Act (Province of Alberta)

Pressure Equipment Safety Regulation Guide AB-516 REV. 2, 2010-05-26, ABSA

Pressure Equipment Safety Regulation Alberta 49/2006

With amendments up to and including Alberta Regulation 238/2009

Pressure Equipment Exemption Order Alberta Regulation 56/2006

This regulation explains clearly when the Safety Codes Act and the Pressure Equipment Safety Regulation do not apply to different situations

Standards, Acts, Codes & Regulations

Power Engineers Regulation 85/2003 Alberta

With amendments up to and including Alberta Regulation 270/2004
Supervision Scope of Practice Tables (AR 85/2003 Sections 2, 3 & 4)

Inspection & Servicing Requirements for In-Service Pressure Equipment AB-506 Rev 6 Issued 2009-05-29

Alberta Regulation 16/2004

With amendments up to and including Alberta Regulation 68/2008
Administrative Items Regulation Reporting Fires, Accidents and Unsafe
Conditions (Sec 8)

Standards, Canada

BOILERS AND PRESSURE VESSELS ACT, Canada

CSA B51 Boiler, Pressure Vessel, and Pressure Piping Code

CSA B52 Mechanical Refrigeration Code

CSA Z662 Oil and Gas Pipeline Systems

Standards, Acts, Codes & Regulations

ASME

Section I	Rules for Construction of Power Boilers
Section II	Materials
Section III	Rules for Construction of Nuclear Power Plant Components
Section IV	Rules for Construction of Heating Boilers
Section V	Nondestructive Examination
Section VI	Recommended Rules for Care and Operation of Heating Boilers
Section VII	Recommended Guidelines for Care of Power Boilers
Section VIII	Rules for Construction of Pressure Vessels Division 1, 2 and 3
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 Construction and Continued Service of Transport Tanks

Standards, Acts, Codes & Regulations

ASME Pressure Piping Codes

B31.1 Power Piping

B31.3 Process Piping

B31.5 Refrigeration Piping and Heat Transfer Components

B31.9 Building Services Piping

Safety & Relief Valves performance Test Codes ANSI / ASME PTC 25.3

ANSI / ISA-91.00.01-2001. Identification of Emergency Shutdown Systems that are Critical to Maintaining Safety in Process Industries.

ANSI / ISA-84.00.01-2004, Parts 1-3 (IEC 61511-1 to 3 Mod). Functional Safety: Safety Instrumented Systems for the Process Industry Sector and ISA-84.01-1996. Application of Safety Instrumented Systems for the Process Industries.

Standards, Acts, Codes & Regulations

API RP 573	Inspection of Fired Boilers and Heaters (Furnaces) used in petroleum refineries and petrochemical plants. Focused to improve equipment reliability and plant safety
API RP 572 510 (in process)	Covers the inspection of pressure vessels
API RP 576	Describes the inspection and repair practices for automatic pressure-relieving devices commonly used in the oil and petrochemical industries.
API 520	Describes the design, sizing and selection of components for pressure relief systems,
API 521	Guidelines for evaluating causes of overpressure and pressure relief systems
API RP 554-1995.	Process Instrumentation and Control.

Standards, Acts, Codes & Regulations

ANSI / API RP 754

Process Safety Performance Indicators for the Refining and Petrochemical Industries
Identifies leading and lagging process safety indicators that are useful for driving performance improvement.

ANSI / API RP 755

Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries

API RP 1112

Developing a Highway Emergency Response Plan for Incidents involving Hazardous Materials

API 770

A Manager's Guide to Reducing Human Errors- Improving Human Performance in the Process Industries

API RP 2009

Safe Welding, Cutting and Hot Work Practices in the Petroleum and Petrochemical Industries

Standards, Acts, Codes & Regulations

API 2221 Contractor and Owner Safety Program Implementation

API 2217 Guidelines for Work in Inert Confined Spaces in the
Petroleum and Petrochemical Industries

API RP 580 **Guidance on developing a risk-based inspection (RBI)**
program for fixed equipment and piping in the hydrocarbon
and chemical process industries

ANSI / API 560 Applies to fired heaters for general refinery services.
It covers the minimum requirements for their design,
materials, fabrication, inspection, testing, preparation for
shipment, and erection.

and more