•••POWER ENGINEERING

Fourth Class

Edition 3.5

Boiler Plant
Operation and Management

Part B

Unit B-4

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March 2026

A. Ojimelukwe	Rysen Jordan	Sanja Boskovic
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PanGlobal
Partner in Education
1–1339 40 Ave NE
Calgary, Alberta
T2E 8N6

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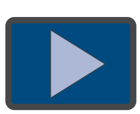
MEDIA 	Media icons show that some form of supporting medium is available. These media may include videos, animations, 2D and 3D models, multi-views of cutaways, simulations, and more. Media elements are available to registered textbook purchasers online via MyPower Study.
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4th Class Edition 3.5 • Part B

UNIT B-4

BOILER PLANT OPERATION AND MANAGEMENT

Unit Introduction

Power Engineers are specialists who operate individual pieces of equipment. More importantly, they are experts at operating the processes that integrate the various functions of plant equipment. The core of the Power Engineer's knowledge and expertise, though, is boiler plant operation.

This unit introduces the elements of boiler and auxiliary plant operation. It begins with typical preparatory steps for placing a power plant in service. It then follows the startup, routine operation, and shutdown of both heating and power boiler plants. The importance of shift handover, performing rounds, documenting conditions, and safety is stressed throughout. As well, this unit performs a detailed examination of how to recognize and respond to various adverse conditions that arise on occasion.

The processes and procedures discussed in this unit form the core Power Engineer duties and responsibilities. Before studying this unit, a firm knowledge of boiler parts, fittings, pumps, fans, combustion controls, fuel systems, and control systems is required.

Unit Rationale

Novice Power Engineers often feel unprepared to take on the responsibilities demanded of them in plants where they are newly employed. It can be a harrowing experience the first time a Power Engineer starts an unfamiliar boiler, cuts a boiler into a pressurized header, or performs a try lever test. This unit presents newly minted Engineers the information they need to deal with these situations safely and responsibly.

The topics in this unit cover most typical steam and hot water power plants. While general in nature, the operating situations presented in this unit address circumstances common to power plants of various capacities, operating pressures, and applications. This unit provides an invaluable knowledge resource that Power Engineers will want to refer back to throughout their careers.

Chapter 1

Boiler Plant Startup

Learning Outcome

When you complete this chapter you should be able to:

Describe the operational procedures related to starting up auxiliary equipment in a boiler plant.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the basic auxiliaries that need to be checked, prepared, or placed in service before starting a boiler plant.*
2. *Describe the general procedures for starting a plant for the first time, or restarting after an outage or turnaround.*
3. *Discuss basic operating practices for starting pumps and fans.*
4. *Describe the general preparation for a hot water boiler startup.*
5. *Describe the general preparation for a steam boiler startup.*
6. *Describe the safety and housekeeping preparation requirements for boiler plant startup.*

Chapter Introduction

A boiler must be carefully and properly prepared for startup. Preparation is a step-by-step process. Each plant will have its own procedures based on the role the steam system plays in that plant. It is important to note that the boiler and steam system are often prepared and started before the process units in a large plant. Many of the other processes depend on the steam system for their own startup, or for ongoing energy supply. If something has been overlooked in boiler preparation, it may mean costly downtime later on.

Boiler preparation procedures will also vary depending on the reason for the boiler shutdown. Obviously, it takes more steps to prepare a newly constructed and commissioned boiler than it does for one that was shut down overnight to replace a leaking fitting. This chapter will look at some general considerations that apply to either new boilers, or those that have undergone extensive maintenance work. The steps and procedures in this chapter assume that:

- All safety systems and devices on the boiler, such as low-level switches and safety valves, were verified as operational during the commissioning period.
- The boiler, external piping, and fittings have been checked for leaks.
- The boiler has a valid inspection certificate. If not, the chief engineer will need to contact the local boiler inspector and make appropriate arrangements.

This chapter will focus on common operational tasks performed on boiler plants being brought online for the first time, or that have recently come out of a maintenance outage, such as:

- Operation of boiler plant auxiliaries
- Safety and housekeeping
- Concerns specific to new or recently maintained boilers
- Operating good practices
- Preparing for a hot water boiler start
- Preparing for a steam boiler start

Prior knowledge of boilers, fuels, valves, pumps, and basic instrumentation will help the learner frame the tasks that will be discussed in this chapter.

Objective 1

Describe the basic auxiliaries that need to be checked, prepared, or placed in service before starting a boiler plant.

In preparing to start any type of boiler plant, there are a number of auxiliaries that must be proven operational before proceeding. All boiler plants have feedwater, fuel, and combustion air systems. This objective covers the critical elements that must be placed in service prior to lighting the boiler, or to be ready for service as the boiler is started.

Feedwater

Confirm the readiness of the feedwater system.

1. Check all the valves in the water line from the source, and manually verify that they are open.
2. Ensure bypass valves around automatic control valves are closed.
3. Ensure that feedwater pre-treatment equipment is in service and functional. Such equipment may include ion exchangers, water softeners, filters, or clarifiers.
4. Confirm that the raw and treated water tanks are at their proper levels.
5. Ensure that the deaerator level is at set point, and that all the corresponding valves are positioned for service.
6. Verify that the boiler feedwater pumps are in service, and that all operating parameters are within range. The parameters include oil level, temperature, and vibrations.
7. Confirm that the boiler water level is within range.

Fuel

Power Engineers will regularly encounter two main fuel types, and should be familiar with them. Both fuel oil and natural gas are common in many plants today. Each type has its own handling requirements.

1. Verify that all necessary valves in the main and pilot fuel supply systems are open.
2. Verify that the oil is at the correct temperature and pressure, or that the gas is at the correct pressure.
3. Ensure the main gas cock and other related valves are in their proper positions to initiate the startup ignition sequence.

Natural Gas

Check the natural gas lines, starting at each burner. This should include positioning, or verifying the position of each valve in the train. In this scenario, most manual valves should be open to provide alignment for a proper boiler start.

A typical gas train is shown in Figure 1. This gas train configuration will be similar to what 4th Class Engineers will operate in 4th and 3rd class plants.

Side Track

Gas trains vary in configuration based on the:

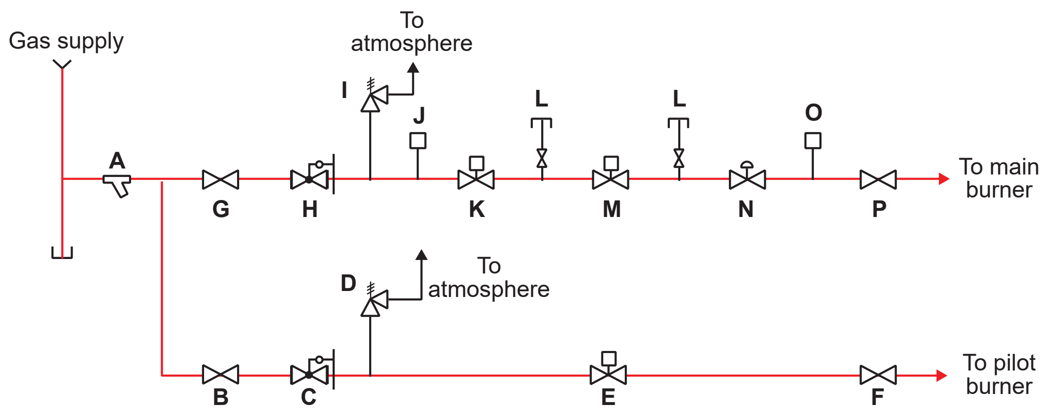
- Gas pressure supply
- Gas pressure the burner requires
- Amount of gas the burner is designed to burn

The number and location of safety devices varies as burners become larger and more complex. These devices include safety shut-off valves, manual valves, limit switches, bleed valves, and relief valves. The complexity of fuel trains therefore increases as boilers become higher in capacity. The increase in complexity is necessary to make larger burners as safe as their smaller counterparts.

For startup, the following valves must be opened:

- Emergency isolation valve at the gas service entrance (not shown)
- Boiler isolating valve (in the case of multiple boilers – not shown)
- Main burner manual isolation valve (G)
- Main burner **test firing valve** (P)
- Pilot gas manual isolation valve (B)
- Pilot burner test firing valve (F)

Figure 1 – Typical Gas Train for Boilers from 1200 kW to 3000 kW (120 BoHP to 300 BoHP) Output



A	= Fuel strainer	I	= Main burner gas pressure relief valve
B	= Pilot gas manual isolation valve	J	= Low gas pressure cut-off switch
C	= Pilot gas pressure regulator	K	= Main burner safety shut-off valve
D	= Pilot gas pressure relief valve	L	= Pressure test ports
E	= Pilot burner safety shut-off valve	M	= Main burner safety shut-off valve
F	= Pilot burner test firing valve	N	= Main burner firing rate control valve
G	= Main burner manual isolation valve	O	= High gas pressure cut-off switch
H	= Main burner gas pressure regulator	P	= Main burner test firing valve

During the checks, pressures should be noted at each pressure reducing station to ensure the correct delivery pressure range is achieved.

CAUTION

It is important to be aware of any unusual smells while putting a natural gas line in service. Natural gas is colourless and odourless; therefore, a chemical compound called mercaptan is added to the gas so that it is easier to detect a leak. Mercaptan smells strongly of sulfur and is often described as the smell of rotten eggs. If a leak is detected, it is important to quickly isolate the leak, and inform the supervisor.

Fuel Oil

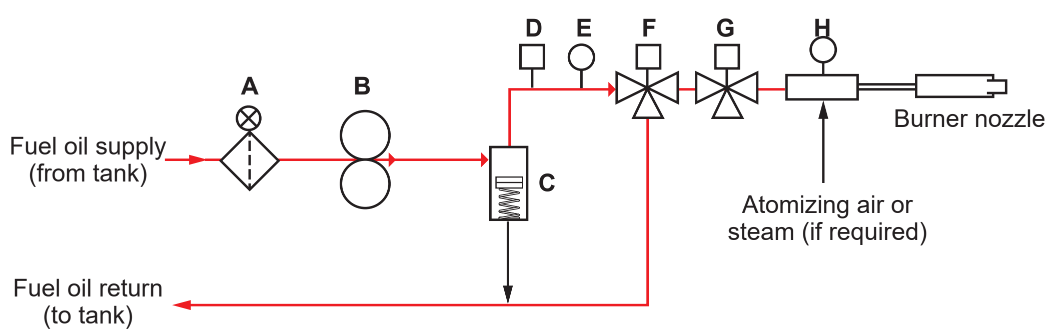
Pre-start checks of a fuel oil system should include a comprehensive tour (also called a **walk down**) of the oil storage and delivery system, all the way from the supply oil tank (tank farm or pipeline) to the burner. The walk down should include positioning, or verifying the position of each valve in the fuel train. In this scenario, most manual valves should be open to provide the proper line-up for a boiler start.

At the fuel oil supply tank, it is important to check that the fuel tank has a sufficient level to meet the needs of the plant.

On Track

For a boiler plant fired on heavy fuel oil, the temperature of the oil must be raised to approximately 55°C before it can be circulated. The temperature must be raised further, to approximately 95°C, before it can be atomized and burned. As such, accurate temperature monitoring and control must be maintained. This topic is covered in more detail in other chapters.

Figure 2 – Typical Oil Train for Boilers up to 3000 kW (300 BoHP) Output



A = Fuel filter
B = Fuel pump
C = Shutoff valve and/or pressure relief valve
D = Low oil temperature cut-off switch
E = Low oil pressure cut-off switch
F = Safety shut-off valve
G = Safety shut-off valve
H = Low atomizing media pressure cut-off switch

Verify that all valves are in the correct startup position. Then, start the fuel oil system. Referring to Figure 2:

1. Start the fuel pump.
2. Check the pressure drop across the fuel filter. If the drop is excessive, the fuel filter may need servicing. If there is no pressure drop, oil may not be flowing. Confirm that fuel oil flow is within range.

3. Confirm fuel oil supply pressure is within range.
4. Reset the low oil pressure, low oil temperature, and low atomizing media pressure cut-off switches.
5. Inspect each piece of equipment for expected operation. Typical equipment includes:
   - Fuel filters
   - Fuel supply pumps
   - Fuel supply valves
   - Fuel recirculation valves
   - Pressure control valves
   - Fuel supply pressure (suction and discharge)
   - Fuel heaters (for heavy fuel oils)
   - Fuel supply temperature (for heavy fuel oils)
6. Walk down the fuel oil supply system to check for leaks.
   - While placing a fuel oil system in service, it is imperative to check the system for leaks.
   - If leaks are found, stop and isolate the fuel supply pumps. Lockout, tagout, and drain the affected parts of the fuel supply system. Repair leaks by tightening fittings or replacing defective fittings. NOTE: Oil leaks must be cleaned up and collection pans put in place to prevent environmental release.

Note that Figure 2 does not show the oil burner ignition system. If an oil-fired boiler is ignited with a propane or natural gas pilot, follow the steps for preparing a pilot gas burner.

Combustion Air

Before starting the fan, check for adequate lubricant in the bearings. If it is belt driven, check the belt for cracks or fraying, and replace as necessary. Stroke the air dampers to make sure they are free to move their full range. Ensure there is an adequate supply of air available. If the boiler draws air from inside the boiler room, make sure the **combustion air openings** to the outdoors are unobstructed. Verify that any screens at the outside air entrance are clean, and are not covered with frost.

If the combustion air opening is equipped with dampers, ensure the dampers are secured in the fully open position. If the dampers are automatically operated, ensure that they operate correctly across their range. In either case, the dampers must be interlocked with the burner system so that the boiler cannot fire with the combustion air dampers shut, or even partially closed.

If the boiler draws air directly from outdoors (as in the case of a **sealed combustion system**), check that the air intake openings are unobstructed. If equipped with screens, ensure they are clean and free of frost. This point is especially important in winter when frost can entirely block the combustion air flow.

Check the lubrication system for the fan bearings and motors. Ensure no debris or tools have been left on or near the fan openings, or the fan damper actuator.

Start the draft fan (or fans). Check the furnace pressure, and adjust into range if necessary.

After the fan has started, check for vibration in the motor and bearings. Listen for unusual noises, and confirm the bearings do not run hot.

Objective 2

Describe the general procedures for starting a plant for the first time, or restarting after an outage or turnaround.

When starting a boiler plant for the first time, or after a major outage, the Power Engineer may need to address concerns not regularly seen. The Power Engineer must take extra precautions, and perform operational testing on all safety and control devices. This objective covers the major tasks that must be performed as a new boiler, or one that has been shutdown, is being brought online.

Boiler

Boiler Proper

Before closing up the boiler, it must be inspected both internally and externally. The internal inspection is done to make certain it is free from scale, oil, tools, debris, and other foreign material. In particular, if furnace refractory work has been done, it is important to make sure all debris has been removed from inside the boiler.

All internal baffles should be checked to confirm they are secure, particularly if they are steam drum internals. If maintenance has been done on the water side of a watertube boiler, all tools taken into the boiler should be checked off as removed, to ensure that nothing has fallen into a water tube. Check that the burners are clean and ready for firing. Check that the soot blowers are properly aligned and move freely.

Following these steps, the boiler can be closed up. New handhole and manhole gaskets must be used. Some gaskets should be coated with a graphite paste to prevent them from sticking to the metal. This coating will make them easier to remove the next time the boiler is shut down. Other gasket manufacturers recommend the gaskets be installed without any coating. Check the gasket manufacturer's recommendations for gasket coating and torque specifications. Careful gasket installation will prevent dangerous blowouts and costly unplanned boiler outages.

Ensure that all work permits have been surrendered, and that all lockout tags have been removed. Before filling the boiler, verify that the blowoff valves are closed, and the vent valve is open, so that air may escape from the boiler as it is filling. Ensure the water added is soft, deaerated, and chemically treated as appropriate.

Refractory Dry-Out

If new refractory has been installed in the furnace, it needs to be slowly dried out before raising the furnace to normal operating temperature. Castable and plastic types of refractory contain water when newly installed. If the water does not evaporate, it becomes trapped behind the refractory as it cures. When the furnace is at normal temperature, the trapped water evaporates. This will create internal pressure in the new refractory, and damage it.

Drying is done by firing the boiler at the lowest firing rate. At times, even a low fire can damage new refractory. In this case, the boiler is fired on low fire for a specified period of time, and then turned off for a period of time. This pattern is repeated over several hours, or even days, until the refractory is dry and cured. Often, a refractory specialist is consulted to determine the best method of drying the refractory. By consulting a specialist and drying the refractory slowly, the refractory will not sustain damage.

Before starting the dry-out, fill the boiler to the normal level with soft, chemically treated, and deaerated water. Leave a drum vent open to prevent pressure buildup while the boiler is firing. Next, ensure that the furnace has been adequately purged. Maintain the water level by replacing any water that leaves the drum due to the heating process.

Boiler Boil Out

If the boiler is new, it will have to be boiled out. The **boil out** removes all the grease, welding debris, dirt, and oil from construction. If this step is not taken, the boiler will experience major water level control problems when started up, as the greases and oils contribute to foaming conditions. In addition, important sensing lines for instruments and gauge glasses can get plugged. In extreme cases, the accumulation of debris in one area of the boiler could impede water circulation enough to cause overheating and tube failure.

The boiler is cleaned by adding detergent type chemicals to the boiler water, heating the water, and then periodically blowing down to dislodge dirt and remove sludge. On large units, the process may be repeated several times over a period of days. The chemicals used are types of alkaline solutions, including:

- Soda ash
- Caustic soda
- Trisodium phosphate
- Sodium silicate

The amount of each chemical used varies with the overall cleaning program. An experienced water treatment specialist should be consulted to assist with the boil out.

New boilers may be boiled-out and have their refractory dried-out at the same time.

Safety and Controls

During the initial firing of a new boiler, or one that is coming out of an extended outage, the safety devices and control systems must be tested as the boiler is coming online. This includes safety valves, safety devices, combustion controls, and operating controls. The following is a brief description of the tests that should take place. More test details are covered in other chapters.

Safety Valves

Safety valves must be tested when firing a boiler for the first time, or when bringing a boiler back online after a maintenance outage. As the steam pressure rises, two tests must be performed to verify operation of each safety valve on the boiler:

- Try lever test
- Pop test

These tests are described in detail in **Chapter 4 Operational Checks**.

Side Track

Testing of safety valves must be done with the utmost diligence. The safety valve is a critical fitting on any boiler. More details on testing safety valves can be found in the **ASME Academic Extract.**

Combustion Safeguard Controls

Combustion controls must be tested before the boiler is initially fired, or if it has been out of service for a prolonged period of time. It is recommended that the combustion controls be given a **dry run** before placing the fuel and air systems into service. The dry run ensures that the fan dampers, fan speeds, firing rate control valves, safety shut-off valves, ignition transformer, airflow proving switches, flame sensors, and fuel pressure cut-off switches operate correctly.

CAUTION

In the event of a burner management system malfunction, a furnace explosion could occur. Therefore, a thorough check of the burner safeguard controls must be performed. Only an experienced operator or a licensed gas/oil fitter should perform the work. The person performing the work must also be familiar with the equipment.

The following is a general dry run procedure for a mechanical draft boiler between 1200 and 3000 kW capacity, equipped with both pilot and main burners, as shown in Figure 1. When actually performing the dry run, ensure that the manufacturer's procedures are followed.

For a dry run, shut the main burner and pilot burner test firing valves, and observe the operation of the burner management system. With the manual fuel valves shut, there is no danger of delayed fuel ignition and furnace explosion.

To test the ignition sequence, make sure that the burner management system operates as follows:

1. **Pre-purge** period
   a) Draft fans are at high speed, if fans are variable speed
   b) Air dampers are fully open
   c) Purge is proper duration
2. **Low fire start** period
   a) Draft fans are at low speed, if fans are variable speed
   b) Air dampers are at minimum position
   c) Main burner firing rate control valve is at minimum position
3. **Pilot trial for ignition** period
   a) Ignition transformer on, and spark is robust
   b) Pilot SSOV opens
   c) No pilot flame is observed
   d) Main flame SSOV does not open
   e) Burner management system displays zero flame signal
   f) A safety shutdown and lockout occurs within 4 seconds
4. **Post-purge** period.

If the ignition sequence is correct, the pilot test firing valve can be opened, and the boiler restarted. On restart, observe that:

5. The pilot flame is established at the proper stage in the ignition sequence. Make sure the pilot flame is the correct size, shape, and colour, so it is capable of lighting the main flame.
6. The main burner safety shut-off valves open, and attempts to ignite the main burner.
7. The burner management system display shows zero flame signal.
8. A safety shutdown and lockout occurs within 4 seconds.
9. The boiler enters a post-purge period.

After successfully completing these two cycles of testing, the main burner test firing valve can be opened, and the boiler restarted. A successful combustion safeguard test proves that the burner management system can manage the ignition, and detect the pilot and main flames. After establishing a main flame, other safety limits can be checked.

Safety Devices

Safety devices monitor for safe operating conditions during boiler operation, and may also be **pre-ignition interlocks** (**permissives**). Testing of the following devices should be completed as soon as boiler conditions permit.

a) **Low water cut-off** (all boilers). Run the test prior to firing to prove it functions as a permissive. Test again, once operating conditions permit, to prove that it will trip the boiler in a low water condition.

b) **High steam pressure cut-out** (high limit control – steam boilers). This test proves that the boiler will trip once the high steam pressure set point has been reached.

c) **High water temperature cut-out** (high limit control – hot water boilers). This test proves that the boiler will trip once the high water temperature set point has been reached.

d) **Low water flow cut-off** (forced-flow hot water boilers). This test proves that the boiler will trip when the hot water flow is inadequate to protect the boiler against overheating and failure of the heat exchanger. This switch is also a firing permissive.

e) **High and low gas pressure cut-offs** (for boilers fired on natural gas or propane). Test these switches to prove they will cause the main and pilot safety shut-off valves to close, and make the boiler trip. These switches are also firing permissives.

f) **Low oil pressure cut-off switch** (for boilers fired on fuel oil). Test this switch to prove it will cause the main fuel safety shut-off valve to close, and make the boiler trip. This switch is also a firing permissive.

g) **Combustion air proving switch** (mechanical draft boilers). This test proves the boiler will trip upon loss of a fan. Also, this switch is a permissive to prevent fuel valves from opening if there is insufficient windbox pressure.

h) **Low atomizing media pressure cut-off switch** (for boilers fired on fuel oil). This test proves the boiler will trip upon loss of atomizing air or steam.

i) **Flame safeguard.** These flame detection devices monitor for flame in the boiler furnace. This test proves that the boiler safety shutoff valves will close upon loss of flame, and cause a boiler trip.

Side Track

Unit 3 provides more description of the function, construction, and purpose of boiler safety devices and burner management systems. **Part B, Unit 4, Chapter 4 Operational Checks** covers these tests in greater detail. Study these other chapters to ensure familiarity with all boiler safety devices.

Objective 3

Discuss basic operating practices for starting pumps and fans.

Becoming a competent Power Engineer includes learning good behaviours and practices early on. Good work practices become good habits. This objective will introduce some of the fundamental expectations of Power Engineers operating in the field.

Basic Operating Skills

Listed below are a number of operating skills that a Power Engineer must learn. These skills must be in practice, at all times, while operating equipment in a boiler plant.

Starting a Pump

Before starting a pump, check that:

a) All valves are correctly positioned (open or shut)
b) Lubricating oil level and supply is adequate
c) Pump is primed and ready to go
d) Feed tank and suction lines are full
e) Discharge tank and pipe are ready for fluids

Before starting a pump, know what the normal operating ranges are, so they can be compared to the actual running parameters. Typical parameters that are observed upon starting a pump include:

- Discharge pressure
- Suction pressure
- Flow
- Noise
- Vibration
- Lubrication
- Bearing temperature

Once the pump has started, check the above parameters to verify they are in acceptable range.

Starting a Fan

Before starting a fan, verify the following:

- Belt condition
- Belt tension
- Lubrication oil level and supply
- Confirm the fan is not **windmilling** (spinning backwards)
- Intake screen differential pressure

Typical parameters observed upon starting a fan include:

- Fan discharge pressure
- Airflow
- Damper position
- Noise
- Vibration
- Lubrication
- Bearing temperature

General Operating Behaviours

Whenever any action is taken in a boiler plant, the Power Engineer should always know the expected result. A boiler plant is not the place for guesswork.

Whenever taking an action, such as starting equipment, use care, no matter how many times the task has been performed in the past. The Power Engineer should never turn on a piece of equipment and walk away. Always check the equipment to confirm the expected results.

When checking motors, such as those serving as pump or fan drivers, always check for heating and vibration using the back of the hand, never the palm. In the case of electric shock, muscles contract. Using the back of the hand will prevent the hand from gripping the equipment.

When checking any rotating equipment, be mindful of body position. Ensure that there are no dangling items, such as loose clothing, jewelry, lanyards, etc., that may get caught in a rotating element. It is also important to always walk around rotating equipment. ***Never*** step over a rotating shaft.

A common expression used to help Power Engineers maintain focus is to follow the STAR principle.

S	Stop
T	Think
A	Act
R	Review

S - Stop

Stop before taking any action; pay attention to the task at hand.

T – Think

Review the expected outcome of the action. What is supposed to happen after taking the action? Ensure the conditions that were planned for have not changed. Confirm the action is taking place on the correct piece of equipment (e.g., pump #1 instead of pump #2).

A – Act

Take the correct action on the correct piece of equipment (e.g., turn on pump #1).

R – Review

Verify that the desired action took place (e.g., pump #1 started, and the discharge pressure was in the expected range). Confirm that what happened was the expected outcome.

Objective 4

Describe the general preparation for a hot water boiler startup.

This learning objective will explain the general guidelines that should be followed when preparing to start any hot water boiler. Consult plant guidelines, standard operating procedures, and the equipment manufacturer's recommendations for startup and operation.

These preparatory steps will be referred to by other related chapters.

Preparation for Startup

Before starting up a new boiler, or putting one into operation that has been shutdown for a prolonged time, there are a few points that should be observed.

1. Make sure the boiler has a valid inspection certificate. Ensure that it has been properly checked over, cleaned, filled with water, closed and tightened up, and that all auxiliary water and fuel systems have been prepared.
2. Review the manufacturer's recommendations for the startup of the boiler.
3. Check the altitude gauge on the boiler. Verify that the system is under the minimum static pressure required to maintain a positive pressure at the highest point in the system during operation. If the boiler is equipped with a combination altitude pressure gauge, the pressure will be indicated in metres. When the boiler and system are heated up and in operation, it can be seen at a glance that this minimum pressure is maintained by ensuring the pressure indication exceeds the altitude indication.
4. Make sure the isolation valve between the expansion tank and the heating system is open. If the tank has a gauge glass, check the level in the tank. The level should be in the lower part of the gauge. If the level is high, the tank may be full. In this case:
    a) Isolate the expansion valve from the system.
    b) Open the expansion tank drain valve.
    c) Vent and drain the expansion tank.
    d) Afterwards, close the expansion tank vent and drain, and open the expansion tank isolation valve.
    e) Recheck the expansion tank level to ensure the water is in the lower part of the gauge glass.
5. If multiple boilers share a common expansion tank, refer to site-specific procedures. Ensure that all on-line boilers, or boilers being brought on-line, are serviced by the expansion tank.
6. Start the primary heating loop circulator pump, and vent the air at high points in the system. Ensure that venting is complete by keeping the valve open until a solid stream of water flows. Entrained air will result in poor heat transfer from the heater.
7. If the system has secondary heating loops, start the secondary circulator pumps. Follow site-specific procedures.
8. Check the fuel and fresh air supplies, and the temperature setting of the high limit control.
9. Make sure the boiler control switch on the panel is in the off position.
10. On boilers with a high–low firing rate control, set the control switch on the panel to low.

11. On boilers with a fully modulating firing rate control, set the manual–automatic switch to manual and the flame control switch in the low-fire position.
12. If the low water fuel cutoff or the high limit control are equipped with mechanical reset devices, push the reset buttons to assure the switches are closed.

After having checked the boiler and auxiliary equipment thoroughly, the boiler is ready for startup.

Objective 5

Describe the general preparation for a steam boiler startup.

This learning objective will explain the general guidelines that should be followed when preparing to start any steam boiler. These preparatory steps will be referred to by other related chapters.

General Startup Preparation of a Steam Boiler

1. Make sure the boiler has a valid inspection certificate. Ensure that it has been properly checked over, cleaned, filled with water, closed and tightened up, and that all auxiliary water, fuel, and steam systems have been prepared.
2. Review the manufacturer's recommendations for the startup of the boiler.
3. If the piping system is going to be warmed up with the boiler, open the suction and discharge valves on the vacuum or condensate pumps, if equipped. Set the pump switches in the "auto" or "on" position. Open the water supply to the feeder valve, if so equipped. Ensure the deaerator and feedwater make-up system are filled to the operating/startup levels, and are ready to operate.
4. Ensure that fuel is available to the stop valves in the pilot and main burner supply lines. If fuel oil is used, open the stop valve in the return line. Make sure that the lines, filter, and fuel pump are operating as expected, and all parameters are within expected range.
5. Ensure that the fresh air supply to the boiler room is unobstructed.
6. Check the pressure settings of the operating and high limit controls.
7. Verify that the boiler control switch on the panel is in the "off" position.
8. On boilers with a high–low firing rate control, set the control switch on the panel to "low."
9. On boilers with a fully modulating firing rate control, set the manual–automatic switch to "manual" and the flame control switch to the low-fire position.
10. If the low water fuel cut-off and/or high limit control are equipped with a mechanical reset, push the reset button.

After having checked the boiler and auxiliary equipment thoroughly, the boiler is ready for startup.

Objective 6

Describe the safety and housekeeping preparation requirements for boiler plant startup.

Proper housekeeping in a boiler plant is important for maintaining a safe work environment. This includes the safety of personnel and equipment. In this objective, the expectations that surround housekeeping are introduced.

Housekeeping

Housekeeping is the practice of keeping workspaces clean, and free of clutter. The following are some of the tasks that the Power Engineer needs to observe:

a) Make sure that floors are swept and mopped.

b) Spills and leaks are cleaned up when discovered.

c) Tools and equipment are properly stored when not in use.

Cleaning up leaking oil and glycol reduces the chance of equipment fires. Ensuring the floors are clean and dry helps ensure worker safety.

Housekeeping is a habit that must be developed and practiced on a continual basis. For the Power Engineer, this is a skill of the craft. It demonstrates professionalism and good workmanship. It is not an extra task, but rather a way of working.

Housekeeping plays such an important role in a safe work environment that it is one of the factors considered by safety inspectors when investigating accidents.

Figure 3 shows an example of a daily housekeeping checklist:

Figure 3 – Housekeeping Report Example

Power Plant Daily Housekeeping Report
Date:
Time:
Performed by (please print):

	Area of Inspection	Complete (check box if adequate, if not, note in deficiencies)
1.	Fire extinguisher available and inspection valid	☐
2.	Floors clean	☐
3.	Tripping hazards removed or posted (spills, hoses, power cords, etc.)	☐
4.	Ladders stored if not in use	☐
5.	Tools stored if not in use	☐
6.	Chemicals stored properly	☐
7.	Oil leaks from equipment wiped up	☐
8.	Flammable waste stored in proper waste can	☐
9.	Equipment can be accessed freely (panels, valves, pumps, etc. are not blocked)	☐
10.	Maintenance is being performed in a defined laydown area	☐
11.	Doors and exits are free from obstructions	☐
Deficiencies noted:		
Performed by: (please sign)		
Performed by: (please sign)		

After the checklist is complete, personnel (including the Power Engineers on shift) must be assigned to cleanup.

Chapter Summary

A boiler plant startup involves many tasks which must be completed with great care. Every system in place to support boiler operation has its own operating parameters. Each of them must be monitored for safety and correct operation.

Starting a plant for the first time, or starting one that has been in prolonged shutdown, can be challenging. If the Power Engineer uses a systematic approach, and understands how each system impacts boiler operation, the boiler startup can be completed successfully.

In this chapter, the critical systems that support boiler operation were covered. Feedwater, fuel, and combustion air were discussed, along with the importance of good housekeeping. The non-routine tasks associated with starting a new boiler, or one coming out of an outage, such a boil out or a dry out, were introduced. The operational testing concerns surrounding combustion control, safety valves, and safety devices were highlighted.

Power Engineers are not only concerned about equipment operation, however. They also care about operator skills and operating practices. The preparations for starting a hot water and steam boiler were discussed to prepare the Power Engineer and the equipment for boiler firing.

This chapter has covered many critical points that lead the Power Engineer to the next chapter, Boiler Startup. It is important to note here that while this chapter is dedicated to preparing for a boiler start, many of the skills are transferable to day-to-day plant operation.

CHAPTER 2

Boiler Startup

Learning Outcome

When you complete this chapter you should be able to:

Describe procedures for safely starting boiler systems.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe operating considerations when warming a cold boiler.*
2. *Describe how to start and cut-in a hot water boiler.*
3. *Describe how to start a single boiler steam plant.*
4. *Describe how to cut-in a steam boiler in a multiple boiler plant.*
5. *Describe semi-automatic burner ignition systems.*
6. *Discuss the post startup inspection for boilers returning to service after a major outage.*

Chapter Introduction

Starting a boiler is one of the most challenging tasks for a Power Engineer. Transitioning a cold boiler plant to an operating plant is a dynamic process. It requires operators to use all their skills and faculties.

A cold, off-line boiler plant presents minimal hazards. A hot on-line boiler plant has numerous hazards. During startup, plant conditions and related hazards constantly change. New hazards can appear, while other ones can disappear. Performing a boiler and plant startup safely can challenge a Power Engineer's knowledge and skills.

In this chapter, the startup and warm-up of hot water and steam boilers will be discussed. The procedures for putting steam headers in service, along with post startup checks will also be covered to ensure the Power Engineer can complete the startup process safely and effectively.

In order to start boilers and power plants, a Power Engineer must have a firm understanding of boiler and plant preparation. The following objectives assume that the preparatory steps covered in the previous chapter are complete.

Objective 1

Describe operating considerations when warming a cold boiler.

Before starting a boiler from cold, operators need to know the effects rapid heating has on boiler metal, and what to expect while a boiler warms up. Some conditions encountered during warm-up cause leaks and premature boiler failure. Therefore, to ensure the safety and long life of boilers, operators must pay attention to boiler the warm-up rates, as prescribed by the boiler manufacturers.

During startup of a boiler, abnormal conditions may occur during the light-off or warm-up period. **ASME VI Recommended Rules for the Care and Operation of Heating Boilers** warns that if abnormal conditions occur, the operator should shut down the boiler immediately, and close the main and pilot test firing valves. The cause of the trouble must be identified and corrected before the boiler can be restarted. Never restart the boiler before correcting the problem. This is also good advice for operators of **power boilers**.

This objective provides the information a boiler operator must keep in mind while a boiler is warming up.

Cold Start and Warm-Up Considerations

Normal Cold Start Conditions

There are two conditions typically encountered during the warm-up period that may seem to be abnormal. These conditions should disappear after the boiler is hot. They are:

- Slight smoking
- Condensation

Slight Smoking

When a cold oil-fired boiler is started, the operator may notice slight smoking from the stack. This is normal since the furnace temperature is not yet high enough to vapourize the incoming fuel oil immediately and completely. As a result, combustion will not be entirely complete until the furnace heats up.

If there is still slight smoking after the boiler is warmed up, follow these steps:

- Ensure the atomizing air or atomizing steam is at the correct pressure.
- Ensure the fuel pressure is correct.

If smoking persists, take the burner out of service. Make sure the burner nozzle is clean and properly assembled. If the burner continues to smoke, then a knowledgeable operator or a qualified tradesperson should adjust the air-fuel ratio. Contact the local jurisdiction to find out who is qualified to service oil burners and perform combustion analysis.

CAUTION

A heavily smoking burner, while in operation, MUST NEVER be given additional combustion air. This may create an explosive condition. Shut down the boiler and contact a qualified technician to set-up the burner.

Condensation

Colder boilers, firetube boilers, boilers with large water content, and packaged boilers with economizers are more prone to experiencing condensation. When a cold boiler is first started, flue gas condensation (sweating) may take place to such an extent that the boiler may appear to be leaking. This condensation occurs when the water vapour in the flue gases contacts the cold heating surfaces of the boiler and condenses.

This phenomenon happens frequently in firetube boilers because of their large water content. When condensation occurs in firetube boilers, water runs out of the reversing chamber doors. Condensation will stop when the boiler is hot.

Harmful Cold Start Conditions

It is vitally important for a boiler operator to know the damage that can be done when cold boilers are fired at too high a rate. This especially applies to firetube boilers. High firing rates cause boilers to warm up rapidly, but unevenly. Rapid heating also causes thermal shock and refractory damage. Thermal shock and uneven expansion usually result in leakage, premature boiler failure, and costly repairs.

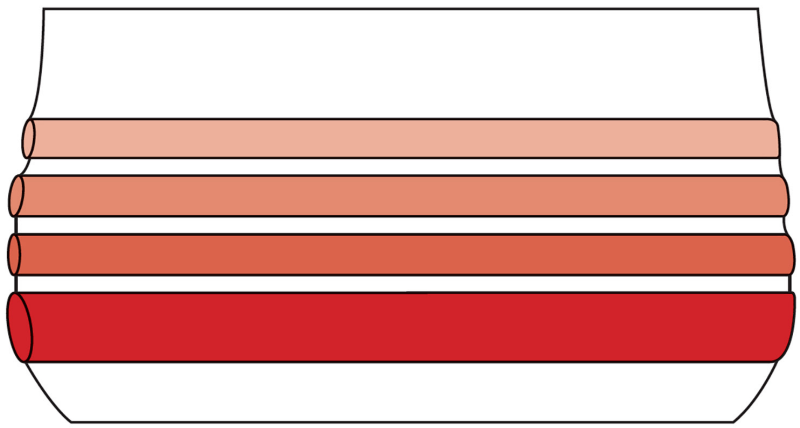
Uneven Expansion

When the burner of a cold firetube boiler is lit, the furnace and the first pass of the firetubes heat up more quickly than the rest of the firetubes. In a steam boiler, or a hot water boiler that is isolated from the heating system, the heat is not readily carried off by the water until there is positive water circulation. As a result, the furnace tube temperature rises at a faster rate than the firetube temperature, creating temperature differential and uneven expansion. In hot water boilers with forced circulation, the metal temperature will not rise to the same extent.

The furnace and the firetubes are attached to and constrained by the tube sheets at either end of the boiler. Because of the temperature differential, the difference in expansion rate between shell, furnace, and tubes is quite large. Because the tubes and furnace expansion is restricted, the tubesheet develops localized stress. When the firing rate is too high, the stress may be so great that a plain furnace may crack the welds that fasten it to the tubesheets, and the firetube ends may slide in their seats and work loose.

Figure 1 shows a four-pass firetube boiler, with the thermal expansion of each pass exaggerated. In order to demonstrate the uneven stress on the tube sheets, the furnace tube is shown expanded the most, and the fourth (coolest) pass expanded the least.

Figure 1 – Multi-Pass Firetube Boiler Under Thermal Stress



(Courtesy of Sellers Manufacturing Ltd.)

Uneven expansion is worse when there is scale buildup on the furnace and firetubes. Scale insulates the furnace tube and firetubes from the cooling effect of the boiler water. This interferes with heat transfer and increases metal temperatures.

Thermal Shock

When metal is subjected to a sudden change in temperature, the temperature change will not be even throughout the thickness of the metal. This will result in irregular expansion and contraction. It will cause strong internal stress, called thermal shock, in the metal. The larger the temperature change and the thicker the metal, the greater the internal stresses will be.

The heating surfaces of boilers, such as furnace walls, firetubes, and tubesheets, are subject to thermal shock when the boiler is first fired, since rapid temperature changes take place. If a cold boiler is started up and the maximum firing rate is applied, the thermal shock may be so strong that it will result in the formation of tiny cracks in the metal, especially in the tube ends and tubesheets. This condition is worsened by the stresses set up by uneven expansion and by scale buildup.

A rapid drop in temperature can also cause thermal shock. This occurs when cold water is suddenly introduced to a hot boiler. The source of cold water can be the cool return water of a hot water heating system that is not yet at operating temperature. Steam heating boilers can be thermally shocked with cold make-up water (either municipal or well water), or feedwater from a condensate source that is not yet at operating temperature. Steam power boilers can be shocked with cool return condensate from a deaerator or condensate tank that is not at operating temperature.

To protect a boiler from the damaging effects of uneven expansion and thermal shock, the following precautions should be taken:

a) Always warm up boilers slowly.

b) Keep boilers free from scale buildup.

c) For hot water heating systems, do not allow a full flow of cool return water to pass through a warm boiler. Instead, bypass part of the flow around the boiler until the water temperature difference between the supply and return lines has reached its normal operating value.

d) For steam boilers, do not permit cold make-up or feedwater to discharge directly on heated boiler surfaces. If possible, keep make-up water sources at normal operating temperature.

Boiler Warm-Up

The rate at which a boiler can be brought up to its normal operating temperature and pressure depends on:

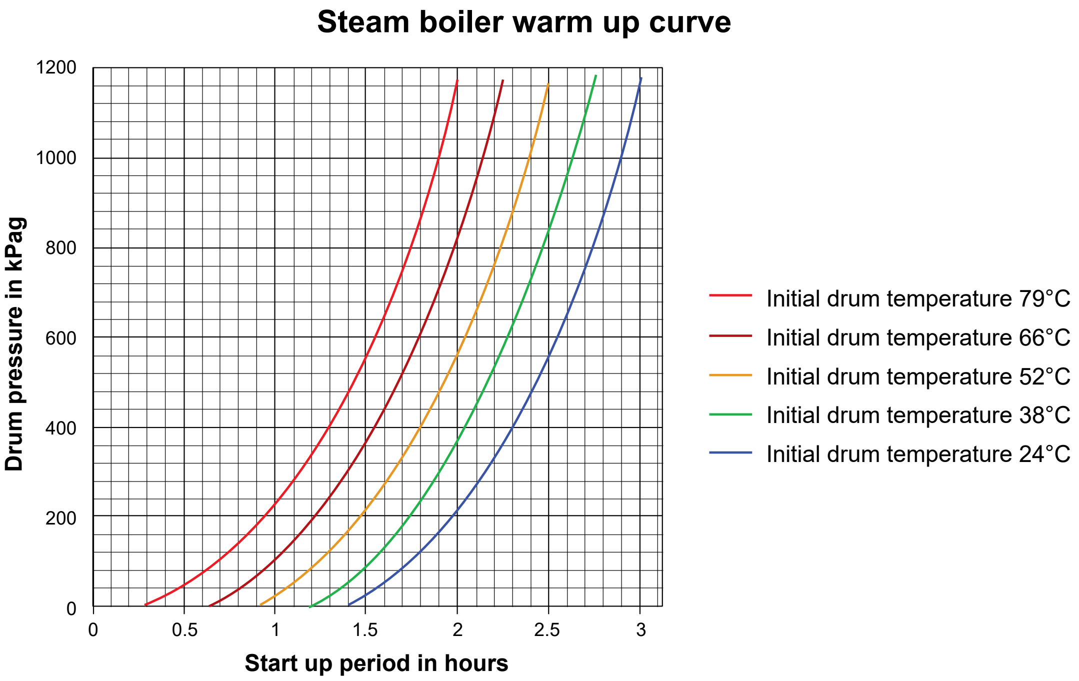
- Physical size of the boiler
- Boiler water content
- Boiler design (firetube or watertube)
- How long the boiler has been shut down

In general, the larger and colder a boiler is, the longer it will take to warm up or pressurize. It is important to take care to prevent thermal shock of the metal and refractory. As well, thermal expansion must be allowed to occur gradually. In the absence of manufacturer's specific warm-up instructions, a good rule is that for larger boilers, the boiler water temperature should not increase at a rate greater than 55°C per hour.

Figure 2 shows the expected drum pressure after a period of firing, at a 55°C temperature increase per hour. Five different curves represent five different drum temperature conditions at startup. If a boiler has relatively cold water on initial firing (24°C), it should develop steam pressure after about 1.4 hours of firing. It should have a drum pressure of about 210 kPa after 2 hours of firing. If a boiler has relatively hot water on initial firing (79°C), it should develop steam pressure after about 15 minutes of firing, and should have a drum pressure of about 1175 kPa after 2 hours of firing.

The 55°C per hour is a conservative firing rate. It is designed to minimize thermal shock and to permit reasonable rates of thermal expansion. Some boiler manufacturers may specify faster or slower warm-up rates. Always consult manufacturer specifications.

Figure 2 – Steam Boiler Warm Up Curve at 55°C Temperature Increase per Hour



Following ignition, the firing rate must be kept on manual low-fire control. For steam boilers, the water level control system is usually placed on automatic as soon as the boiler is started.

Continually monitor the boiler while it is warming up and pressurizing:

a) Check the flame pattern to ensure it is symmetrical and sufficiently turbulent. Look for signs of poor combustion (flame too rich or too lean).

b) Look for "hot spots" on the metal surface. Black, peeling paint is a good indication of refractory damage.

c) Check the furnace draft pressures and compare them to historical data (paper charts or digital control system trends). This is make sure that combustion gases are passing normally through the furnace and flue gas passages.

d) Check fans and feedwater pumps for normal operation.

e) For steam boilers, ensure the water level in the boiler is properly maintained and accurately shown in the gauge glass.

f) Confirm the proper operation of the low water level alarm and cut-off, and blow the water column clear of sediment.

CAUTION

Never leave a boiler unattended during its warm-up period. Monitor the boiler and stay alert, in case operator intervention is required.

After boiler pressure approaches its normal pressure or temperature set point, switch the firing rate control to automatic. From previous log sheets and history, verify that the boiler is performing "as expected." Enter a summary of the startup events in the daily log.

Warm-up steps for hot water and steam boilers are discussed in more detail in the following objectives.

Objective 2

Describe how to start and cut-in a hot water boiler.

The safe startup of a hot water boiler requires the Power Engineer to monitor all aspects of startup. This includes furnace purge, ignition, and main burner light-off. This objective covers the main steps that should be performed when starting a hot water boiler.

The following steps are general in nature. The boiler manufacturer operating procedures and site-specific standard operating procedures must be followed. As well, **ASME VI Recommended Rules for the Care and Operation of Heating Boilers** is an excellent reference for heating boiler operating practices.

Hot Water Heating System Startup (Single Boiler Plant)

Smaller hot water systems may have only one boiler. In this case, the entire system will be heated simultaneously from a cold start. It is assumed the boiler and heating system have been filled with treated water.

1. Prepare the boiler plant auxiliaries, such as the boiler water circulating pumps, expansion tank, make-up water system, fuel system, combustion air system, compressed air systems, and others, according to site-specific procedures. Plant preparations were discussed in the previous chapter.
2. Review the manufacturer recommendations for burner and boiler startup.
3. Open the boiler return and supply valves, if applicable.

Side Track

A boiler in a single boiler downfeed hot water system may not have inlet and outlet isolation valves.

4. Ensure the boiler control switch is in the "off" position.
5. Close the main disconnect switch to supply power to the boiler.
6. If the boiler has a gas-fired **atmospheric burner** and a continuous, intermittent, or interrupted pilot, it will not have a draft fan to provide a mechanical purge. Furthermore, if the boiler has a continuous pilot, the pilot will have to be lit manually. Allow at least 5 minutes for the furnace to purge naturally with the pilot and main gas valves shut. After this period of time, follow the manufacturer's instructions for lighting a continuous pilot burner. When the pilot flame is established, open the main burner test firing valve.
7. If equipped with a high-low firing rate control, place the boiler on low fire. If equipped with a fully modulating firing rate control, place the control in manual low fire.

8. Turn the boiler control switch to the “on” or “start” position. If equipped with a **power burner**, the burner management system will take over, and start the boiler in the proper sequence. The ignition sequence should resemble the following:
   a) The forced draft fan will start.
   b) The air damper will fully open and the boiler will purge for a given time period (between 30 and 90 seconds; enough time for four combustion chamber air changes).
   c) The air damper will go to the low fire position.
   d) The electrodes in the igniter will begin to spark.
   e) The pilot fuel will be admitted to the igniter, and a stable pilot flame should be present.
   f) After the pilot ignition trial is over (approximately 10 seconds), the main burner ignition trial begins. The main burner safety shut-off valves should open and a stable flame should be present at the main burner.
9. Raise the water temperature slowly, by operating the boiler at low fire, until the boiler and the heating system reaches its normal operating temperature and pressure. The entire water content of the system and boiler must be warmed prior to increasing fuel input. If the flame at low fire provides insufficient heat to reach normal operating temperature after 30 minutes, gradually increase the firing rate using the manual firing rate control.
10. While the boiler is warming up, perform the operating and safety limit checks, as outlined in the previous chapter.

CAUTION

The boiler should be fired at low fire until the water temperature has reached its normal operating range. This will limit the differential expansion between the furnace tube and firetubes, or risers and downcomers, which occurs when firing a cold boiler. Warming up a boiler on high fire creates significant differential expansion, resulting in boiler metal stress and decreased boiler life expectancy.

11. Check the boiler frequently for leaks. Make sure the burner is operating properly.
12. Do not leave the boiler until the operating control reaches its cut-out temperature. Make sure the control shuts off the burner.
13. When the burner shuts down, check the water pressure on the **tridicator** gauge (combination altitude, pressure, and temperature gauge), and the water level in the expansion tank. The altitude gauge reading will confirm that the heating system is full when it reads a pressure greater than the altitude of the heating system.
14. Check the safety relief valve for evidence of leaking. Perform the try lever and pop tests.
15. If equipped with a high-low firing rate control, the boiler can be left in high fire. In this position, the boiler will alternate between low and high fire to meet the heating demand. If equipped with a fully modulating firing rate control, the boiler firing rate control can be placed in “auto.”
16. Enter the required information in the log book:
    a) Date and time of startup.
    b) Observed irregularities and corrective actions taken.
    c) Time when controls shut off burner at established temperature, tests performed, and results of tests.
    d) Signature of operator.

Cutting In a Hot Water Boiler (Multiple Boiler Plant)

Larger hot water heating systems have multiple boilers, to provide the required heating capacity. This also ensures that capacity is available on standby, when needed. The term **cutting in** is used to describe the activity of adding a previously non-operating boiler to a system that is already in operation. When cutting in a boiler, the entire system will be hot and under pressure, but the boiler being brought on-line will be firing from cold.

To prepare and warm-up a hot water boiler for cutting in, follow the procedures for preparation and startup already described. However, there are exceptions:

a) If a common expansion tank is used for all boilers, the valve in the connecting line between the boiler and the tank will be closed while the boiler is out of operation. Fill the boiler the normal way. Then, raise the pressure to at least the minimum required static pressure for the cold system. Crack open the valve in the expansion tank connecting line and let the pressure of all the system boilers equalize. Next, open the valve fully.

b) Keep stop valves in the supply and return lines to the boiler closed during warmup. Raise the temperature of the boiler water slowly. When a common expansion tank is used, make sure that sufficient space is available in the tank to accommodate the expanded water produced during warmup. Ensure that an ample air cushion is maintained in the tank.

CAUTION

When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

c) When the temperature of the boiler water reaches the temperature of the water in the supply main, open the stop valve on the boiler outlet slightly. If there is no unusual disturbance, such as noise or vibration, continue opening the valve slowly until it is fully open. Then open the valve in the return line slowly.

As an alternative, the cold boiler can be warmed to system temperature before firing it. In this case:

a) Slowly open the inlet valve to the cold boiler. Crack open the outlet valve, to establish flow through the cold boiler without causing shock to the boiler or the heating system.

b) When the cold boiler is at or near the system temperature, fully open the outlet valve. The boiler can now be fired on low-fire until sufficiently warmed up.

c) After warming up, the boiler can be switched to "high fire" or "automatic," as applicable.

Note that this alternative method will only work if the on-line boilers have sufficient capacity to heat the extra boiler. Plan ahead for heating loads, and have standby boilers warmed up prior to being required.

Objective 3

Describe how to start a single boiler steam plant.

The safe startup of a steam boiler requires the Power Engineer to monitor all aspects of startup, which includes the furnace purge, ignition, and main burner light off. This objective covers the main steps that should be performed when starting a steam boiler. It also highlights the steps of the ignition sequence.

The following steps are general in nature. The boiler manufacturer operating procedures and site-specific standard operating procedures must be followed. **ASME VI Recommended Rules for the Care and Operation of Heating Boilers** and **ASME VII Recommended Guidelines for the Care of Power Boilers** are excellent resources to refer to for starting, warming, and cutting in steam boilers.

Steam Boiler/Steam Line Startup (Single Boiler Plants)

To prevent **water hammer** and the severe damage it causes, it is ***imperative*** that steam lines and **headers** be warm before boilers are placed in service. During a steam boiler warm up, consideration must first be given to how the plant steam lines will be warmed up. Then, the steam piping system must be prepared so that it will be warm, dry, and ready to go on line when the boiler is ready.

Simultaneous Warm-Up

In the case of a single boiler steam heating system, **ASME VI** advises operators to warm up **heating boilers** and their steam piping simultaneously. To perform this procedure, open the boiler steam outlet valve prior to firing the boiler. Keep the valve open during the warm-up period.

ASME VII states that a high-pressure steam plant comprised of a single power boiler may have its boiler and steam lines warmed either simultaneously or independently of each other. Figure 3(a) shows a single power boiler supplying steam into a header. The block valve at the outlet of the boiler (the steam stop valve) is usually a standard gate valve. Non-return valves are not needed in single power boiler plants.

The header stop valve shown is not a requirement for single boiler installations. The piping downstream of the header stop valve is referred to as the steam header (or steam main). It supplies all the plant equipment taking steam at a given pressure. In this system, it is advisable to warm the steam header with the boiler stop, header stop, and drain valves open.

When warming up a steam header or main at the same time as the boiler, the steam piping and boiler will warm and pressurize at the same rate. The steam entering the cold steam piping will condense heavily at first, but decreasingly as the steam piping comes up to temperature. The condensate that forms will be removed quickly from the header and steam main by low point drains, steam traps, and steam trap bypass lines. By the time the boiler is up to its normal operating pressure, the headers should be warm and dry.

Independent Warm-Up

For either power or heating boilers, it is possible to leave the boiler stop valve closed until the boiler reaches its operating pressure. At this point, the stop valve is slowly opened and the header warmed up. As before, it is very important that the trap bypasses, header drain valves, and all other related drain valves are opened during this procedure.

Steam Boiler and Steam Piping Simultaneous Warm-Up Procedure

The following is a general procedure for simultaneously warming a steam boiler and its steam piping, from cold. This procedure applies to both heating and power boiler systems. Ensure site-specific procedures and manufacturer instructions are followed at all times.

1. Following site-specific procedures, prepare the steam plant auxiliaries as discussed in previous chapters. This includes preparing the boiler feed pump, condensate return system, make-up water system, feedwater system, fuel system, combustion air system, compressed air system, and others. If the boiler has a superheater, open the superheater vent at this time so that it does not overheat due to lack of steam flow.
2. Check all steam system valves are correctly lined up. Make sure low point system drains are opened to release condensate as it forms. Open **trap bypasses** where they exist, and have **steam traps** in service.
3. Review manufacturer recommendations for burner and boiler startup.
4. Open the main steam shutoff valve.
5. Open the boiler drum vent. This will permit the release of corrosive dissolved gases, such as oxygen and carbon dioxide, from the boiler water.
6. Ensure the boiler control switch is in the "off" position.
7. Close the main disconnect switch to supply power to the boiler.
8. If the boiler has a gas-fired atmospheric burner and a continuous pilot, follow the manufacturer instructions for lighting the pilot burner. When the pilot flame is established, open the **main test firing valve**.
9. If equipped with a high-low firing rate control, place the boiler on low fire. If equipped with a fully modulating firing rate control, place the control in manual low fire.
10. Turn the boiler control switch to the "on" or "start" position. If equipped with a power burner, the burner management system will take over and start up the boiler in the proper sequence.
11. Raise the water temperature and pressure slowly, by operating the boiler at low fire. This will prevent excessive stress due to thermal shock and uneven expansion. Maintain low fire until the boiler and piping system reach normal operating pressure.
12. While the boiler is warming up, perform the operating control and safety limit checks, as outlined in the previous chapter.
13. Inspect the boiler frequently during the warm-up period. Observe the operation of the burner. Check washout plugs, valves, handholes, and pipe connections for leakage.
14. Close the drum vent valve when the boiler pressure reaches 15 to 20 kPa. At this point, all the air should be expelled from the boiler.
15. Pinch back on the steam line low point drains if they are blowing excessive steam.
16. Follow the warm-up instructions of the boiler manufacturer. The firing rate may be increased slowly when the boiler has thoroughly warmed up, the boiler is steaming, and good water circulation has been established.
17. When the steam lines are warmed up and very little condensate is blowing from the drains, close trap bypasses and place steam traps in service. Close low point drains. The superheater drains or vents can be kept open until adequate flow of superheated steam is established (as specified by the boiler manufacturer and site-specific procedures).
18. While the boiler is building up pressure, blow down the water column and gauge glass to ensure the connections are clear, and the level is correct. Also, test the low water cut-offs by opening the drains on the water column and the low water cut-off float cage.

19. Stay with the boiler until the operating control reaches its cut-out point. Make sure it shuts off the burner at the set pressure.
20. Check the safety valve for evidence of simmering. Perform the try lever and pop tests.
21. Enter the required information in the log book.

Objective 4

Describe how to cut-in a steam boiler in a multiple boiler plant.

Larger steam systems have multiple boilers, to provide the required thermal capacity. This also ensures that additional capacity is available on standby, when needed. When cutting in a boiler, the entire system will be hot and at normal operating pressure, but the boiler being brought on line will be firing from cold.

Steam headers in multiple boiler systems conduct steam from the boilers to other equipment in the plant. Larger and more complex high-pressure steam plants can have several different headers, identified by the pressures at which they operate. For example, a plant may have:

- A 10 000 kPa header for high pressure turbine and processes
- A 2500 kPa header for intermediate pressure turbines and processes
- A 100 kPa header for steam heating and auxiliary equipment

Each of these headers may have its own steam generators and users. Commonly, these headers are connected in sequence; the high pressure header "lets down" to the intermediate pressure header which, in turn, lets down to the low pressure header.

Headers, and the piping that connects the boilers to the headers, must be properly warmed up to avoid thermal stress, and to remove condensate as it forms. If not correctly warmed up, pressurized, and drained, severe water hammer will occur during the plant startup. Severe piping damage and loss of life occurs due to water hammer.

In a multiple boiler or multiple header plant, header warm-up procedures can be very complex. This manual operation must be under the control of a competent Power Engineer, who is following approved site-specific procedures.

Steam Heating Boilers: Cutting In Additional Boilers

Cutting in is accomplished somewhat differently for steam heating and steam power boilers. Steam heating systems are slightly less complex; they may not have all the valves and drains that power boiler systems have. As well, heating boilers are generally not equipped with non-return valves. It is important to be familiar with the steam heating system prior to cutting in additional heating boilers. Consult site-specific procedures.

When placing a steam heating boiler on line with other heating boilers that are already in service, first start the boiler using the procedure in Objective 3, but have the boiler supply stop valve and the non-return stop valve closed. If there is a drain valve between the stop valve at the boiler outlet and the steam main, open it. When the pressure within the boiler is approximately the same as the pressure in the steam main, open the stop valve slightly. If there is no unusual disturbance, such as noise, vibration, or water hammer, continue to open the valve slowly until it is fully open.

Steam Power Boilers: Warming Steam Headers

As in the case of heating boilers, the steam header warm-up should occur during boiler warm-up. Never cut-in a steam boiler to a cold header.

Warming High-Pressure Steam Headers in a Multiple Boiler Plant

There are two common multi-boiler situations that require different warm-up procedures:

1. All the boilers have been shut down. The boiler being started up is the first to go on line. All steam headers are cold.
2. The main steam headers are already warmed up and pressurized. There are other boilers in the plant already on line.

Regardless of the steam line and header configuration, it is imperative that ALL DRAIN VALVES at ALL SYSTEM LOW POINTS are opened. This permits discharge of condensate as the steam lines warm up, so that water hammer does not occur.

All Boilers Have Been Shut Down

Refer to Figure 3(a). This situation is treated exactly like the warm-up procedure for a single steam boiler plant. The header stop, the boiler stop, and the drain valves are left open during boiler warm-up. Boilers that are to remain off-line must have their boiler and header stop valves shut, and their drain valves open. The entire system warms and pressurizes, as the boiler warms, except for the boilers being left off line.

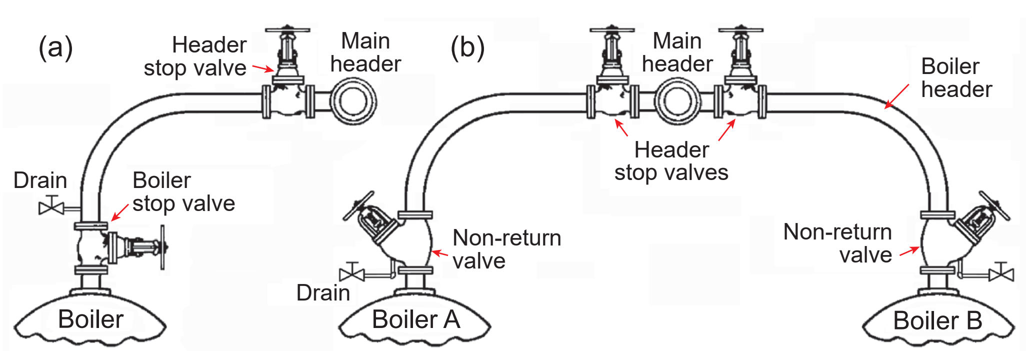
Main Steam Headers are Already Warmed Up and Pressurized

A E

Figure 3(b) shows multiple boilers (Boiler A and Boiler B) feeding a common steam header. Each boiler is equipped with a stop valve, a header stop valve, and a free-blowing drain between the two, as required by **ASME I PG-58.3.2**. This double block and bleed arrangement is necessary when multiple power boilers with manholes are connected to a common steam header. This is to protect workers inside boiler drums when the connected header is energized.

Assume the main header in Figure 3(b) is energized, and Boiler B is on-line. Boiler A is being warmed up to place it on line along with Boiler B. The main steam header is already in service, and only the interconnecting steam piping from Boiler A to the header needs warming. Even though this is a relatively short length of pipe compared to the overall steam header system, it is extremely hazardous to put it into full service without warming it up and drying it out.

Figure 3 – Boiler Stop and Header Valve Arrangement for Steam Boiler Plants



Method One: Warming Boiler Header

1. Open the drain on the Boiler A non-return valve. This drain is connected internally to the downstream side of the non-return valve plug. When it is open, it will drain condensate that accumulates above the non-return valve.
2. Slightly open the header valve for Boiler A. This allows steam to flow from the steam header into the boiler steam line and out the drain. The boiler steam line will warm up using steam from the header. Any condensate that forms will be forced out the drain valve.
3. Boiler A header valve can be slowly opened wide when the pressure has equalized between the steam header and the boiler steam line. Note that pressure gauges are not shown on this diagram. Refer to Figure 4 for common pressure gauge locations.
4. Permit the drains to blow until the header and interconnecting piping are fully up to pressure and temperature, and the boiler is ready to be cut-in. Then, close the drains.

Method Two: Warming Boiler Header

An alternate layout of multiple boilers feeding a common header is shown in Figure 4. In this situation, the steam line to the header can be warmed up by steam from the boiler, from the header or from either steam source.

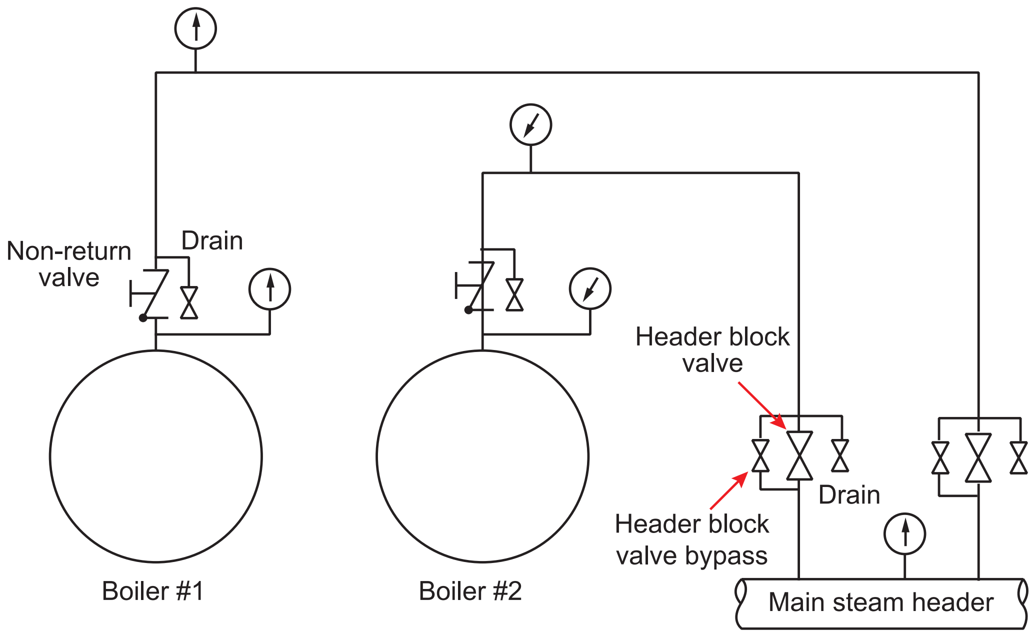
Drains are located at the non-return valves and at the header block valves. The header block valves have bypass valves of relatively small size. These bypass valves are used to warm up the steam lines to the boilers, so that the main steam header block valves do not wear prematurely due to wire drawing. Also, these smaller globe valves permit finer adjustment of the warm-up rate for the steam piping.

Warming Up Using Boiler Steam

Refer to Figure 4. Assume Boiler 1 is on-line, and the steam header is energized. Boiler 2 is being warmed to place it on line with Boiler 1. To warm the steam line to the header using the steam from Boiler 2:

1. Keep Boiler 2 header block valve closed.
2. Open Boiler 2 non-return valve drain.
3. Open the header block valve drain.
4. Open Boiler 2 non-return valve about 25%.
5. Begin warming up Boiler 2. As Boiler 2 produces steam, its non-return valve will open. The steam produced by the boiler will warm the steam line to the header, and condensate will discharge from the drains.
6. Permit the drains to blow until the header and interconnecting piping are fully up to pressure and temperature, and the boiler is ready to be cut-in. Then, close the drains.

Figure 4 – Steam Supply with Drain and Bypass Valves at Header



Warming Up Using Header Steam

Refer to Figure 4. To warm the steam line between the header and Boiler 2, using steam from the header:

1. Keep Boiler 2 header block valve closed.
2. Open Boiler 2 non-return valve drain.
3. Open the header block valve drain.
4. Open Boiler 2 non-return valve about 25%.
5. Slowly open the header block valve bypass valve. The steam from the header will warm the steam line to Boiler 2, and condensate will discharge from the drains. The boiler can be firing and warming up during this period of time.
6. Permit the drains to blow until the header and interconnecting piping are fully up to pressure and temperature. This can be determined by comparing the pressure on the main steam header to the pressure of the steam line to Boiler 2. If the pressures are equal, close the header stop valve drain, and pinch back on Boiler 2 non-return valve drain. This will permit a flow of steam to keep the steam line warm. As well, this will ensure any condensate accumulating above Boiler 2 non-return drain valve is removed as it forms.
7. When the pressure in the main steam header and the steam line to Boiler 2 are equal, slowly open the main header steam block valve, and close the bypass valve. The steam line and header are now ready to accept steam from Boiler 2.

Steam Power Boilers: Cutting In Additional Boilers

The procedure for cutting a power boiler into a pressurized steam header is described in **ASME Section VII**. Cutting in can happen when the boiler, header, and interconnecting piping are up to operating pressure, and the piping is up to temperature and is dry.

Before cutting in a boiler, ensure that it is operating in manual low-fire mode. When multiple boilers are on line and operating in automatic firing mode, one boiler will shed all its load causing the other to do most of the work. The boiler left in manual operation is referred to as the base-loaded boiler.

Cutting In Boilers with Non-Return Valves

Cut-in the boiler when the boiler steam line to the header and the steam header are up to temperature, and their pressures are equal. The actual cut-in procedure will vary depending on the header arrangement and the procedure followed when warming the interconnecting piping.

Method One: Cutting in a Boiler

Refer to Figure 3(b) and **Method One: Warming Boiler Header**. Boiler A is being warmed to place on line. Its non-return valve is opened about 25% when its pressure is still a few kPa below the header pressure. Because the non-return valve is a stop-and-check valve, it will not actually open at this time. It will only open when the boiler pressure exceeds the header pressure. Backing off on the stem of this valve permits it to automatically open as the boiler pressure exceeds the header pressure. Sometimes, a non-return valve sticks in the closed position and then opens suddenly. By initially restricting the opening of the non-return valve, flow surges and pressure upsets caused by sticking valves are avoided.

When Boiler A is supplying steam, and there are no unusual conditions, its non-return valve is opened fully. Now, both boilers are on line.

Method Two: Cutting in a Boiler

Refer to Figure 4 and **Method Two: Warming Boiler Header**. The header stop valve for Boiler 2 is opened fully when its steam line pressure equals the steam header pressure. Now, Boiler 2 non-return drain valve can be shut, as long as it is no longer discharging condensate. Boiler 2 header stop bypass valves can also be shut at this time.

As Boiler 2 pressure continues to rise and exceed header pressure, the non-return valve will open until it reaches the 25% limit. Boiler 2 non-return valve can then be slowly opened the remainder of its travel if no system disturbances are noticed. The boiler is now fully on line.

Cutting In Boilers that Do Not Have Non-Return Valves

In this situation, the boiler does not have non-return valves. Rather, the main steam stop valves, shown in Figure 3 as non-return valves, are conventional **OS&Y** **rising stem valves**. The drain identified as the non-return drain is not part of the valve body; it is a drain valve installed on the steam line just downstream of the boiler main steam stop. The remaining layout is the same.

In the absence of a non-return valve, the boiler stop valve should be opened slowly when the pressures in the boiler, header, and steam line from the boiler are approximately equal. Equalize the pressure between the boiler and header stop valves using the header stop valve bypass. When the header pressure equals the boiler steam line pressure, the header stop valve can be slowly opened fully and its drain shut. When the pressure in the boiler steam line and the boiler are approximately equal, slowly open the boiler steam stop valve.

Objective 5

Describe semi-automatic burner ignition systems.

Most boilers in smaller power plants have fully automatic burner management systems. These systems automatically recycle on call for heat, regardless of whether an operator is in attendance. However, in larger plants, boilers are commonly equipped with semi-automatic ignition systems.

Semi-automatic systems follow the same startup sequence as fully automatic boilers, but are equipped with additional safety features. These features may operate automatically, as in the case of fuel line bleed valves, or may require manual operation, such as supervised main test firing valves. Because they have manual control elements, these boilers require interaction with trained operators to progress through their ignition sequences.

Semi-Automatic Ignition Systems

Although boilers have many different ignition systems, they all follow the same sequence of steps:

1. Pre-purge
2. Purge
3. Pilot ignition
4. Main burner ignition
5. Run period
6. Post purge

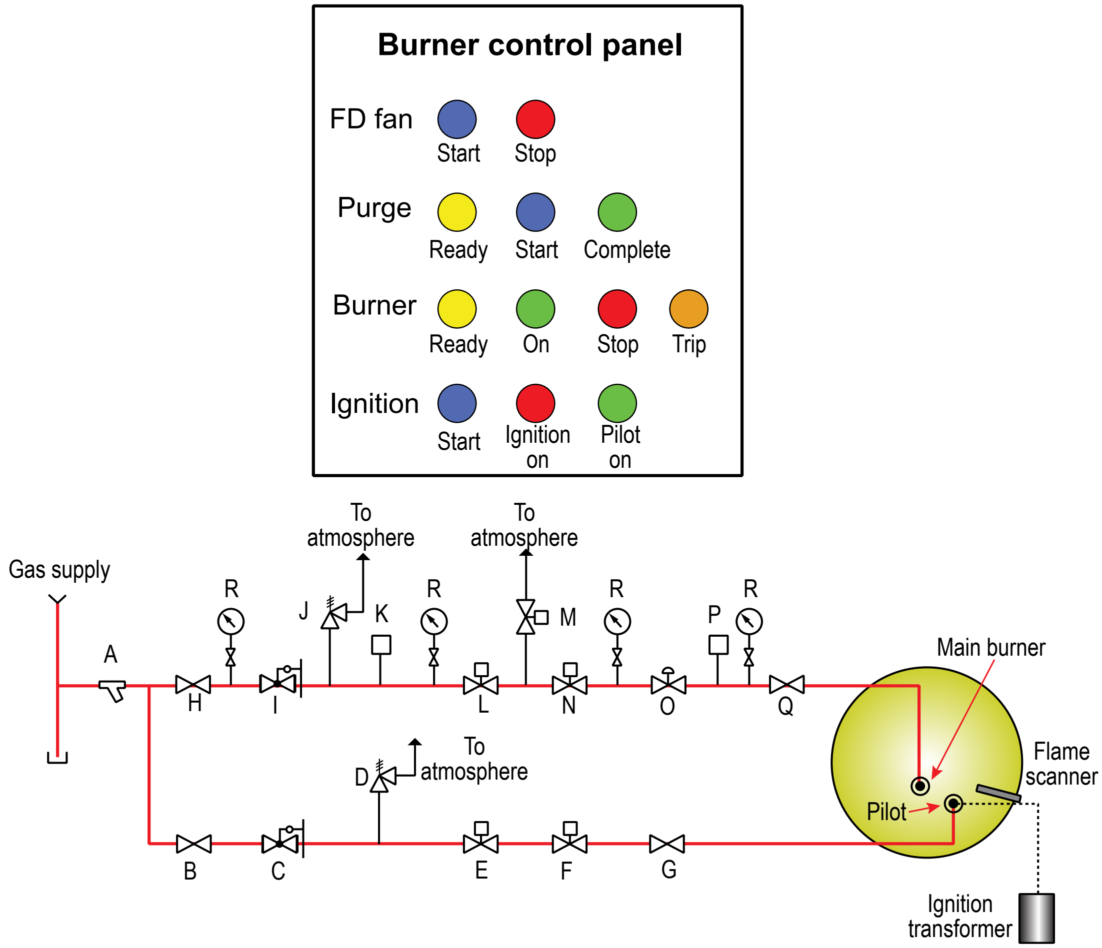
Side Track

A detailed account of the boiler ignition sequence can be found in the **PanGlobal Fourth Class, Part B, Unit 3, Chapter 2 Combustion Safety.**

Semi-automatic systems control the order of events that an operator must perform to light-off the boiler. As well, semi-automatic systems force the operator to complete these steps within a set time period. For example, a boiler may require its main test firing valve to be opened within 10 seconds of the SSOVs energizing.

Figure 5 shows a fuel train for natural gas burners over 12 500 000 Btuh (300 BoHP or 3000 kW). The pilot gas line is equipped with two safety shut-off valves (valves E and F). The main gas line is equipped with two automatically operated main burner SSOVs (valves L and N), each having a **proof of closure switch**. These switches are mounted to the SSOV valve stems. If the valve fails to close completely, due to mechanical failure or debris on the valve seats, the proof of closure switch will not close. This will prevent the ignition sequence from beginning. Therefore, proof of closure switches are burner **pre-ignition interlocks** or **permissives**.

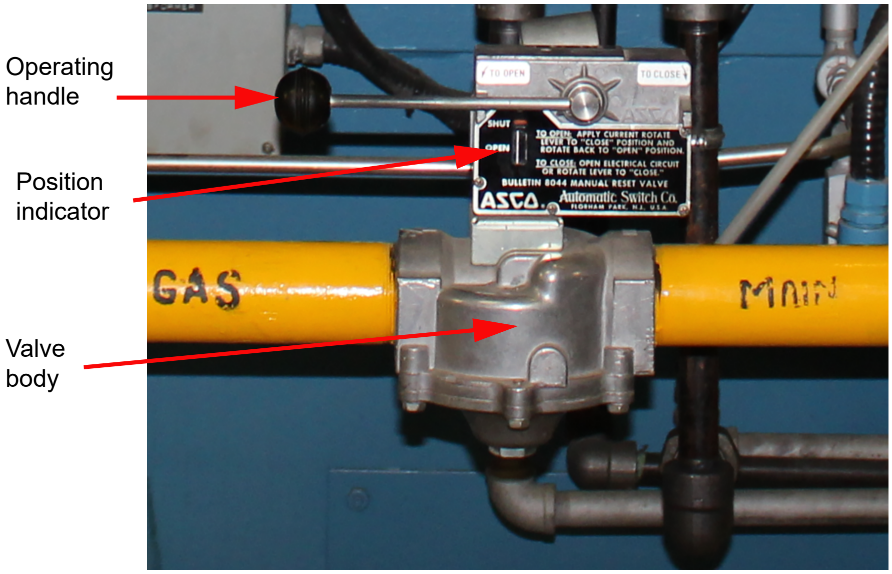
Figure 5 – Semi-Automatic Burner Ignition Equipment for Single Burners Greater than 12 500 000 Btuh (3000 kW or 300 BoHP) Input



A = Fuel filter
B = Pilot gas manual isolation valve
C = Pilot gas pressure regulator
D = Pilot gas pressure relief valve
E = Pilot burner SSOV
F = Pilot burner SSOV
G = Pilot burner test firing valve
H = Main burner manual isolation valve
I = Main burner gas pressure regulator
J = Main burner gas pressure relief valve
K = Low gas pressure cut-off switch
L = Main burner SSOV (with proof of closure switch)
M = Safety vent valve (bleed)
N = Main burner SSOV (with proof of closure switch)
O = Main burner firing rate control valve
P = High gas pressure cut-off switch
Q = Main burner test firing valve (with supervisory switch)
R = Pressure gauges

The SSOV closest to the burner may be a semi-automatic **magnetic latching SSOV**. It must be manually opened, but closes automatically (see Figure 6).

Figure 6 – Semi-Automatic Magnetic Latching SSOV



Side Track

Most higher capacity boiler burners have SSOVs with proof of closure switches, regardless of whether the boiler is fully or semi-automatic. In all cases, proof of closure is a pre-ignition interlock.

Between the SSOVs, Figure 5 shows a **safety vent valve** or "bleed" solenoid that ensures no gas can enter the furnace when the boiler burner is off. When the burner is off, valves L and N are both closed, and vent M is open. When the burner is operating, L and N are both open, and M is closed. In the event of a boiler or burner trip, L and N will close, and M will automatically open. During light-off, L and N will automatically open, and M will automatically close. (If valve N is a magnetically latched semi-automatic SSOV, it must be manually latched open during light-off.)

The main test firing valve (Q) is sometimes called a **supervised cock**. It has a built-in proof of closure pre-ignition interlock switch. This prevents a boiler from recycling or even pre-purging unless the main test firing valve is in the fully closed position.

Figure 5 also shows a local burner control panel, located beside the fuel train and mounted on the boiler. This panel has switches that start and stop the forced draft fan, start the purge sequence, and start the burner and ignitor. It also has status lights that show when the purge is permissive, when the purge is complete, when the burner is ready for start (permissives satisfied and purge complete), and when the burner has tripped. For simplicity sake, the alarm horn, the alarm acknowledge/silence button, the burner e-stop button, and the pushbutton switch for testing the panel lamps are not shown. Not all semi-automatic boilers have equipment identical to this, but it is fairly typical of most large packaged boiler systems.

Before the ignition sequence can begin, all the boiler permissives must be satisfied. For example, the water level, boiler pressure, and fuel pressure must be within their acceptable limits. The SSOV and main test firing valve proof of closure switches must be closed. The boiler "run" switch must be in the "on" position.

Some larger boilers have their own dedicated steam pressure controller. This controller (called the boiler master) sends control signals to the airflow controller and the fuel flow controller, in response to the boiler master pressure set point. During startup, this type of system must have its boiler master on manual, and the control output of the boiler master set to zero (minimum fire). Depending on the system, the airflow controller and fuel flow controller may be required to be on manual, and set to the required light-off set points.

To start the burner:

1. Start the forced draft fan, using the control panel **FD Fan START** button. Make sure that the fan starts. If all of the boiler permissives are satisfied, the **PURGE READY** light will come on.
2. Press the **PURGE START** button. The minimum airflow setting on the airflow controller will be temporarily overridden during the purge period. Make sure that the forced draft fan ramps up to high speed (if it has a variable speed drive), or that the forced draft fan dampers open wide. The pre-purge period will continue until at least four furnace volumes of air have been exchanged.
3. When the purge is done, the **PURGE COMPLETE** light will come on. Make sure that the fan returns to its low-fire start speed, or low-fire start damper position. When the forced draft fan returns to its minimum airflow setting, the **BURNER READY** light should come on.
4. Press the **IGNITION START** pushbutton. The ignition transformer will start, the pilot gas safety shut-off valves will energize, and gas will flow to the pilot burner. The **IGNITION ON** light will come on. Keep holding the **IGNITION START** pushbutton until the pilot flame is detected. When a stable pilot flame is detected, the **PILOT ON** light will come on. The operator may now release the igniter push button.

The next two steps must be completed quickly (within the main flame trial for ignition period, which is typically only a few seconds).

5. If SSOV “N” is of the magnetic latching valve style, it must be reset. Rotate the operating lever to the **CLOSED** position, and then rotate it back to the **OPEN** position (Figure 6). This must be done as soon as the valve energizes. Vent valve “M” will close automatically as soon as the SSOVs energize.
6. Finally, the operator must manually open the supervised main test firing valve. Open this valve gradually, to allow the burner to light gently. Gas will now flow to the main burner, where it will ignite from the pilot flame. If these steps are done in time, the ignition sequence is complete, and the boiler can be warmed up.

Many modern burners do not have semi-automatic magnetic latching SSOVs. In this case, SSOV “L” and SSOV “N” would automatically open during the main flame trial for ignition period. In this case, the operator only needs to open the main burner test firing valve as in step 6.

On Track

Opening the supervised main test firing valve at any point in the sequence other than at step 6 will immediately cause the burner to undergo safety shutdown and lockout. The burner must then be reset, and the sequence restarted from the beginning.

Objective 6

Discuss the post startup inspection for boilers returning to service after a major outage.

Once a boiler has been successfully fired, warmed up, and placed on line, an inspection of the boiler operating parameters should be carried out. This includes routine instrument checks, heating system checks, and auxiliary system checks.

Post Startup Inspection for a Hot Water Boiler

Circulating Pump

The hot water system circulating pumps should be checked on a regular basis for proper operation. Some circulating pumps have stuffing boxes which need to be checked for proper amount of leakage. Other circulating pumps have mechanical seals, and should not show any signs of leakage. Each style of pump should have adequate flow of clean water to its seals for cooling, sealing, and lubrication. Ensure the pump is running quietly and without vibration. Monitor pump discharge pressure, suction pressure, and differential pressure to ensure the pump is operating within the expected range.

Flame

The boiler flame should be visually checked to ensure there is complete combustion. A typical natural gas flame is blue, with orange at the tip of the flame. A light fuel oil (number 2 light oil) flame should be bright yellow, with orange tips. Flames should never have black tips.

Flames should always be turbulent and symmetrical. They must not impinge on any refractory or metal surface, and there should be no hot spots on the diffuser.

Fuel Train

Periodically walk down (alongside) the line of the fuel train of the hot water boiler, and confirm there are no fuel leaks (fuel oil or natural gas). Check the pressure gauges on the fuel supply downstream of the pressure regulators and at the burner. Confirm the fuel oil pump suction and discharge pressures are operating within prescribed ranges, fuel pumps are not excessively noisy, and that vibration is minimal. Confirm that fuel flow is sufficient to meet the load demand of the boilers.

Operating Pressure

High pressure is a common unsafe condition found in hot water boilers. It is caused by the failure of the safety relief valve to open at the set pressure. Often, this is due to deposit buildup between the disk and seat of the valve, caused by the valve leaking or weeping. To prevent weeping and to protect the safety relief valve, the normal boiler operating pressure should be 25% or 69 kPa (10 psi) less than the safety relief valve setting.

Once the boiler has been fired, the system pressure should reach the desired set point and should not increase beyond that point. The tridicator gauge on the boiler should have its movable hand (actual system pressure) above the stationary hand (full system pressure). This indicates that the boiler pressure is greater than the minimum required to keep the heating system full. A general rule is that the movable hand should read at least 1.2m (11.8 kPa) greater than that of the stationary hand.

Stack Temperature

Monitor and record the stack temperature once the boiler has completely warmed up, and the system has been brought to normal operating pressure and temperature. Along with this reading, record the boiler load or firing rate. Rising stack temperatures, at a given firing rate, indicate heat transfer surfaces are becoming dirty. Comparing this reading over time will help determine when waterside or fireside surfaces require cleaning.

Water Temperature

For hot water heating systems, the maximum operating temperature of the boiler water should never exceed 120°C. It should be as low as possible to heat the space adequately under design conditions. Higher temperatures will accelerate corrosion.

Monitor water temperature to ensure the heating needs of the system are being met, and to prove that the boiler operating controls are functioning properly. Observe that the **aqua-stat** cuts off the burners once the temperature set point is reached.

Expansion Tank

For hot water systems, check the expansion tank pressure regularly. The pressure in this type of system may vary, but in most systems (those having a MAWP of 207 kPa), boiler pressure should not go below 80 kPag, or above 140 kPag.

If the expansion tank bladder has failed, or if a non-bladder style tank is full of water, there will be no room for expansion as the water is heated. This will result in the safety valve opening. Figure 7 is an example of an expansion tank.

Figure 7 – Expansion Tank

Post Startup Inspection for a Steam Boiler

Water Level

Maintaining water at a safe level in a boiler is of vital importance. The boiler water must not be allowed to go low enough to endanger the boiler through overheating. As well, the water level must not be so high that it interferes with steam/water separation drum internals, or enters into the steam outlet piping.

Water level maintenance includes checking the water level controls, indicators, and recorders, and ensuring they agree with one another. Check that the water level is being maintained within range in the boiler. Check the boiler feedwater control valve is responding to drum level changes as expected. This is a critical step in steam boiler operation and should be checked using direct methods (observing the gauge glass), and indirect methods (at the control panel).

Feedwater Pumps

Confirm feedwater pump operation by checking suction and discharge pressure, noise, vibration, and flow rate. Inspect the shaft seals for leakage. Ensure pump and motor bearing lubrication and temperature is within range. Periodically alternate the boiler feed pumps (perhaps once a month).

Flame

The boiler flame should be visually checked:

- A typical natural gas flame is blue, with orange at the tip of the flame.
- A light fuel oil flame should be bright yellow, with orange tips.
- Flames should never have black tips or appear smoky.
- Flames should always be turbulent and symmetrical.
- Flames must not impinge on any surface.
- Flame diffusers should not have hot spots.

Figure 8 shows a port for observing a boiler flame. The manually operated gate protects the observation glass from excessive heat when the flame is not being viewed. When the gate is open, the observation port glass is protected by a flow of cooling air.

Figure 8 – Air-Cooled Observation Port for Viewing a Boiler Flame

Fuel Train

Periodically walk down (alongside) the fuel train line of the steam boiler, and confirm there are no fuel leaks (fuel oil or natural gas). Check the pressure gauges on the fuel supply, downstream of the regulators, and at the burner. Confirm fuel oil pump suction and discharge pressures are operating within prescribed ranges, fuel pumps are not excessively noisy, and that vibration is minimal. Confirm fuel flow is sufficient to meet the load demand of the boilers. Record both burner pressure and firing rate, to help evaluate whether the burner is operating properly.

Operating Pressure

Steam Heating Boilers

Commonly, heating boilers are found unsafe because they have safety valves incapable of opening at their set pressure (105 kPa or 15 psi). Often, this is due to deposit buildup between the disk and seat of the valve, caused by valve leakage. To prevent weeping and to protect the safety valve, normal steam heating boiler operating pressure should be 35 kPa (5 psi) less than the safety valve setting. In other words, the boiler pressure set point should not exceed 70 kPa (10 psi). This pressure differential is also required to help ensure that the safety valve will seat tightly after popping, and when the boiler pressure returns to normal.

Power Boilers in Steam Service

Power boilers must have a high steam pressure cut-off to prevent the boiler pressure from exceeding the boiler's maximum allowable working pressure. Preferably, the high-pressure cut-off should be set to the boiler safety valve with the lowest set point, minus the safety valve blowdown. For example, a safety valve may be set to 1035 kPa and have a blowdown of 23 kPa. The high-pressure cut-off should be set to no greater than 1012 kPa. This will allow a popping safety valve to reseat before the high-pressure cut-off permits recycling of the boiler.

Once the boiler has been fired, observe that the steam pressure reaches the desired set point, and does not increase further. Confirm operating controls maintain set point under changing load conditions.

Stack Temperature

Monitor and record the stack temperature once the boiler has completely warmed up and is at normal operating pressure. Along with this reading, record the boiler load or firing rate. Rising stack temperatures, at a given firing rate, may indicate heat transfer surfaces are becoming dirty. Comparing this reading over time will help determine when waterside or fireside surfaces require cleaning.

Chapter Summary

Boiler plant startup is a critical process for a Power Engineer. It is a time when plant conditions are constantly changing, requiring the operator to have a high situational awareness.

In this chapter, starting hot water and steam boilers were discussed highlighting the checks required in each scenario. The conditions surrounding a cold startup of a boiler along with warm-up rate considerations were also covered to ensure the Power Engineer is equipped with knowledge to proceed through these evolutions safely. The safe and effective methods for cutting boilers into their systems was also examined to equip the operator with sound knowledge on how to take their equipment on line and support the process for which they were intended.

A thorough understanding of the content of this chapter should prepare a Power Engineer for starting various boiler plants.

Chapter 3

Boiler Operation

Learning Outcome

When you complete this chapter you should be able to:

Describe operational procedures related to operating boilers.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the operation of a hot water heating boiler under routine conditions.*
2. *Describe routine steam boiler operating duties.*
3. *Describe emergency conditions in boiler plants and the required responses.*
4. *Describe basic boiler troubleshooting activities.*

Chapter Introduction

When a power plant is in a normal operating state, the boilers are producing steam and the process equipment is operating. Most of the time, this is the condition that an operator will encounter. It is of utmost importance that the operator knows, and pays attention to, all of the key operating parameters. The operator must not become complacent while monitoring equipment. During these times, problems can be discovered and remedied before they cause equipment failure or a shutdown.

It is important to comprehend the preceding material on boiler startup in order to understand the content of this chapter. This content includes:

- Routine monitoring checks for hot water and steam boilers
- Emergency operation
- Basic boiler troubleshooting

Objective 1

Describe the operation of a hot water heating boiler under routine conditions.

Generally, hot water heating boilers do not legally require continuous supervision. For this reason, regular checks of hot water heating boilers takes on additional importance. Operators must be certain that during the unsupervised period, the boiler will function safely and efficiently. Routine boiler checks include pressure, temperature, flame condition, and stack temperature. Also, pump operation, make-up water supply, and water treatment must also be monitored.

Hot Water Boiler Operation

Most hot water boilers are fully automatic. This means they start when there is a call for heat, they automatically maintain the hot water at set point, and stop when heating conditions are satisfied, all without operator intervention. As well, the burner programmed combustion control sequences the operation of the burner, maintains safe and efficient burner operation, and shuts down the boiler when an unsafe firing condition exists.

Despite their automatic systems, hot water boilers still need regular attention to ensure safe and dependable operation. Below is a general list of routine operation procedures.

Daily Routine Procedures

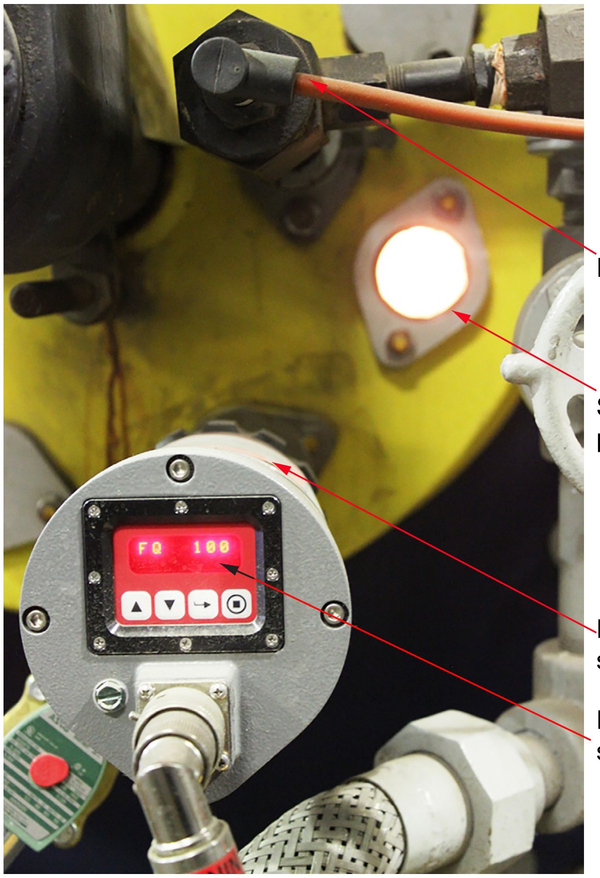
There are several checks and functions that operators must perform every day to ensure the safe operation of the boilers under their care.

Burner Operation

Observe the condition of the burner flame. It should be bright and symmetrical. When burning natural gas, it should be predominantly blue. Some orange colouring at the flame tips is unavoidable, and considered acceptable. A light fuel oil flame should be bright yellow, with orange at the tips of the flame.

Observe the flame signal on the **flame scanner** or **programmed combustion control**.

Figure 1 – Flame Scanner Showing a Flame Signal



Check the chimney for any signs of smoking. A white plume indicates the presence of water vapour from the combustion process. It is not a problem unless the surrounding area shows signs of white **ash**.

If the flame is smoky, the burner nozzle may be dirty (oil firing), the fuel temperature may be too low (heavy oil firing), or the fuel-air ratio may be incorrect (gas and oil firing). Take the necessary action to correct these conditions. This may involve hiring a certified burner technician, gas fitter, or oil fitter to perform combustion analysis, and adjust the air-fuel ratio.

Check the combustion air intake to the boiler room. Remove any obstructions from the outside or inside of the intake, such as snow, frost, litter, and dirt.

Flue Gas Temperature

Check the temperature of the flue gases regularly. This is a good indication of the effectiveness of the heat exchange between the flue gases and the boiler water. When the heating surfaces are clean on the fire and watersides, the heat transfer is most efficient. This results in the lowest flue gas outlet temperature at a given firing rate.

Waterside **scale** and sludge deposits, and fireside **soot** deposits caused by poor combustion, foul the heating surfaces, and reduce heat transfer. When heat transfer surfaces are fouled, flue gases leave the boiler at a higher temperature, reducing boiler efficiency. Flue gas temperature should be recorded regularly. By tracking the stack temperature, a gradual increase in temperature can be identified. This informs the operator that the heating surfaces are fouling, and that heat transfer efficiency is decreasing. Fireside or waterside cleaning may be required.

A small rise in flue gas temperature lowers boiler efficiency, but will not harm the boiler. An excessive temperature rise indicates serious trouble. Excessive soot indicates potentially dangerous furnace conditions that may result in a furnace explosion. Heavy scale build-up may cause the tube temperature to rise above the safe limit, and damage the tubes.

High flue gas temperature can also result from too much excess air. When this happens, gases travel at a higher velocity through the furnace and gas passes. This reduces the amount of time for the heat to transfer to the heating surfaces, and results in higher flue gas temperatures. To correct this situation, a flue gas analysis must be performed, and the excess air adjusted to the manufacturer specification. This should be done by a licensed gas fitter, oil fitter, or burner technician.

Boilers that are over-fired may also have abnormally high flue gas temperature. Over-firing is when the burner produces more heat than the boiler is designed to transfer. This may occur if the main fuel regulator is providing excessive fuel pressure. A qualified burner technician should be hired to set up the burner to factory specifications.

Boiler Water Temperature

Check that the boiler discharge water temperature is at, or near, the hot water supply set point. The operating temperature of the boiler water should not be higher than is necessary for adequate building heat.

Unless the boiler is a condensing type, the hot water set point must not be below 75°C, to prevent flue gas condensation. Too low of a temperature will cause chimney, vent connector, and fireside corrosion. Hot water heating boilers must never operate above 120°C. Check that the high temperature cut-off is set to below 120°C.

Boiler Pressure

The operating pressure of low-pressure hot water heating boilers varies considerably, because of the many different types of buildings they serve. However, **ASME VI** states that the differential between the safety relief valve set pressure and the boiler operating pressure should be at least 69 kPa or 25% of the safety relief valve setting, whichever is greater. For example:

- If the safety relief valve is set to open at 250 kPa, the operating pressure should not exceed 180 kPa.
- If the safety relief valve is set to open at 828 kPa, the operating pressure should not exceed 621 kPa.

This is to ensure the safety relief valve stays tightly closed unless required to open. With a small pressure differential, the valve may leak or weep. This may cause solid deposits on, or corrosion of, the safety valve seats. Either condition may prevent the valve from opening at its set pressure, which may lead to pressure vessel failure.

Self-Test 1

A hot water boiler has safety valves set to 1100 kPa. Determine the maximum pressure at which the boiler should operate.

825 kPa (Ans.)

Water Losses and Make-Up Water Supply

To ensure satisfactory operation of the entire system, the operator should regularly check that the heating system is completely filled with water. Under ideal circumstances, a hot water system should not require **make-up water** once the system is properly filled and vented. However, small leaks may not be easily noticed. Any loss of water will require make-up water.

When make-up water is needed on a regular basis, the water losses may be caused by:

- Leaking piping and valves
- Leaking circulating pump packing or seals
- Leaking boiler
- Full expansion tank

Most hot water heating systems use automatic feed valves to add make-up water. When make-up is added automatically, water losses may not be easily noticed, especially in large heating systems. In systems that do not make up water automatically, leaks reduce the amount of water in the system. At first, this will show up as a reduction in boiler pressure. Depending on the type and location of the expansion tank, a drop in the expansion tank level may be noticed. If left unaddressed, the upper part of the piping system will run dry, and parts of the building will be cold.

In an upfeed system, the boiler is located in the lowest part of the heating system. Minor water losses will not seriously affect the operation of the boiler, but it will affect the heat supply to the upper floors of the building.

If the heating system is equipped with an automatic make-up valve, installing a water meter in the make-up line may be a worthwhile investment. Early detection of abnormal water make-up due to leakage in piping and heat exchangers may prevent costly structural damage.

Expansion Tanks

A common cause of water loss from a hot water heating system is due to a lack of expansion volume in the **expansion tank**. This can occur for several reasons:

- Bladder-style expansion tanks may have lost their air charge.
- Bladder-style expansion tanks may have damaged bladders.
- Conventional air cushion expansion tanks may leak air from fittings, such as dry gauge glass gaskets and leaky vent valves.

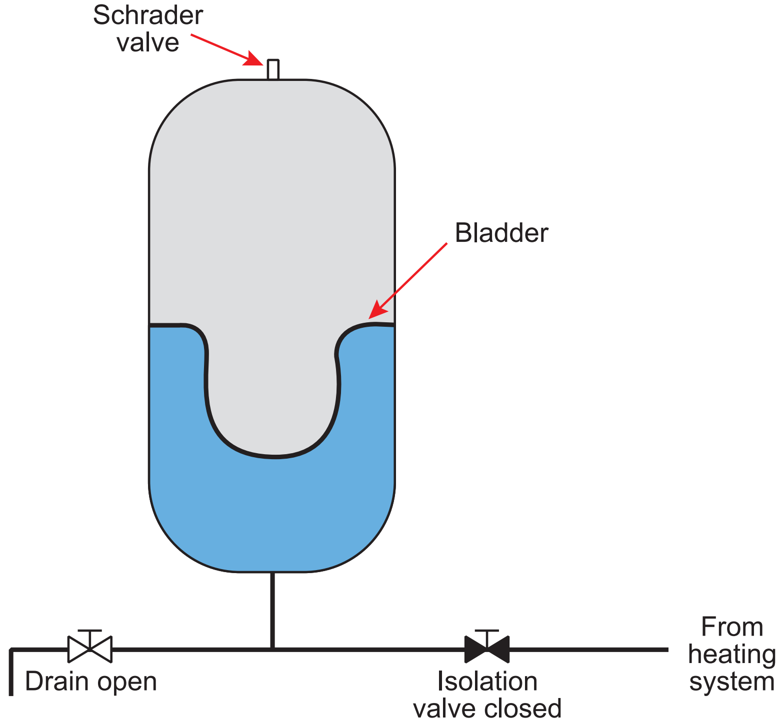
When an expansion tank is full, the piping system cannot accommodate the increase in water volume that occurs when the boiler fires. This volume increase pressurizes the boilers to higher than the safety valve set point, causing the valve to open and discharge water. This occurs repeatedly as the system water increases in temperature and expands. If unaddressed, a full expansion tank causes water, heat, and chemical wastage. As well, corrosive and scale-forming compounds are introduced to the system by the make-up water, which causes system damage.

Bladder-Style Expansion Tanks

Check expansion tanks regularly to ensure they have adequate room for expansion. For bladder-style tanks (Figure 2), to check the air charge:

1. Isolate the expansion tank by closing the isolation valve.
2. Drain the water from the tank by opening the drain valve.
3. Use a tire pressure gauge to read the tank pressure. This pressure will vary according to the type of tank and the system requirements. Typically, the correct pre-charge is indicated directly on the expansion tank.
4. To adjust the air pressure, use a simple hand pump to add additional air.
5. After adding air, shut the drain and re-open the tank to the heating system.

Figure 2 – Bladder-Style Expansion Tank



If the tank pressure does not increase when adding air, the tank bladder may be damaged. An easy check is to depress the **Schrader valve** stem while the system is in operation. If water issues forth with air, the bladder is likely damaged, and must be replaced. Some tanks do not permit bladder replacement; therefore, the tank itself must be replaced.

Sometimes the Schrader valve will leak air, and cause the tank to fill with water. The Schrader valve can be re-cored with parts available from any tire shop. After replacing a bladder, or re-coring a Schrader valve, recharge the tank.

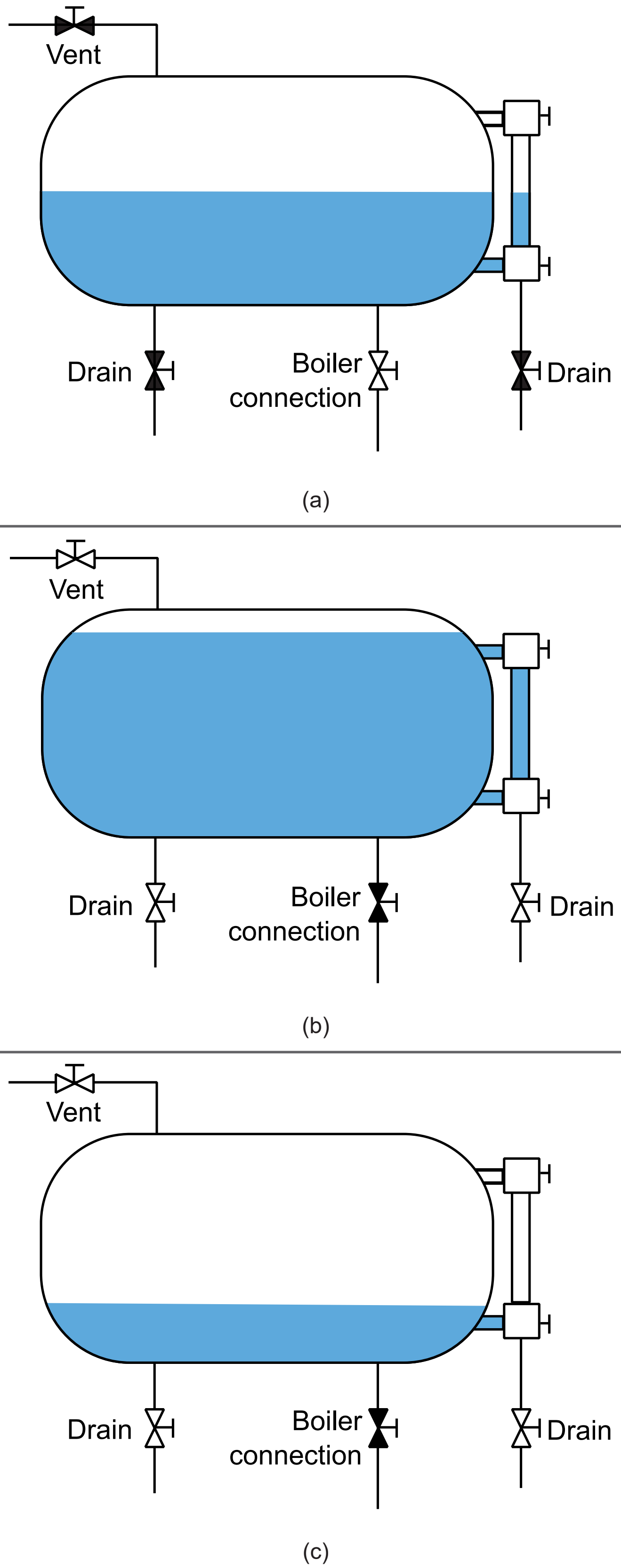
Conventional Air Cushion Expansion Tanks

Conventional air cushion expansion tanks may fill with water if fittings are passing air. It is important to determine and repair the cause of the air leak before returning the expansion tank from service. A common leak source is old, brittle, and cracked **gauge glass** gaskets. When the expansion tank is isolated and drained, the gaskets can be easily renewed. Leaky vent and drain valves can be replaced at this time as well. It is good practice to use pipe plugs or caps on the vent and drain lines to further secure the system from air leaks.

Figure 3(a) shows a conventional air cushion expansion tank in normal service. The vent and drain are shut, and the line to the boiler is open. If the tank loses air, it fills with water, as shown in Figure 3(b). To drain the expansion tank, shut the valve to the boiler or heating system, open the drain valve, and then open the vent. The gauge glass drain can also be opened at this time. When the tank is drained to below the bottom of the gauge glass (Figure 3(c)), the drain valves can be shut. This is a good opportunity to renew gauge glass gaskets.

To restore the expansion tank to service, shut the vent valve, and ensure the drains are shut. Then, slowly restore the boiler isolation valve. After restoring the expansion tank to service, the position of the valves should resemble Figure 3(a).

Figure 3 – Draining a Conventional Air Cushion Expansion Tank



Water Treatment

Hot water heating systems require internal chemical treatment to prevent corrosion and scale formation. When these systems use little or no make-up, they require little **internal water treatment**. For systems that have had major leaks, equipment repair, or equipment replacement, additional treatment chemical is required.

Closed hot water heating systems are checked regularly to make sure the water has a residual of corrosion inhibitor. Some systems are tested monthly, by drawing a water sample and performing a chemical residual test. Water treatment chemicals are often "shot fed" into the system, using a pot feeder. All water treatment should be based on boiler water analysis and the advice of a water treatment professional.

Blowoff and Blowdown

Under normal conditions, hot water heating boilers are not blown off or blown down. The **blowoff** valves are usually opened only to drain boilers that require structural repair or waterside inspection. **Blowdown** valves are operated more regularly to test low water cut-offs. Restricting blowoff and blowdown reduces the need for internal water treatment, because it reduces the amount of make-up required.

Objective 2

Describe routine steam boiler operating duties.

Larger capacity steam boilers require continuous supervision. This is because of the hazards they pose to public safety. Steam boiler operators must attend to steam pressure, water level, and burner conditions with vigilance. Safety devices, such as **low water fuel cut-offs (LWCO)** and limit controls must be verified regularly. Flue gas temperature, quality of feed and make-up water, and heat transfer efficiency are part of the operator's regular inspections. These and others are discussed in this objective.

Steam Boiler Operating Duties

Most packaged steam boilers are now fully automatic. However, they still need regular attention to ensure safe and dependable operation. Below is a general list of routine operation procedures.

Daily Routine Activities

Operators must perform several checks and functions every day. This is to ensure the safe operation of the boilers under their care.

Checks include:

- Burner operation
- Flue gas temperature
- Steam pressure
- Water level
- Low water fuel cut-offs, and float-type water level controls
- Heat transfer

Operator duties include:

- Boiler water treatment tests
- **Feedwater** treatment tests
- Make-up water monitoring and tests
- **Continuous blowdown (CBD)** adjustment
- Bottom blowoff
- Routine inspection
- Housekeeping
- Log book entry

Burner Operation and Flue Gas Temperature

Burner operating principles are the same for hot water and steam boilers. Refer to Objective 1 for guidance on conducting burner checks.

Steam Pressure

When going on duty, always check the boiler steam pressure. In order to maintain the boiler pressure at set point, the amount of fuel burned must correspond to the boiler load. That is, if the boiler load (the rate of steam demand of the boiler) increases, then the amount of fuel burned in the boiler furnace must increase. If the boiler load decreases, then the amount of fuel burned must also decrease.

The amount of fuel admitted to the furnace is normally controlled by an automatic system which senses changes in steam pressure and adjusts the fuel feed accordingly. However, the operator must be able to take over from the control system in case of failure of the automatic arrangement. Therefore, the operator must be familiar with the method of changing over from automatic to hand control.

Boiler pressure should be between the cut-in and the cut-out of the operating control. Do not carry a higher pressure than is necessary to satisfy the heat load.

Boiler pressure should not be greater than the operating control cut-out set point. Under no circumstances should boiler pressure be higher than the setting of the high-pressure cut-off.

The operating control cut-off should be set to prevent the boiler pressure from approaching the setting of the **safety valve**. If subject to pressure at or near its set pressure, safety valves will tend to weep or simmer. This will cause deposits to accumulate in the seat and disk area. Eventually, this can cause the valve to seize shut and fail to open at the set pressure, causing a rupture of the boiler shell, drum, or tubes. Therefore, the pressure differential between the safety valve set pressure and the boiler operating pressure control must be great enough to prevent the valve from weeping or simmering. Table 1 shows the guidelines for operating control set point, given the set pressure of the lowest set safety valve of the boiler.

Table 1 – Minimum Pressure Differential Between Safety or Safety Relief Valve Setting and Maximum Boiler Operating Pressure (According to NBBI)

Power Boilers (Steam)		Heating Boilers (steam)	Heating Boilers (Hot Water)
100 kPa to 2100 kPa	10% but not less than 50 kPa	35 kPa (Boiler operating pressure should not exceed 70 kPa)	70 kPa, or 25% of the safety valve setting, whichever is greater
Over 2100 kPa to 6890 kPa	7% but not less than 200 kPa		
Over 6890 kPa to 13800 kPa	5% but not less than 480 kPa		
Over 13800	Per designer's judgement		

Example 1: Hot Water Heating Boiler

A hot water heating boiler safety relief valve is set to 207 kPa. What should the maximum boiler operating pressure be?

Solution 1

The **National Board of Boiler and Pressure Vessel Inspectors (NBBI)** recommends that the difference in pressure between the safety relief valve and the maximum operating pressure should be the greater of 70 kPa or 25% of the safety valve setting.

$$207 \times 0.25 = 51.75 \text{ kPa}$$

Choosing the greater of 70 kPa or 25%, the maximum recommended boiler operating pressure is:

$$207 - 70 = \mathbf{137\ kPa\ (Ans.)}$$

Example 2: Power Boiler

A steam power boiler has a safety valve set point of 1725 kPa. What should the maximum boiler operating pressure be?

Solution 2

The NBBI recommends that the difference in pressure between the safety valve and the maximum operating pressure should be 10% of the safety valve setting, but not less than 50 kPa.

$$1725 \times 0.10 = 172.5$$

Choosing the greater of 50 kPa or 10%, the maximum recommended boiler operating pressure is:

$$1725 - 172.5 = \mathbf{1552.5\ kPa\ (Ans.)}$$

Self-Test 2

A steam power boiler has a safety valve set point of 2760 kPa. What should the maximum boiler operating pressure be?

2560 kPa (Ans.)

Water Column and Gauge Glass

The most important rule in the safe operation of steam boilers is to keep water in the boiler at the proper level. Never depend entirely on water level controls, emergency water feeders, or automatic alarms. The gauge glass is the primary indicator of boiler water level, and must be reliable.

Precipitated sediment accumulates in areas of slow boiler water circulation. This includes **float cages** for feeders, level control switches, **water columns**, and low water fuel cut-offs. If sediment is permitted to accumulate, the water connection piping may plug off and render the level controls inoperative. For this reason, the gauge glass, water column, low water cut-offs, and all boiler connecting piping should be blown through at regular intervals. This ensures the lines are clear, that sediment cannot accumulate in the float cages, and that the controls are operative.

When a considerable amount of make-up water is used, the gauge glass and water column should be blown down daily. When little or no make-up water is required, blowing the column and glass through should be part of the weekly routine. After blowing through, the level should quickly return in the glass.

Side Track

Specific details on blowing down a water column and gauge glass are in the chapter on **Operational Checks (Part B, Unit 4, Chapter 4)**.

Keep the gauge glass clean, so that the water level can be easily identified. If rust is evident in the gauge glass, check the boiler water to make sure that the water treatment chemicals are at the proper concentration. Also, check the return line and other parts of the system for evidence of corrosion. **Condensate pH** is a good indicator of condensate system corrosiveness.

Make sure that the water level is relatively steady. A wide fluctuation of the water level may indicate that the boiler is **foaming** or **priming**. This problem may be caused by the water level being carried too high, or by a very high rate of steaming (especially in low-pressure boilers). Foaming may also be caused by an excessively high concentration of dissolved or suspended solids in the water, or by the presence of oil.

Mild cases of foaming can be controlled by the use of antifoam chemicals. More severe foaming is usually controlled by blowdown. Lower the level in the boiler by 5 to 8 cm, and refill to the normal level. Repeat this several times. In persistent cases, it may be necessary to take the boiler out of service, and to cool, drain, and wash it out thoroughly. Then refill the boiler, and put it back into service.

Low Water Fuel Cut-Offs and Float-Type Water Level Controls

If a considerable amount of make-up water is used, the housings of these devices should be blown through daily, to remove sediment.

Testing of a low water cut-off should be done regularly to prove it will trip the boiler. Three common tests are as follows:

1. Draining the float chamber (intermittent blowdown), to see if the control shuts off the boiler.
2. Isolating the feedwater, and blowing off the boiler (a “slow drain” test).
3. Isolating the feedwater, and allowing the boiler to steam off water.

Side Track

Specific details on low water cut-offs, and boiler level controls are in the chapter on **Operational Checks (Part B, Unit 4, Chapter 4)**.

Table 2 – Periodic Testing of Level Controls per ASME CSD-1

Type of Boiler	Test Frequency		
	Daily	**Weekly**	**Semi-Annually**
High-Pressure Boilers	Test the low water fuel cut-off device according to the manufacturer instructions.		
Low-Pressure Boilers		Test the low water fuel cut-off device according to the manufacturer instructions.	
Steam Boilers			Perform a slow drain test in accordance with ASME Boiler and Pressure Vessel Code, Section VI.

Heat Transfer

To allow for the most efficient transfer of heat to boiler water, it is necessary to keep the heating surfaces free from soot and ash. While the boiler is in service, this is accomplished by soot blowing. **Soot blowers** should be operated when required. In some cases, once a shift is sufficient.

The boiler load should be above 50% of maximum when sootblowers are in service, which ensures the burner flame is strong enough to remain stable. This also ensures that the fine dust will be carried rapidly from the furnace, before an explosive mixture forms.

Another cause of poor heat transfer is the formation of scale on the heating surfaces. Scale formation can be prevented by proper treatment of the feedwater, boiler water, and proper regulation of the amount of intermittent and continuous blowdowns. For these reasons, the operator must take regular tests of water conditions as outlined below.

To ensure heat transfer is efficient, it is necessary to regularly monitor the flue gas temperature, firing rate, and steam production. In smaller plants, it may only be possible to compare daily fuel consumption and flue gas temperature to provide indication of heat exchanger fouling. In larger plants, chart recorders may track steam production, fuel flow, and flue gas temperature on a common screen for easier analysis.

Water Treatment

Take samples of the boiler water, deaerated feedwater, and condensate. Perform the required tests at the intervals laid out in the water treatment program. From the results of these tests, determine the amount of chemicals required to give the boilers and the system the greatest protection. Fill the mixing tanks and pot feeders accordingly, and start the feeding of chemicals. Blow off the boilers as needed. Monitor the external water treatment equipment. Filters may require backwashing, and ion exchange softeners may need regeneration.

Continuous Blowdown

The continuous blowdown (CBD) should be opened just enough to keep the concentration of dissolved and suspended solids below the maximum allowed. Keep in mind that excessive blowdown is wasteful, and will increase operational costs. Record the CBD setting and the boiler water conductivity in the daily log.

Inspection

Make a full inspection of the boiler. Check for any signs of leakage from the following:

- Safety valves
- **Manholes**
- **Handholes**
- Clean-out plugs
- Valves
- Pipe connections

Determine the cause of any unusual noises or conditions, initiate work requests, and record these in the daily log.

Auxiliary Equipment

Check the operation of the auxiliary equipment in the boiler room. This includes feedwater, condensate, and vacuum pumps. If the boiler is oil-fired, check the operation of the fuel pump, clean the filter if necessary, and check the fuel level in the tank.

Housekeeping

Keep the boiler room and equipment clean. Wipe up oil spills immediately. Remove all articles that may present a fire hazard. Store materials needed in the boiler room in such a way that they cannot cause an accident.

Boiler Log

Maintain the Boiler Room Log. Record each test performed, the time of the test, and the result of the test. Record each condition observed. Record each adverse condition that occurred, the time of occurrence, and the steps taken to immediately address the adverse condition. Sign and date each entry.

Make-Up Water

Use every practical means to exclude oxygen from the boiler water. Since make-up water is a source of oxygen, try to keep make-up to a minimum. Monitor the make-up water flow, and calculate the percentage of make-up water used. Depending on the plant and the processes that consume the steam, the percent make-up should be quite regular. Unexplained increases in make-up water indicate an abnormal system water loss.

Low-pressure steam boilers often do not have comprehensive flow metering. When used exclusively in heating service, a loss of 7 – 8 cm of water per month in boiler water level indicates possible water leakage. The leak should be found and repaired.

If a steam heating system includes a condensate return tank, it is preferable to feed make-up water into the condensate tank instead of directly into the boiler. Since the condensate is relatively hot, while make-up is usually much cooler, the condensate will raise the temperature of the make-up water. As a result, a large part of the dissolved gases in the water will be released. These gases are then vented to the atmosphere from the top of the tank with any air returned from the system with the condensate.

Objective 3

Describe emergency conditions in boiler plants and the required responses.

Emergency conditions in a boiler plant require rapid response to prevent worker injury or property damage. Although there are many automatic safeguards that serve to protect against catastrophe, the boiler operator is the first and last line of defense. The operator should be trained to recognize a situation that may lead to an emergency, and take actions towards its prevention. Low water level, high water level, fan failure, or flame failure are adverse conditions that will be discussed in this objective.

Emergency Conditions

The following situations are rare occurrences if the boiler has been receiving proper routine operation and care. Nevertheless, when upset conditions do occur, they can develop rapidly into serious situations. The operator must be prepared to act calmly and efficiently; this requires a prior knowledge of emergency procedures. The following list is general in nature. Every operator must become completely familiar, and at ease, with the specific procedures in the plant. Emergency conditions that will be discussed in this objective include:

- Low water level
- High water level
- **Draft fan** failure
- **Flame failure**
- Broken gauge glass
- Loss of electrical power to plant (shut down boiler safely without power—no feedwater supply)
- Loss of feedwater pump
- Loss of fuel supply

Low Water Level

A rapidly falling water level in the boiler may be caused by:

- A faulty feedwater level controller
- Feedwater or condensate pump failure
- Interruption of the water supply to the pump
- Leakage from the boiler due to ruptured tubes or open blowoff valves

Normally, when the level drops to the low water cut-off point, the boiler will shut down automatically. However, should the cut-off fail to shut the boiler down, the water level may drop to a dangerous level.

If the operator finds the boiler in operation while unable to see the water level in the gauge glass, it may be that the glass is either completely full, or completely empty. This status should be checked quickly by opening the drain on the glass. If the level is found to be below the gauge glass, the boiler fuel and air should be shut off immediately.

CAUTION

If a boiler sustains a low water condition, do not feed water into the boiler to raise the level. Do not open the safety valve or vent valve to release pressure. A sudden flow of cool feedwater will quench any overheated heating surface, which could cause a catastrophic failure.

Let the boiler cool slowly until it is at hand-touch temperature. Then drain it, and open it to inspect for damage due to overheating. If no damage is found, the boiler can be closed up again and filled. However, it should not be put back into operation until the cause of the feedwater shortage, and the failure of the low water cut-offs to shut the boiler down is found and corrected.

If there is any possibility that the boiler has been damaged, the Boiler Inspector must be notified.

Upon discovery of a low water level below the lowest visible point of a gauge glass, immediately shut off the fuel and air to the boiler.

High Water Level

High water level can cause severe plant damage and loss of life if water should enter steam lines. If the water in the gauge glass of a boiler is higher than normal, the level should be brought back to normal by manually reducing the feedwater flow to the boiler. If the water level does not enter the visible range of gauge glass within two minutes, operate the main blowoff valves to lower the water level.

If the water level is proven to be above the visible range of the gauge glass, shut off the feedwater, fuel, and combustion air in that order.

If **carryover** or priming is suspected, it is necessary to isolate the boiler from the main steam header. Open the drain valve between the boiler outlet and header valve, open all **superheater** drain valves, and then close the main steam valve at the header.

The underlying cause of the high water condition must be determined, and the appropriate corrective action taken, before resuming normal operation. The water level should be controlled manually until the automatic control is known to be functioning correctly. It may be necessary to manually operate the level control system while the fault is being determined and repaired. This may be done with the control system in manual, or with the feedwater control valve isolated and the bypass valve throttled.

CAUTION

When manually controlling drum level with a bypass valve, at least two operators must be present. One operator must be stationed at the feedwater bypass valve, ready to receive instruction from the other operator.

Draft Fan Failure

Should the draft fan fail, the supply of combustion air will cease. This failure may be due to a:

- Motor or fan bearing failure
- Tripped breaker
- Broken coupling between the motor and fan
- Broken drive belt

If a draft fan fails, the fuel supply must be shut off immediately to prevent a furnace explosion. Modern automatically-fired **packaged boilers** are equipped with a low-air cut-off switch, or combustion air proving switch, that will cut the power to the fuel **safety shut-off valves (SSOV)** as soon as the pressure at the blower discharge, or windbox, drops below the minimum safe value.

Flame Failure

Some of the reasons why the flame may fail during operation include:

- Insufficient fuel oil supply due to a plugged filter
- Water in the fuel oil
- Excessive air supply
- Insufficient gas pressure

When flame failure occurs, the fuel flow must stop immediately to prevent the furnace from filling with unburned fuel, causing an explosion. Nearly every fluid-fired boiler is equipped with flame detection devices that shut off the fuel supply immediately after the flame fails. Regular testing of the operation of these devices is a must.

Side Track

Specific details on flame failure devices are in the chapter on **Combustion Safety (Part B, Unit 3, Chapter 2)**.

Boiler Accidents

Investigations show that the great majority of boiler accidents could have been prevented. These investigations also show that the number of accidents can be significantly reduced through the proper application of operating procedures and maintenance logs.

Some reasons that boiler accidents occur include:

1. The misconception that no supervision is required for automatically fired boilers.
2. The inexperience or lack of training of operating personnel.
3. Inadequate maintenance of boilers and controls.
4. Overheating of the heating surfaces due to a low water condition caused by failure of operating or protective controls.

Although automatically fired packaged boilers are well protected by automatic devices, these devices are only as good as the maintenance they receive.

Since these boilers require little attention during operation, it is easy to neglect the mandatory, regular checking of operating and protective devices. Unknown to the operator, these controls may become inoperable due to neglect. Such a malfunction means trouble when adverse conditions develop.

Boiler Explosions

Boiler explosions may be listed under two general classifications:

1. Furnace explosions
2. Pressure explosions

In both cases, the results of an explosion are almost always extensive damage to property, and either personal injury or loss of life. The operator must know the basic causes of explosions, and refrain from unsafe practices that may lead to them.

Furnace Explosions

Furnace explosions occur when an explosive air/fuel mixture ignites and explodes within a boiler's furnace or gas passes. These may be caused by:

a) Insufficient purge of the furnace before lighting.

b) Repeated unsuccessful attempts to light off without appropriate purging, resulting in the accumulation of an explosive mixture.

c) Admission of the fuel to the main burner before the **pilot burner** or other ignition source is established.

d) Fuel leakage into an idle furnace, and the subsequent ignition of the accumulated explosive mixture. This may be caused by defective safety shut-off valves, or valves with foreign matter under their seats.

e) A brief interruption of the fuel supply, air supply, or ignition energy to the burners. This may cause momentary loss of flame, followed by restoration, and delayed re-ignition of the accumulated explosive mixture.

f) The accumulation of an explosive mixture of fuel and air as a result of a complete furnace flameout, caused by the failure of the main fuel safety shut-off to close on main flame failure.

g) A pilot flame too small or unstable to effectively light the main burner.

h) An insufficient amount of combustion air, resulting in incomplete combustion. This may create pockets of combustible gas products in the gas passages that may ignite on increase in firing rate.

i) Attempting to light burners from hot refractory.

j) The accumulation of an explosive fuel/air mixture as a result of flame failure; or incomplete combustion of one or more burners in the presence of other normally operating burners; or during the light-off of additional burners.

Pressure Explosions

Pressure explosions occur when a pressure part of the boiler, such as the shell, watertube, or firetube, bursts due to excessive steam pressure or structural weakness. The causes include:

a) Weakening, due to corrosion.

b) Overstressing of the material, due to overly rapid boiler warm-up.

c) A low water condition combined with a low water fuel cut-off failure. Low water can cause overheating and weakening of the heating surfaces.

d) Scale and sludge buildup, causing overheating and weakening of the heating surfaces.

e) Failure of the boiler operating controls, combined with an inoperative pressure relief valve, may cause the pressure to rise far above the maximum allowable working pressure.

Even though most boilers are fully automatic, the boiler operator should pay regular attention to how the boiler is operating. The operator should conscientiously follow the instructions regarding testing and maintenance of fittings and controls in order to prevent an explosion.

If an explosion does occur, the person in charge of the boiler or pressure vessel must notify the proper authorities.

In the event of an explosion, legislation generally states that the person in charge must report all particulars concerning the explosion. This includes the exact place or location, names of persons killed or injured, and the cause of the explosion, if known. Nothing shall be moved or interfered with at the scene until an inspector has investigated the accident, and has determined the cause of the explosion, unless it is for the purpose of saving life or limb, protecting property, or the removal of the dead.

Objective 4

Describe basic boiler troubleshooting activities.

Many issues can arise during the operation of a steam or hot water boiler. The following list is not exhaustive, but covers many of the common problems experienced during routine boiler operation. Fundamental equipment knowledge must precede any boiler operation. This knowledge will be put to the test while troubleshooting.

Troubleshooting Guide

The following are some general guidelines to help find the cause of trouble that may occur during startup and operation of automatically fired boilers.

It is assumed that the boiler has been properly installed and adjusted, and that it has been in operation for some time prior to the onset of the problem. It is further assumed that the operator is thoroughly familiar with the firing equipment and controls, as well as, the boiler operations manual.

The points under each heading are stated as briefly as possible, to make it simpler to pinpoint the source of the trouble. Methods of correcting the trouble can usually be found in the boiler manual, or the accompanying equipment bulletins.

A good knowledge of the control system will make troubleshooting much easier. Costly downtime or delays can be prevented by systematic checks of the actual operation against the normal sequence, to determine at what point the operation strays from normal. Follow a routine so that obvious causes of trouble are not overlooked.

Table 3 – Troubleshooting Guide – Automatically Fired Boilers

Possible Cause	Remedy
Problem: Draft Fan Does Not Start	
1. Main disconnect switch open	Close switch.
2. Blown fuses, tripped overloads, loose electrical connections	Refer to manufacturer manual. Check for power to supply terminals on programming control. If master relay pulls in and timer starts but blower motor does not start, check for power on motor starter circuit.
3. Programmed combustion control flame failure, safety lockout switch tripped	Reset flame failure lockout switch on programmed combustion control.
4. Limit control circuit not completed	Boiler pressure or temperature above cut-in setting of operating control. Water below required level. Low water indication light, if provided, should indicate this condition. Check manual reset button, if provided, on low water fuel cut-off.
5. Motor defective	Replace motor.
6. Blower starts, but stops again after 5-10 seconds	Check the low air pressure switch.

Problem: No Ignition	
1. Lack of spark	Electrodes grounded, or porcelain cracked. Improper electrode setting. Loose terminal on ignition cable, cable shorted. Inoperative ignition transformer. Check appropriate program relay contacts.
2. Spark, but no flame	Lack of fuel, due to closed manual valves, clogged oil filter, empty fuel tank, incorrect pilot gas pressure, inoperative solenoid on pilot or low–fire fuel valve.
3. Low-fire switch open	Damper motor not operative, slipped cam, or defective switch. Damper jammed or linkage binding.
4. Programmed combustion control “test/run” switch in test position, and timer stopped in **pre-purge**	Place test/run switch in the run position.
Problem: Pilot or Low-Fire Flame, No Main Flame	
1. Insufficient pilot or low-fire flame	Adjust pilot or low-fire flame.
2. Supply to main nozzles restricted or cut off	Check for obstruction, or closed valve. Inoperative solenoid valve. Check oil nozzles.
3. Inoperative programmer	If flame relay does not pull in when pilot flame lights, check flame, detector, contacts, and amplifier. Flame detector defective, sight tube obstructed, or detector lens dirty. If flame relay pulls in but fuel valve is not energized, check for voltage at test jacks or programmer.
Problem: Burner Stays on Low-Fire	
1. Boiler pressure above high-low fire control setting	Wait until pressure drops to where there is a load demand.
2. Damper positioning switch in wrong position	Check damper linkage.
3. Inoperative damper motor	Check motor for cause and replace if necessary.
4. Defective high-low fire or modulating control	Replace modulating control.
5. Binding or loose linkage cams, setscrews, etc.	Repair linkages.

Problem: Shutdown Occurs During Firing	
1. Loss or stoppage of fuel	Check fuel system for reason.
2. Defective fuel valve, loose electrical connections	Repair or replace fuel valve.
3. Flame detector weak or defective	Change detector.
4. Lens dirty or sight tube obstructed	Clean lens or sight tube.
5. Limit switches open, interlocks open, or draft fan motor failure, combined with a programmer flame failure lockout switch that has not tripped.	The programmer flame failure light is energized when the programmer flame failure lockout switch is open. This may be caused by ignition failure, inadequate flame signal, or an open control in the non-recycling interlock circuit. The light will not be energized by the opening of any control in the limit circuit. Therefore, if the programmer flame failure light is off, check the limit circuit controls, interlock, or blower motor.
6. Lockout switch has tripped	Check fuel lines and valves. Check flame detector. Visually check appropriate timer and relay contacts (refer to program control manual). Check blower motor and all interlocks. Lockout switch malfunctioning. Sticky contacts; repair or replace.
7. Improper air-fuel ratio	Slipping linkage. Damper stuck open. Fluctuating fuel supply pressure. Temporary obstruction in fuel line. Pressure-reducing valve in gas line defective.
8. Interlock device inoperative or defective	Replace or repair interlock.
Problem: Air Dampers Not Functioning	
1. Damper positioning switch in wrong position	Place switch in correct position.
2. Linkage loose or jammed	Repair linkage.
3. Motor does not drive to “open” or close during pre-purge, or close to burner shutdown	Check appropriate contacts (see manual).
4. Motor does not operate on demand	Damper positioning switch in wrong position. High-low fire or modulating control improperly set or inoperative.

Chapter Summary

This chapter covered objectives surrounding hot water and steam boiler routine operation, along with emergency situations. It also provided a basic boiler troubleshooting guide. Power Engineers will use many of these concepts, from when they first start in a boiler plant, right through to the end of their career.

The importance of boiler water level can never be overstated. The same applies to performing routine monitoring of boiler conditions. These are keys to stopping issues before they become problems.

This chapter introduced the operator to performing routine checks. The contents of this chapter must be understood before studying the chapter on **Operational Checks (Part B, Unit 4, Chapter 4)**.

CHAPTER 4

Operational Checks

Learning Outcome

When you complete this chapter you should be able to:

Describe operational checks for operating boiler plants.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the shift based operator responsibilities for boiler plants.*
2. *Describe the safety device operational checks carried out on boilers.*
3. *Describe routine maintenance activities for boiler plant operation.*
4. *Describe the use of Standard Operating Procedures (SOPs).*
5. *Describe the need for boiler operating and maintenance logs, and the type of information that should be recorded.*

Chapter Introduction

Operational checks are performed by operators every shift. These routine checks must be performed regularly to ensure safe and efficient boiler plant operation. The procedures that will be examined are common to most boiler plants. These include checks on operational equipment, along with those relating to safety.

This chapter covers:

- Routine checks for hot water and steam boilers
- Safety checks for hot water and steam boilers
- Routine maintenance activities
- Use and adherence to procedures
- Requirements for keeping boiler log books.

Objective 1

Describe the shift based operator responsibilities for boiler plants.

Operators must perform many checks while on shift. This chapter covers many of the fundamental and necessary boiler plant checks. Checks specific to hot water or steam boilers will be identified as such. These activities are required in addition to those found in **Chapter 3 Boiler Operation**.

Read the Log Book

Prior to the start of a shift, it is essential to have a handover discussion with the previous shift members. The activities of the previous shift are discussed, the log book is read and clarified, and the on-coming shift is made aware of the state of the power plant. Engineers returning to shift after a set of days off should read the log book as far back as the last time they took charge of the plant.

Operator Rounds

After the log book is read, log sheets are reviewed, and the shift handover is complete, the Power Engineer coming on shift must immediately become familiar with the operating condition of all plant equipment. Commonly, this is referred to as doing "rounds." Depending on the complexity of the plant and the type of shift rotation, a complete set of rounds may be done once, twice, or three times per shift. Critical equipment may be checked more often. Less critical equipment may be checked only once per shift.

On Track

The following is a general treatment of operator rounds. These will vary with the type of equipment installed, and the complexity of the plant. Always consult manufacturer operations manuals and site-specific procedures to determine what should be checked, and the frequency of checks.

Rounds often include tests and formal log sheet entries. However, not all important information is captured on log sheets. A comprehensive set of rounds involves using all the senses to assess the operating condition of the plant. For example, equipment can be touched to assess temperature and vibration, unusual sounds can be heard, steam or water leaks can be observed, and refrigerant leaks can be smelled.

Rounds may be done by the shift engineer, the assistant shift engineer, or both. Boiler rooms, turbine houses, water treatment plants, and process areas may all have specific rounds associated with them. A comprehensive set of rounds may take one to two hours.

Boiler Plant Rounds

The shift engineer usually performs the boiler plant rounds.

Steam Boiler Plant Rounds

The sections below are part of the rounds that need to be performed in a steam boiler plant.

Water Level

The boiler water level should be at set point (about half way up the gauge glass).

Blow down the water column, gauge glass, low water cut-offs, water feeders, feedwater flow transmitter, and drum level transmitter, according to plant practices.

Steam Pressure

The main steam header pressure should be normal. The boiler pressure should be at or near set point, near the same pressure as the steam header, and below the setting of the high-pressure cut-off. The boiler firing rate should vary with the steam demand to maintain steam pressure at the set point.

Boiler Feed Pumps

Check the boiler feed pumps for vibration, unusual noise, leaks, and discharge pressure.

Adjust the pump packing if shaft leakage is excessive.

Ensure the pumps have adequate lube oil. Larger feed pumps may have lube oil coolers and lube oil pumps. Check the lube oil temperature, and adjust the lube oil cooling water flow. Check the lube oil pressure, and make sure it is normal.

Ensure that the standby pump is ready to be put in service if the primary boiler feed pump fails.

Condensate Receiver

Check the condensate receiver level indicated on the gauge glasses. Rusty coloured condensate indicates corrosion in the condensate return system.

Check the condensate pH and hardness. Acidic condensate causes corrosion. Hard condensate can result from defective make-up water softening equipment or heat exchanger leakage.

Low condensate level indicates failure of water to return from the steam system. High condensate levels can occur shortly after systems are brought on-line, and may be normal.

Condensate Transfer Pumps

Check the pumps that transfer condensate from the receiver to the deaerator for vibration, unusual noise, leaks, and discharge pressure.

Adjust the pump packing if shaft leakage is excessive.

Ensure that the standby pump is ready to be put in service if the primary condensate transfer pump fails.

Condensate Return Tanks

Make sure the condensate return tank vents are not blowing steam. This occurs when steam traps are defective.

Ensure water does not flow from the condensate tank vent. This may indicate that the condensate return tank pump has failed.

Manually activate the condensate tank float switch to start the pump. Listen to the pump for unusual noises. Ensure the pump turns off while water is still visible in the condensate tank gauge glass.

Deaerator

Ensure that the deaerator water level is normal.

Ensure the deaerator vent valve is open, and that non-condensable gases are venting.

Check the deaerator pressure. Deaerators typically operate between 70 and 400 kPa, depending on the design pressure.

Check the deaerator water temperature against the deaerator pressure. The temperature should correlate to the saturation temperature of water at the steam pressure. If the water temperature is below the saturation pressure of the steam, the deaerator vent is likely obstructed. In this case, the obstruction must be cleared.

Example 1

A deaerator operates at 99 kPa gauge pressure. What should the temperature of the deaerated water be?

Solution 1

A|S

The steam tables list pressures in absolute. So, 99 kPag is approximately 200 kPa absolute. From Table 1 of the **Academic Supplement Steam Tables**, the saturation temperature is given as 120.23°C. The deaerated water should be close to this temperature.

Self-Test 1

A deaerator operates at 299 kPag. What should the deaerated water temperature be?

143.63°C (Ans.)

Because the pressure gauges and thermometers installed on deaerators are not perfectly calibrated, they may be difficult to read with great accuracy. So, variations from the temperature and pressure correlation are acceptable. For example, the thermometer on a deaerator operating at 100 kPag may show a temperature of 115°C. Such a temperature may be perfectly acceptable. A temperature reading of 105°C, though, may not be acceptable.

Water Treatment Plant Equipment

Water treatment tests are not considered part of a set of rounds. However, it is important to check the operation of equipment in the water treatment area of the power plant.

Check pumps for vibration, noise, discharge pressure, and look for leaks. Check required system flows.

If **sodium zeolite softeners** are used, check the brine tank. There must always be un-dissolved lumps of salt in the brine tank. Add softener salt to the tank if necessary. Check the brine tank level. If the brine is below its normal level, the softener could be in the process of regenerating. If not, the tank is failing to automatically refill. The cause should be investigated and corrected.

Ion-exchange softeners are usually equipped with flow totalizers. Check the flow totalizer to see how much water has flowed through the exchanger, and to determine when a regeneration is necessary. If a regeneration will occur during the shift, monitor it at key points in the cycle. Perform a water test to ensure the regeneration completed successfully.

Hot Water Boiler Plant Rounds

Hot Water Temperature

The boiler temperature should be at or near set point, and below the high temperature cut-off set point. The heating loop temperature should be at the required set point, which often varies with outside air temperature and heating load.

Expansion Tank

Check the level of water in the expansion tank. It should be about half way in the gauge glass. Observe the operation of the system safety valves. If the safety valves on the boilers or the heating system are lifting, the expansion tank may be full.

Circulating Pumps

Check the hot water circulating pumps for vibration, unusual noise, leaks, and discharge pressure.

Adjust the pump packing if shaft leakage is excessive.

Confirm bearing lubricating oil level is within expected level and temperature ranges.

Some modern circulating pumps are sealed and very quiet. Confirm proper pump operation using methods such as pump differential pressure, or flow meters.

Common Boiler Plant Rounds

Boiler Draft

Check the furnace draft gauges, and ensure the draft is correct. Excessive draft loss can be due to fireside obstruction that may result from boiler leaks or soot accumulations.

Check the draft fans for unusual noise or vibration. Squealing noises may come from slipping drive belts. Vibration can be the result of damaged drive belts, couplings, or bearings.

For natural draft boilers, ensure the products of combustion are venting effectively by ensuring **dilution air** is entering the boiler **draft hood**, and no combustion products are spilling into the boiler room. Check that when the boiler fires, flames do not leave the furnace and roll out beside the boiler enclosure. This situation could arise due to fireside accumulations of soot or scale.

Flue Gas Temperature

Observe the flue gas temperature when the boiler is warmed up and firing. Abnormally high temperatures may be caused by over-firing, too much excess air, or heat exchanger fouling from soot, ash, or waterside scale.

Flame Condition

The flame should be bright and free of soot. It should not impinge on any heat transfer surface or on refractory. The flame should be vigorous and symmetrical in shape. The burner should ignite smoothly, without a puff.

Ventilation and Combustion Air Supply

Boiler rooms must be supplied with fresh air for ventilation and combustion air.

Ensure the air openings into the boiler room are unobstructed. If the ducts contain air dampers or louvres, make sure they operate freely.

If a fan is used to supply combustion air, listen for vibration caused by damaged drive belts or bearings.

Check the intake screen or louvres on the exterior of the building. Make sure there is nothing blocking the flow of air. Sometimes a build-up of frost, snow, ice, or debris can block air from entering the boiler room.

Check the linkage on the intake louvres for corrosion. Make sure it is free to operate. This is especially important in coastal areas due to salt spray carried by the wind.

Plant Rounds

The assistant shift engineer usually conducts the plant rounds. This is because the shift engineers are usually required by regulation to remain in the immediate boiler operating area whenever the plant is in operation.

Air Compressor

The air compressor is the heart of the power plant. Dry compressed air is used to drive most automatic valves and damper positioners, including those found on boilers.

Check the pressure of compressed air in the air receiver. Make sure it is at or near the set point.

Blow off water from the base of the air receiver.

Ensure adequate cooling water flow through the aftercooler. If the compressors are liquid cooled, make sure they have adequate coolant flow. Adjust the flow if necessary.

Check the compressor lube oil pump pressure to confirm that it is operating according to manufacturer's specifications.

If the compressor is fed with outside air, ensure the air inlet is free of obstruction. Check the inlet air filter or the air filter pressure differential, and make sure the filter is not plugged.

Air Dryer

Check the **dew point** of the compressed air. Modern air dryers use sensing devices to determine dew point, and display the dewpoint on a control interface. Ensure the dew point is adequate, according to the air dryer design and plant requirements.

If the air dryer is a refrigerated design, blow off liquids from the **coalescing filter** and the moisture trap.

Observe the pressure drop across the coalescing filter, and ensure it is not too great.

Figure 1 – HMI for Refrigerated Air Dryer, Showing Dewpoint

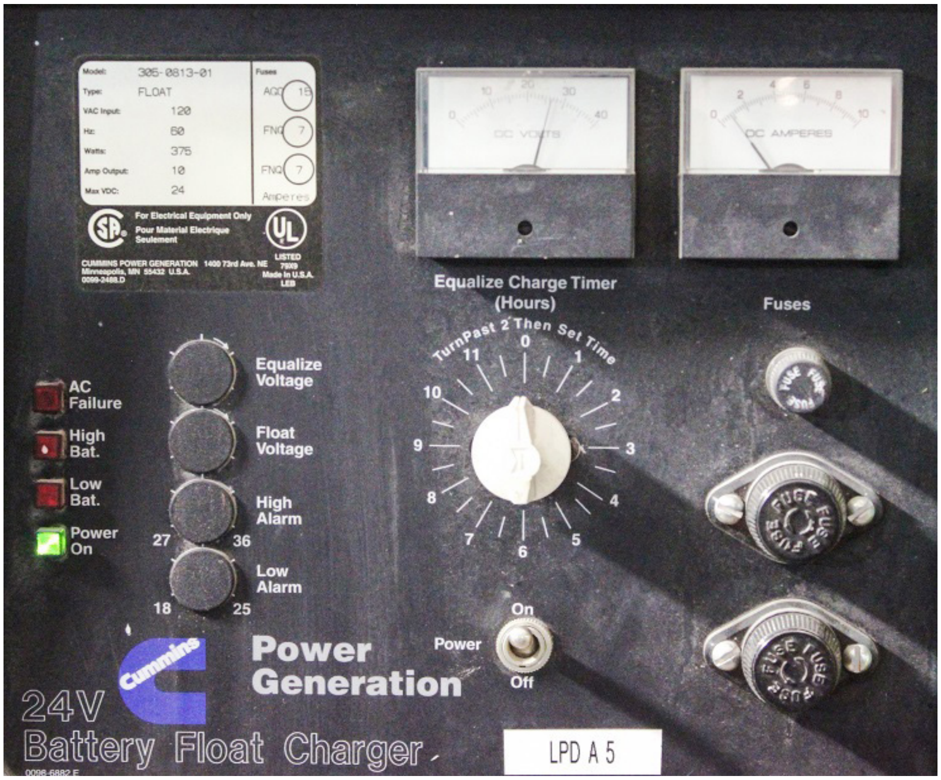
Standby Generator

The standby generator must be ready to start without delay in the event of a power failure.

For electric start diesel and gas engines, make sure the battery charger is working correctly. Check the **electrolyte** levels in the batteries, and add distilled water to cells with low levels.

For compressed-air start diesels, ensure the dedicated air receiver has the correct compressed air pressure.

Figure 2 – Battery Charger for Diesel Standby Generator



Most engines are kept very warm, or even hot. Ensure the block heater is operating, and that the engine is warm or hot to touch.

Some engines have a lube oil pump that runs continuously. Check the lube oil pressure and temperature and ensure they meet manufacturer specifications.

Diesel engines have **day tanks** to provide them with fuel oil. Ensure the day tank is full by checking the tank level gauge.

Make sure the generator automatic transfer switch is on automatic.

Housekeeping

Overall housekeeping during routine rounds helps to promote a safe work environment. Look for spills and leaks. Clean up spills immediately, using appropriate spill control methods. Spilled materials require proper disposal. Puddles of water can be easily mopped or vacuumed up. Lube oil, fuel oil, and glycol should be absorbed with special materials. If the area cannot be immediately cleaned, put up traffic cones or safety ribbons to alert other workers.

Look for chemicals that are incorrectly stored or lacking proper WHMIS labelling. Return these materials to proper locations. Segregate materials that are not identifiable, so that they can be safely disposed.

Look for rags, tools, hoses, brooms, extension cords, or temporary equipment that may be tripping hazards. Return tools to their proper locations. Roll up and store unused extension cords and hoses. Place used rags in proper receptacles.

Assess lighting. Plant areas with burned out luminaires are unsafe. Record which areas need replacement lamps, and report to the shift engineer.

Ongoing Maintenance

Engineers must keenly observe changing conditions due to ongoing power plant maintenance. Hazards that do not normally exist can be created during maintenance. Check for and clean up any leaks that develop. Be aware of tripping hazards that can be created by drain hoses or power cords, and any open floor grates that were removed to facilitate maintenance. These areas can be taped off with caution tape, or signposts could be erected warning of the hazards.

Detailed Procedures for Checks while on Rounds

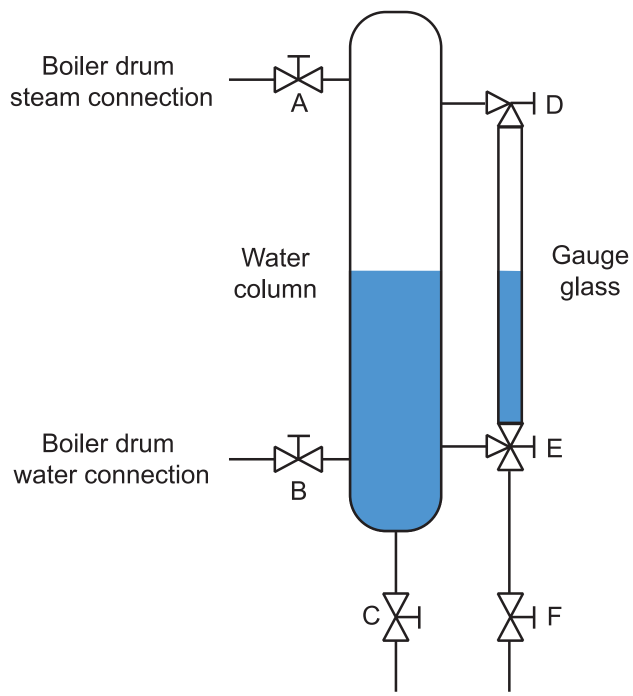
These are specific instructions for performing checks during plant rounds.

Water Column Blowdown

A water column blowdown should be completed at the beginning of every shift. Upon taking charge of a boiler, the first check should be for adequate water level. As part of that process, the operator must ensure the water column is not obstructed, thereby giving a false level indication. If equipped, check that the steam side and waterside isolating valves are fully open. Then, blow down the water column. Figure 3 shows a schematic of a typical water column and gauge glass arrangement.

Water Column with Isolation Valves

Figure 3 – Water Column and Gauge Glass, with Water Column Isolation Valves



On Track

Some high-pressure steam boilers have isolation valves in the steam and water piping, between the water column and the boiler. If valves are provided, they must be locked in the open position. The following procedure is only for water columns with valves.

When a gauge glass is connected to a water column, the piping connections from the water column to both the boiler and the gauge must all be proven clear.

Refer to Figure 3. The following procedure is recommended:

1. Remove the locks or seals from the water column isolation valves (A and B).
2. Close the gauge steam and water valves (valves D and E) to isolate the gauge before checking the water column connections.
3. Close the water column water valve (B), and then open the water column drain valve (C). This allows steam to blow through the steam connection and the water column to prove the steam connection is clear.
4. Close the water column steam valve (A), and open the water column water valve (B). Water flow through the water connection proves that this passage is clear.
5. Close the water column drain (C), and open the water column steam valve (A). This places the water column back in operation.
6. Open the gauge glass steam valve (D), then the gauge glass drain valve (F). This allows steam to blow through the top gauge glass connection, proving it is clear.
7. Close the gauge glass steam valve (D), and open the gauge glass water valve (E). Water flow from the drain proves the lower gauge glass connection is clear.
8. Close the drain valve (F), and open the gauge glass steam valve (D), to put the gauge glass back in operation. The water should rise quickly to its true level, indicating all the passages are clear.

All the connections to both the column and gauge have now been proven clear.

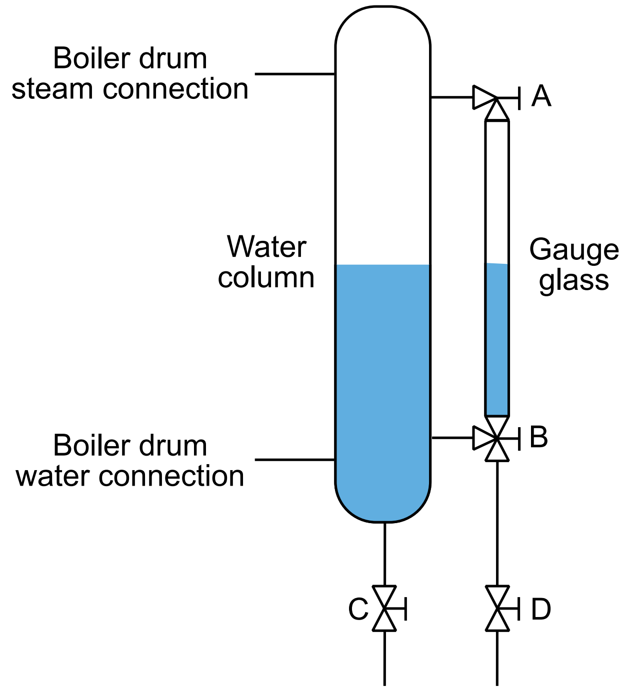
Water Column without Isolation Valves

The following procedure is used to clear the passages on the water column and gauge glass when no water column isolation valves are provided.

On Track

Most high-pressure steam boilers, and all low-pressure steam boilers, do not have isolation valves in the steam and water piping between the water column and the boiler.

Figure 4 – Water Column and Gauge Glass, without Water Column Isolation Valves



Refer to Figure 4.

1. Close the gauge glass water valve (B) to prevent steam from flowing through the gauge glass.
2. Open the water column drain (C) to allow steam and water to blow through the connections to the drain.
3. Close the water column drain valve (C), and open the drain on the gauge glass (D), to prove the steam connection and the gauge glass are clear.
4. Close the gauge glass steam valve (A), and open the gauge glass water valve (B), to prove the water passages on the gauge glass are clear.
5. Close the gauge glass drain valve (D), and open the gauge steam valve (A), to put the gauge glass back in service. The water should rise quickly to its true level, indicating all the passages are clear.

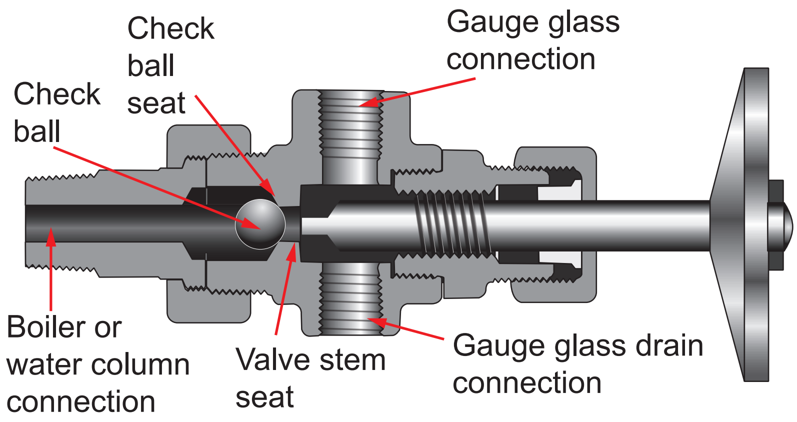
The water column and gauge glass should be blown down every shift to remove any sediment that may collect. This procedure is highly recommended on smaller high-pressure boilers. On large boilers, where the gauge glass contains mica, the gauge glass is blown down less frequently. Frequent blowdown will shorten the life of the mica and increase maintenance costs.

Gauge glasses should be renewed if they become obscured by internal corrosion or deposits. Every plant should carry a substantial reserve of gauge glasses, and washers or packing rings. Gauge glasses should be stored in a safe place where they will not be damaged.

On Track

If gauge glass isolation valves are of the safety ball check type, the valves must be partially closed to prevent the check ball from seating, which would prevent the passage of water and steam. Refer to Figure 5.

Figure 5 – Safety Shut-Off Gauge Glass Valve



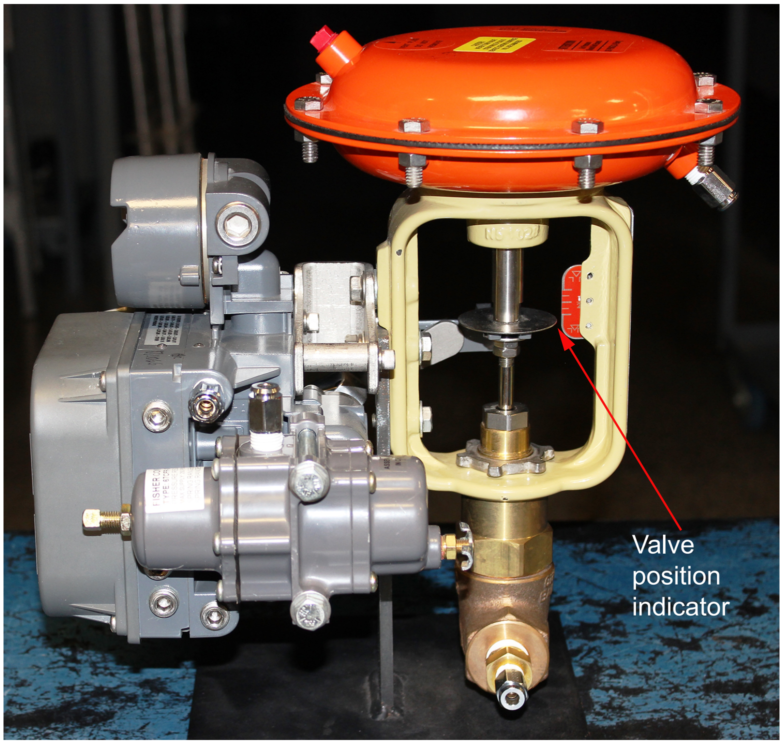
Water Level Control

Feedwater level controllers must be monitored regularly to ensure they maintain the boiler water level at set point. The feedwater control valve position is often indicated on the valve stem (see Figure 6).

To test the operation of the feedwater control valve:

1. Close the isolation valve downstream of the feedwater valve.
2. Observe changes in the valve position as the boiler level drops.
3. Confirm that the feedwater control valve is responding correctly.
4. Re-open the downstream isolating valve.
5. Ensure the boiler water level returns to set point.

Figure 6 – Control Valve with Valve Position Indicator



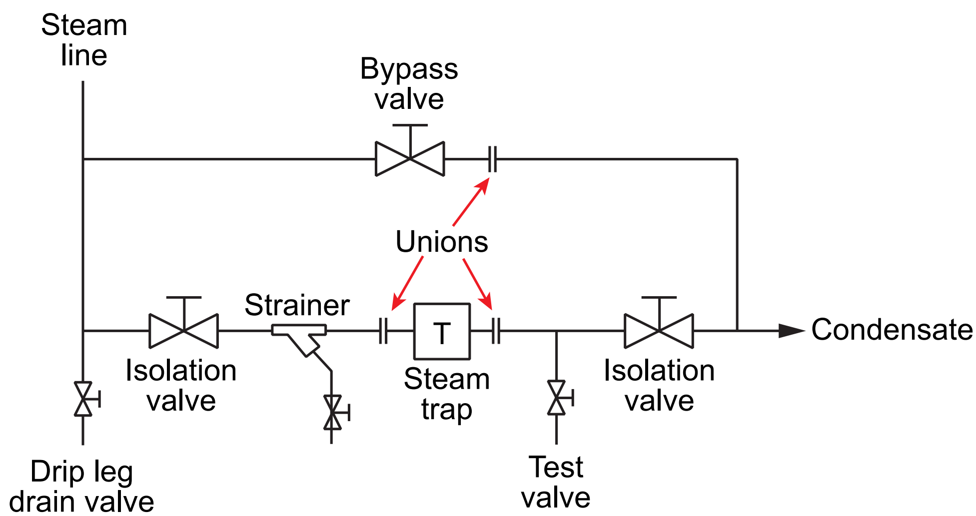
Steam Traps

Steam traps should be observed for proper operation on a regular basis. Traps that pass steam waste a significant amount of energy. Traps that are plugged cause condensate to flood heat exchangers, and impede heat transfer.

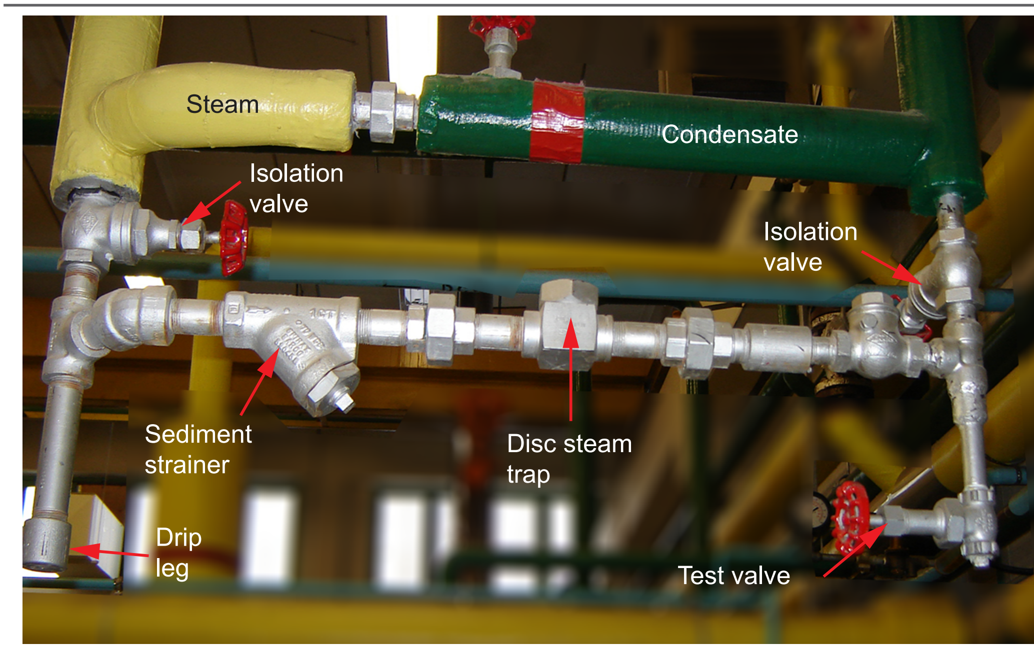
Constant steam issuing from condensate return tank vents is one indication of a failed steam trap. In order to determine which steam trap has failed, the operator can directly or indirectly observe trap operation.

A direct method of checking a steam trap is to close the isolation valve downstream of the trap, and then open a test valve located downstream of the trap. Refer to Figure 7. A constant flow of steam from the test valve is a sure indication that the trap has failed. If there is intermittent condensate flow, the trap is functioning correctly.

Figure 7 – Typical Steam Trap Installation



(a)



(b)

Most steam traps are not installed with test valves. These traps can be checked using indirect methods. One method is to use a hand-held infrared thermometer to compare the trap inlet temperature to the trap outlet temperature. If there is no temperature difference, it is an indication the steam trap has failed.

Objective 2

Describe the safety device operational checks carried out on boilers.

Performing regularly scheduled checks on safety devices ensures a safe and reliable boiler plant. This objective explores many of the common safety checks performed by operators, and their respective testing schedule. Included are checks on combustion controls, low water cut-offs, and high limit controls.

Safety Checks Common to Steam and Hot Water Boilers

ASME CSD-1 Controls and Safety Devices for Automatically Fired Boilers recommends a weekly check of the boiler flame failure detection systems. These tests are performed while the boiler is operating. Therefore, they must be scheduled for a time when they will not adversely affect the operation of the facility.

CAUTION

Always consult the operating manual supplied by the boiler manufacturer regarding the proper procedures for testing and maintenance of safety limit controls. They may differ from the general guidelines given below.

Flame Safeguard Devices

To test the flame failure device on a boiler, it is necessary to simulate a flame failure condition. The following are only general instructions for testing various devices. Manufacturer testing instructions must be followed.

ASME BPVC VI describes the recommended procedure for testing flame safeguard devices.

1. Gas Burner with a Thermocouple or Thermopile Flame Sensor

a) With the main burner firing normally, close the main burner test firing valve.

b) Turn off the pilot burner test firing valve. Note the time required for the safety shut-off valve to close. The time taken should not exceed that recommended by the valve manufacturer.

c) If the test is successful, open the pilot burner test firing valve. Relight the pilot according to the burner manufacturer procedures. When the pilot is lit, slowly open the main burner test firing valve, and light the main burner. Check the burner for proper operation.

2. Gas Burner with an Electronic Flame Rod and Continuous Pilot

a) With the main burner firing normally, close the main burner test firing valve.

b) Close the pilot burner test firing valve. Note the time it takes for the safety shut-off valve to close. This should take four seconds or less, depending on the burner capacity and fuel pressure. Consult manufacturer instructions.

c) If the test is successful, open the pilot burner test firing valve. Relight the pilot according to the burner manufacturer procedures. Reset the combustion controls. After the pilot is lit, light the main burner by slowly opening the main burner test firing valve. Check the burner for proper operation.

3. Gas Burner with Electronic Flame Rod and Interrupted Pilot

a) With the main burner firing normally, close the main burner test firing valve. Note the time it takes for the safety shut-off valve to close. This should take four seconds or less, depending on the burner capacity and fuel pressure. Consult manufacturer instructions.

b) If the test is successful, reset the combustion controls. Relight the pilot. After the pilot is lit and proven, light the main burner by slowly opening the main burner test firing valve. Check the burner for proper operation.

4. Gas Burner with Electronic Flame Scanner

a) Method 1: same as procedure 3.

b) Method 2:

   i. With the main burner firing normally, remove the scanner from its sighting tube and cover it. Note the time it takes for the safety shut-off valve to close. This should take four seconds or less, depending on the burner capacity and fuel pressure. Consult manufacturer instructions. Re-install the scanner.

   ii. If the test is successful, reset the combustion controls. Relight the pilot. After the pilot is lit and proven, light the main burner by slowly opening the main burner test firing valve. Check the burner for proper operation.

5. Oil Burner with Electronic Flame Scanner

a) With the main burner firing normally, close the manual test firing valve in the oil supply line. Note the time it takes for the oil solenoid valve (safety shut-off valve) to close. This should take four seconds or less, depending on the burner capacity and fuel pressure. Consult manufacturer instructions.

b) If the test is successful, open the manual test firing valve in the oil supply line. Reset the combustion controls, light the burner, and check for correct operation.

Checking Pilot Flame Failure Response

CAUTION

Whenever the pilot burner test firing valve is closed, the main burner test firing valve must also be closed. Otherwise, a furnace explosion may occur. If intending to close the pilot test firing valve, first close the main burner test firing valve.

1. With the burner off, first close the main burner test firing valve. Then, close the pilot burner test firing valve.

2. Start the boiler programmed combustion control. After the pre-purge period, the ignition transformer and pilot burner safety shut-off valve will energize. Because the pilot burner test firing valve is closed, no flame should be detected. The pilot safety shut-off valve should close at the end of the pilot trial-for-ignition period (typically less than ten seconds). The main fuel safety shut-off valve must not energize.

3. The programmed combustion control will proceed with a post-purge and a safety shut-down/lockout, requiring manual reset. Some smaller burners may recycle in order to attempt to relight the burner. After a second attempt, these boilers will undergo a post-purge and safety shut-down/lockout. Audio-visual alarms often accompany flame failure.

Checking Main Flame Failure Response

CAUTION

Do not check the main flame failure response prior to checking the pilot flame failure response. Correct ignition sequencing, and the establishment of a stable pilot flame, are critical for consistent main burner ignition.

1. Close the main burner and pilot burner test firing valves. Reset the programmed combustion control lockout switch. Open the pilot burner test firing valve.
2. Turn the burner on. After the pre-purge period, the pilot will light. The scanner will sense the flame, permitting the main fuel safety shut-off valve to energize. The main burner will not ignite because the main burner test firing valve is closed.
3. After the main flame trial for ignition period is over, the pilot burner shuts off. The scanner will not detect a flame, and the main safety shut-off valve will de-energize.
4. The programmed combustion control will proceed with a post-purge and a safety shut-down/lockout, requiring manual reset. Some smaller burners may recycle in order to attempt to relight the burner. After a second attempt, these boilers will undergo a post-purge and safety shut-down/lockout.

Maintenance of Flame Safeguard Devices

The programmed combustion control requires no maintenance other than occasional blowing out of accumulated dust.

Side Track

Some older programmed combustion controls use drum control sequencers with numerous exposed electrical contact points. Never file the contact points. If the contacts are dirty or slightly oxidized, clean them by drawing a piece of hard finished paper between the contacts while holding them closed.

Some older programmed combustion controls also use flame amplifier circuits that rely on electronic tubes. It is advisable to replace such older programmers with modern solid state controls.

It is important that the scanner should never get so hot that it cannot be held comfortably in the hand. High temperatures affect scanner operation, as well as its life span. Ensure the scanner tube has adequate air supply to keep it cool. The scanner lens should be cleaned at regular intervals. Be sure that the scanner sight tube is always clear of any obstructions.

Ultraviolet flame scanners have a life of around 40 000 hours. As ultraviolet scanners age, they fail to discriminate between the light given off by a flame, and light of lower intensity and different frequency. A simple check involves removing the scanner from its sight tube and exposing it to ambient light. Observe the light-sensitive element under the scanner lens. The scanner should not “fire” repeatedly when exposed to ambient light. This can be seen as frequent bursts of orange light from the light-sensitive element. If the scanner fires excessively, it must be replaced.

Flame rods should be checked regularly for buildup of deposits, such as carbon, as this may affect their operation. As well, ensure the flame rods are not warped and mislocated due to heat.

ASME CSD-1 recommends that flame rods and scanners be replaced annually, in accordance with manufacturer instructions.

Low Gas Pressure Cut-Off Switch

ASME CSD-1 recommends monthly testing of the low gas pressure cut-off switch.

The low gas pressure cut-off can be tested during the operation of the boiler by slowly closing the main gas valve upstream of the low gas pressure switch. Observe the pressure gauge on the gas line. When the gas pressure drops to the cut-off point, the safety shut-off valves must close.

High Gas Pressure Cut-off Switch

ASME CSD-1 recommends monthly testing of the high gas pressure cut-off switch.

This switch can be tested while the boiler is operating. To test the switch, quickly close the main burner test firing valve. This action may increase the fuel pressure enough to open the high gas pressure cut-off switch, and cause the safety shut-off valves to close.

On Track

The gas pressure cut-off switch tests may result in flame instability and flame failure prior to the activation of the cut-off switch. When performing these checks, always determine whether the cut-off switch or the flame scanner tripped.

Combustion Air Proving Switch

ASME CSD-1 recommends monthly testing of the combustion air proving switch.

These switches are difficult to test. Many boiler manufacturers do not provide means for testing them. As well, improper test procedures can cause explosive fuel-rich furnace conditions, which must be avoided at all times.

It is recommended that plants develop approved, safe, site-specific procedures for testing airflow proving switches. These procedures usually require the installation of a means of disconnecting the airflow switch from the combustion air supply. This may be accomplished with pipe unions or three-way valves.

Safety and Safety Relief Valve Tests

Safety and safety relief valves are the most critical boiler safety devices. Their proper functioning is paramount to boiler safety. As such, repair and maintenance must only be performed by qualified shops. The operator's job is to test the valves on a periodic basis to ensure proper operation.

The three tests commonly performed to test safety and safety relief valves are:

1. **Try lever test (or manual check)**: determines freedom of valve movement
2. **Pop test (or pressure test)**: determines popping pressure and blowdown
3. **Accumulation test**: determines relieving capacity

Side Track

The safety valve is a boiler critical fitting. Safety valve testing must be done with the utmost diligence. Descriptions of these tests can be found in **Part B, Unit 3, Chapter 1 Pressure Relief Valves**, as well as in **ASME BPVC Sections I, IV, VI, and VII**.

The minimum frequency of safety valve checks are outlined in **ASME BPVC VI and VII**, as well as in the **NBBI Inspection Code**. This information is summarized in Table 1.

Table 1 – Frequency of Safety and Safety Relief Valve Tests, per ASME and NBBI

Type of Test	Steam Power Boiler (below 2760 kPa MAWP)	Steam Heating Boiler	Hot Water Heating Boiler
Try Lever Test	Semi-Annual (NBBI)	Monthly (ASME BPVC VI)	Quarterly (NBBI)
Pop Test	Annually, prior to bringing the boiler down for internal inspection (NBBI)	Annual, prior to start of heating season (NBBI)	Annual, prior to start of heating season (NBBI)
Accumulation Test	Performed if the safety or safety relief valve capacity cannot be determined, or if it is desirable to verify that installed valve capacity is sufficient. (**ASME BPVC I and IV**)		

It is important to perform a manual try lever test prior to performing a pop or accumulation test. This establishes that the safety valve is free to operate under pressure. As well, annual pop tests should be performed prior to removing a boiler from service. This helps to discover problems with the safety valve, so that repairs can be made while the boiler is scheduled to be out of service.

1. Manual Try Lever Test

To correctly perform this test, the boiler must be in service and under pressure. This test determines whether the valve can operate freely. However, it does not determine whether the valve will open at its set pressure.

Heating Boilers in Steam Service

This test should not be performed unless the boiler pressure at least 35 kPa. This is to ensure that any loose deposits or foreign material, which could lodge between the valve and the valve seat, will be blown away when the valve opens.

With the boiler under pressure, lift the try lever on the safety valve to the wide-open position. Allow steam to discharge for 5 to 10 seconds. Release the try lever, and allow the spring to snap the disk to the closed position. If the valve simmers, operate the try lever two or three times to allow the disk to seat properly. If the valve continues to **simmer**, it must be replaced or repaired by an authorized valve repair agency.

The date of this test should be entered into the boiler log book.

Power Boilers in Steam Service

Ensure that all personnel are cleared from the area near the safety valve before conducting a manual try lever test. This is because a large amount of steam may overflow from the outlet and exhaust piping, and enter the operating area.

The safety valve must not be opened with the hand lifting gear when the steam pressure is less than 75% of the set pressure of the lowest set valve on the boiler. This prevents damage to the lifting device, and ensures debris is blown away from the valve seat.

To manually test the valve, raise the try lever handle to the full open position. Then, release the try lever handle to allow the valve to snap closed.

The date of this test should be entered into the boiler log book.

2. Pop Test

The exact pressures at which a safety valve opens and closes can be checked by conducting a pop test. This involves increasing the boiler steam pressure to the safety valve set point, and recording the opening and reseating pressures.

Pop tests should be performed when taking a boiler off-line for annual maintenance. In this way, defective valves can be identified and replaced or repaired prior to the boiler re-entering service.

Pop tests can be preceded by high-pressure cut-off tests.

Prior to performing a pop test, check the set point and blowdown of the safety valve from its nameplate, and record these values. A try lever test should then be performed to ensure the safety valve is not seized. Next, the boiler should be shut down. The boiler steam outlet and feedwater supply valves should be closed. An accurate, recently calibrated pressure gauge should be installed for testing purposes.

On an automatically fired boiler, the operating control and the high limit control must be bypassed. These controls normally shut the boiler down well before the popping pressure of the safety valve is reached. To bypass these controls, de-energize the power supply to the boiler. Using an electrical meter, verify that the electrical terminals on the operating pressure control and high-pressure cut-off are de-energized. Place temporary jumper leads across the appropriate terminals of the operating pressure control and high-pressure cut-off. Operators unfamiliar with this procedure are strongly advised to receive assistance from a qualified tradesperson.

When the boiler is ready for the test, restore electrical power to the boiler. Then, start the burner, and slowly increase the steam pressure.

Just before the boiler reaches popping pressure, the safety valve may begin to simmer. When the safety valve pops fully open, record the opening pressure. Then, shut off the burner. The safety valve will continue to blow steam. Record the pressure at which the valve closes. Enter these pressures in the log book.

If the valve fails to open at the required pressure, shut off the burner. Slowly release the steam pressure either to atmosphere, through the vent valve, or into the steam header. When the pressure falls below the popping pressure, apply the try lever test a few times to confirm that the valve is free to move, then repeat the pop test. If the valve still fails to open, the boiler must be removed from service. The faulty safety valve must be repaired or replaced.

CAUTION

Never try to free a stuck safety valve by hammering or striking the valve body.

After the completion of the pop test, the valve action must be evaluated against the **ASME BPVC** performance criteria.

Evaluating Safety Valve Performance of Heating Boilers in Steam Service

ASME BPVC IV, Part HG-400.1 states:

> *Each steam boiler shall have one or more officially rated safety valves … of the spring pop type adjusted and sealed to discharge at a pressure not to exceed 15 psi (100 kPa).*

ASME BPVC VI, Part HG-401.1 states:

> *The set pressure tolerances, plus or minus, of safety valves shall not exceed 2 psi (15 kPa).*

Therefore, if the safety valve does not open in the 13 to 17 psi range (85 to 115 kPa), it should be replaced. It is not dangerous if the valve opens below 13 psi (85 kPa), but it could indicate a valve spring that is weak or improperly set. If the valve does not open at 17 psi (115 kPa), shut off the burner, and dissipate the steam to the system by slowly opening the supply valve.

ASME BPVC IV, Part HG-401.1(e) states:

Safety valves shall have a controlled blowdown of 2 psi to 4 psi (15 to 30 kPa).

ASME BPVC VI, Part IV (B) states:

The safety valve will stay open until the pressure drops sufficiently in the boiler to allow it to close, usually 2 psi (15 kPa) to 4 psi (30 kPa) below the opening pressure.

Therefore, the blowdown is determined by subtracting the closing pressure from the opening pressure.

Self-Test 2

A low-pressure steam boiler safety valve pops open at 95 kPa. Determine the acceptable range of reseat pressures for this safety valve.

65 to 80 kPa (Ans.)

Evaluating Safety Valve Performance of Power Boilers in Steam Service

ASME BPVC I, Part PG-72.2 states:

The set pressure tolerance plus or minus shall not exceed that specified in the following table:

Table 2 – Safety Valve Set Pressure Tolerance for Steam Power Boilers

Set Pressure	Tolerance, Plus or Minus From Set Pressure
≤ 500 kPa	15 kPa
> 500 and ≤ 2100 kPa	3% of set pressure
> 2100 and ≤ 7000 kPa	70 kPa
> 7000 kPa	1% of set pressure

ASME BPVC I, Part PG-72.1 also states:

Pressure relief valves shall be designed and constructed to operate without chattering, with a minimum blowdown of 2 psi (15 kPa) or 2% of the set pressure, whichever is greater.

Self-Test 3

A high-pressure steam boiler safety valve is set to open at 1035 kPa.

a) Determine the acceptable range of popping pressures for this safety valve.

b) Determine the minimum acceptable blowdown for this safety valve.

1004 to 1066 kPa (Ans. a)
21 kPa (Ans. b)

Safety valves that do not respond within the code-mandated popping and reseating parameters must be either replaced or refurbished by a certified valve repair agency.

3. Accumulation Test

If the safety or safety relief valve capacity cannot be determined, an accumulation test can be performed. This test will also verify if the installed valve capacity is sufficient.

An accumulation test is performed much like a pop test. Before doing an accumulation test, the high-pressure cut-off test and pop test need to be completed.

Preparation for an accumulation test is similar to that of a pop test.

a) Shut down the boiler.
b) Bypass the pressure limit controls with jumpers.
c) Shut the main steam outlet.
d) Install a calibrated pressure gauge.

Unlike the pop test, the feedwater system is kept in service. Also, the firing rate must be manually controlled so the boiler remains on high-fire throughout the duration of the test.

During the accumulation test, the boiler pressure will rise until the energy released by the safety valve equals the energy input to the boiler water. At this point, the boiler pressure will stabilize. The test continues until a stable pressure is reached that falls within the acceptable parameters established by ASME, or until the acceptable ASME parameters are exceeded.

Power Boilers in Steam Service

Guidelines for conducting accumulation tests for power boilers in steam service are found in **ASME BPVC I Appendix A-46.1**, which states:

The pressure relief valve equipment shall be sufficient to prevent an excess pressure beyond that specified in PG-67.2. This method should not be used on a boiler with a superheater, reheater, or on a high-temperature water boiler.

ASME BPVC I Part PG-67.2 states that:

The pressure relief valve capacity for each boiler … shall be such that the pressure relief valve, or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6% above the highest-pressure at which any valve is set and in no case to more than 6% above the maximum allowable working pressure.

Example 2

A boiler with a MAWP of 1380 kPa is equipped with a single safety valve set to 1310 kPa. Because the safety valve is set to below the boiler MAWP, the boiler pressure must not go higher than 6% of the safety valve setting during an accumulation test. Therefore, the maximum acceptable pressure during an accumulation test is 1389 kPa.

Self-Test 4

Determine the maximum pressure during an accumulation test for a high-pressure steam boiler with a MAWP of 1725 kPa, having a single safety valve set to 1725 kPa.

1829 kPa (Ans.)

Heating Boilers in Steam Service

Guidelines for conducting accumulation tests for heating boilers in steam service are found in **ASME BPVC IV, Part HG-512**, which states:

The safety valve equipment shall be sufficient to prevent an excess pressure beyond that specified in HG-400.1(f) and HG-400.2(f).

ASME BPVC IV Part HG-400.1(e) states:

The safety valve capacity for each steam boiler shall be such that with the fuel burning equipment installed, and operated at maximum capacity, the pressure cannot rise more than 5 psi (35 kPa) above the maximum allowable working pressure.

Self-Test 5

Determine the maximum pressure during an accumulation test for a low-pressure steam boiler with a MAWP of 100 kPa.

135 kPa (Ans.)

Water Level Control Tests

Low Water Cut-Offs

Low water fuel cut-offs are automatic devices that require regular attention to keep them in proper operating condition.

Low water cut-off testing should be done regularly. The frequency and types of tests, as recommended by **ASME CSD-1**, was outlined in the previous chapter.

Three common low water cut-off tests involve:

1. Rapidly draining the float chamber, to see if the control shuts off the boiler (float chamber blowdown).
2. Isolating the feedwater, and blowing off the boiler (a slow drain test).
3. Isolating the feedwater, and allowing the boiler to steam off water.

Rapidly draining the float chamber, to see if the control shuts off the boiler (float chamber blowdown)

By opening the float chamber drain, water is expelled suddenly from the float chamber, causing the low water cut-off float to drop suddenly. This action should immediately trip the boiler.

This test does not prove that the low water cut-off mechanism will operate when the water level decreases slowly. However, the advantage of this test is that it discharges sediment from the base of the float chamber. If permitted to accumulate, this sediment will cause the cut-off device to malfunction.

When the float chamber drain valve is closed, the water level in the float chamber should quickly return to normal. If not, piping connections to the drum must be checked and any obstructions should be removed. In this case, it is best to remove the switch box cover to check the switch mechanisms for freedom of movement.

If the low water cut-off proves defective, remove the boiler from service until the low water cut-off is repaired or replaced.

ASME CSD-1 recommends that for power boilers, this test should be completed daily. For heating boilers, this test should be completed weekly.

Isolating the feedwater, and blowing off the boiler (a slow drain test)

First, isolate the feedwater connection to the boiler. Then, perform a bottom blowoff. Confirm that the boiler trips at no lower than the lowest visible part of the gauge glass.

If the low water cut-off proves defective, remove the boiler from service until the low water cut-off is repaired or replaced.

ASME CSD-1 recommends that this test should be completed semi-annually.

Isolating the feedwater, and allowing the boiler to steam off water

First, isolate the feedwater connection to the boiler. Let the water level decrease as the boiler steams. Confirm that the boiler trips at no lower than the lowest visible part of the gauge glass.

If the low water cut-off proves defective, remove the boiler from service until the low water cut-off is repaired or replaced.

This test is recommended as an alternative to the slow-drain test.

In all three of these tests, it is critical that the boiler water level is monitored closely. On a falling water level, if the boiler does not trip at or above the lowest visible part of the gauge glass, immediately add water to the boiler, or trip the boiler.

After testing the low water cut-off, return all valves to their normal operating positions. Then, reset the low water cut-off. The boiler should restart. Observe that the startup sequence proceeds normally.

Feedwater Pump or Feedwater Solenoid Control

Steam boilers may use a combination boiler feedwater control and low water fuel cut-off. The feedwater control may activate a feedwater solenoid valve, or control a boiler feed pump. These devices can be checked in the same manner as a dedicated low water cut-off control.

If the feedwater supply operates on two-position control, the operation of the pump or feedwater valve can be checked by observing the levels at which the feedwater system starts and stops. It is advisable to mark these levels on the gauge glass and record them in a log book for future reference. A change in levels during later checks could indicate possible level control problems. By lowering the water level further, the low-water fuel cut-off activates. This level should also be recorded.

Combined Feeder/Cut-Off Controls

Some steam heating boilers use combined feeder/cut-off controls. These controls feed make-up water in case there is failure of the feedwater or condensate return pump. The operation of the make-up valve, which is connected directly to a float, can be checked by shutting down the feed pump. The make-up valve should open somewhat below the cut-in level of the pump, and should be able to maintain proper level when the boiler is at full load. The make-up valve should be checked for tight closure. With the boiler shut down, an increase in water level with the make-up closed may indicate a leaking valve.

Annual Maintenance and Inspection of Water Level Controls

Low water cut-offs, pump controls, and water feeders should be dismantled annually by qualified personnel. These devices should be checked for obstructions, and proper operation of all the parts must be verified. Leaks in the connecting lines to the boiler should be repaired. Connecting lines must be inspected for sediment and scale, and cleaned if necessary.

The insulation on all wiring must be checked for any deterioration, and the wiring replaced if necessary. All electrical contacts must be examined for cleanliness, and tested for proper operation by moving the float up and down manually. If a mercury switch is used, the bulb must be checked for cracks, and the mercury checked for corrosion. All soldered joints on the bellows and float must be checked. The float should also be checked for leaks and deformation. Complete maintenance instructions are generally provided by the manufacturer.

Pressure Limit Control Tests

Operating Limit Switch

The operating limit switch does not require any special testing as its operation can be observed during routine boiler monitoring. It is important, however, that the cut-in and cut-off pressures are observed and compared to the expected range. If the operating parameters differ from the expected range, the switch will need adjustment.

High-Pressure Cut-Off Control

The high-pressure cut-off cannot be tested during normal boiler operation since it operates above the cut-off point of the operating control. To test the high-pressure cut-off control:

1. Disconnect the power to the boiler controls. Verify power is off using a test meter.
2. Place a test lead (jumper wire) across the terminals of the operating cut-off control.
3. Record the setting of the high-pressure cut-off so it can be compared to the actual cut-off pressure.
4. Restore power to the controls and start the boiler.

5. Allow the boiler to fire until the steam pressure reaches the setting of the high-pressure cut-off control. The control should operate at this point, and shut down the firing equipment.

6. If the test is successful, disconnect the power and remove the test lead.

7. Manually reset the high-pressure cut-off.

8. Put the boiler back into operation.

The high-pressure cut-off of a steam boiler should trip the boiler at a pressure higher than the set point of the operating limit control, but lower than the safety valve popping pressure. If it does not pass this test, it must either be adjusted or replaced.

Safety Checks for Hot Water Boilers

Flow Switch

Copper tubular and copper fin-tube boilers require positive water circulation to protect the heat transfer surfaces from failure due to overheating. To ensure the boiler does not fire unless there is adequate circulation, these types of boilers are equipped with flow switches near their outlets. When the circulating pump is operating, and the supply and return valves are open, the switch is satisfied, and the burner is free to operate. If the flow switch does not detect sufficient flow, the flow switch opens a circuit to prevent the burner from operating.

On Track

The **CSA B51 Code** states that:

> *In lieu of a low-water fuel cut-off device, automatically fired hot water boilers requiring forced circulation to prevent overheating shall be equipped with a flow-sensing device to automatically cut off the fuel supply to the burner if the flow rate is reduced to a point where it is inadequate to protect the boiler against overheating. The device shall be installed on the boiler outlet piping... and installed so that it cannot be rendered inoperative.*

For this reason, many forced circulation hot water boilers are not equipped with low water cut-offs.

To test the flow switch, slowly close the boiler outlet valve and observe the burner. If the burner fails to shut down, or if hammering sounds occur, open the outlet valve fully. Do not test the flow switch by turning off the hot water circulating pump. Take the boiler out of service to repair or replace the flow switch.

Low Water Cut-Off

Hot water boilers and their piping systems are completely filled with water. Their low water cut-off float chambers are directly connected to the boiler above the lowest permissible water level, with no intervening valves. Therefore, opening the low water cut-off drain valve will not empty the float chamber and activate the cut-off. For this reason, it is not possible to test the low water fuel cut-off with the boiler in-service.

For this reason, **ASME BPVC IV Part HG-614** states:

> *A means shall be provided for testing the operation of the external low-water fuel cutoff without resorting to draining the entire system. Such means shall not render the device inoperable except as described as follows. If the means temporarily isolates the device from the boiler during this testing, it shall automatically return to its normal position.*

Special combination test and check valves are designed for such installations. They prevent the system from draining, while testing the low water cut-off. These valves are installed at the top and bottom connections of the low water cut-off float chambers. In normal operation, these valves permit free circulation of water through the connecting piping and float chamber. A sudden onrush of water, such as that caused by opening the low water cut-off drain valve, causes dampers located in each valve to restrict water flow to the float chamber. The water level in the float chamber quickly falls, and trips the low water cut-off with a minimum loss of boiler water. When the float chamber drain is closed, the dampers return to their normally open position.

ASME BPVC VI recommends testing the low water cut-off of hot water heating boilers monthly, as long as it can be done by draining only minimal amounts of water from the system.

Make sure to test the low water cut-off at the end of the heating season. If the control is found defective, it can be repaired or replaced during the period of time the boiler is not required. Test the control again after it is repaired or replaced. Record the results of all tests in the boiler log book.

The care and maintenance required for a low water cut-off of a hot water boiler is similar to that of a cut-off on a steam boiler. In all cases, the manufacturer instructions should be followed closely.

Operating Limit Switch (Temperature Control)

The operating limit switch does not require any special testing, because its operation can be observed during routine boiler monitoring. It is important, however, that the cut-in and cut-off temperatures are observed and compared to the expected range. If the operating parameters differ from the expected range, the switch will need to be adjusted.

High Temperature Cut-Off

The high temperature cut-off cannot be tested during normal boiler operation, since it operates above the cut-off point of the operating control. To test the high temperature cut-off:

1. Disconnect the power to the boiler controls. Verify that the switch is de-energized, using an electrical test meter.
2. Place a test lead (jumper wire) across the terminals of the operating temperature control.
3. Record the setting of the high limit control, so it can be compared to the actual cut-off temperature.
4. Restore power to the controls and start the boiler.
5. Allow the boiler to fire until the water temperature reaches the setting of the high temperature cut-off control. The control should operate at this point, and shut down the firing equipment.
6. If the test is successful, disconnect the power and remove the test lead.
7. Manually reset the high temperature cut-off.
8. Put the boiler back into operation.

On hot water boilers, the cut-off temperature of the high temperature cut-off should be set above the cut-off setting of the operating control. However, it should never be higher than the maximum allowable water temperature for the boiler. **ASME BPVC IV** restricts the water temperature of hot water heating boilers to 120°C. Most high temperature cut-off controls are physically limited to temperature settings lower than 115°C.

Objective 3

Describe routine maintenance activities for boiler plant operation.

Maintenance activities can vary by plant, industry, and in some cases, by collective agreements. This objective will introduce some of the common maintenance tasks for which operators are responsible. These include blowing down drip legs, repairing gauge glass leaks, and assessing packing leaks.

Routine Maintenance Activities

Drip Leg Blowdown

Drip leg blowdown is commonly done each shift. This consists of opening and then reclosing the drain valves on drip legs located in the low points of a steam system. This removes excess accumulations of condensate. In Figure 7, the drip leg drain valve is shown upstream of a typical steam trap installation.

Gauge Glass Valve Stem Leaks

Gauge glass isolating valves will occasionally leak through the valve packing, which allows steam and water to pass. These leaks can become problematic or hazardous for operators performing gauge glass blowdowns. Often these leaks can be repaired while the boiler is on-line.

1. Ensure the boiler water level control system is functioning correctly, and on automatic control.
2. Confirm there is a secondary method of monitoring boiler water level (such as the drum level recorder).
3. Close the steam side gauge glass isolation valve.
4. Close the waterside gauge glass isolation valve.
5. Open the gauge glass drain.
6. Confirm the gauge glass is depressurized.
7. If the gauge glass cannot be suitably isolated, DO NOT proceed. The valve packing will have to be tightened once the boiler is depressurized. Never tighten packing on a valve that is under pressure.
8. Tighten the valve packing nuts.
9. Close the drain valve.
10. If the glass has cooled, allow it to come to operating temperature before proceeding.
11. Slowly open the steam side isolation valve.
12. Slowly open the waterside isolation valve.
13. Check for leaks.

Valve Packing and Bonnet Leaks

Valve leaks occasionally occur in boiler plants. Often, these leaks can be easily stopped. It is important, however, to first depressurize the piping around the valve before tightening. If the piping around the valve is not first depressurized, packing and flange gaskets can fail upon tightening, and may cause injury.

CAUTION

Depressurize the pipework around the valve prior to tightening packing or valve bonnet gaskets. Failure to do so may cause the packing or gasket to fail dramatically, and cause personal injury.

If the leak is in the valve stem, tighten the packing gland nuts. Tighten the nuts evenly. Ensure the gland remains perpendicular to the stem. Make sure that the packing is not so compressed that the valve is difficult to turn. Only tighten the gland as much as is required to stop the leak.

If the leak is on the bonnet or flange, make sure that a cross bolting pattern is used. This will ensure that the flange or bonnet does not distort and leak further.

Stuffing Box

Stuffing boxes are designed to allow a continuous flow between the shaft and packing of a centrifugal pump. If this leakage is excessive, the packing gland can be tightened to reduce it to an acceptable amount. When performing this task, make sure the leakage is not completely stopped. Otherwise, the packing will overheat and damage the pump shaft. As with tightening the packing gland on a valve, ensure the gland is adjusted evenly so that it remains perpendicular to the pump shaft.

Objective 4

Describe the use of Standard Operating Procedures (SOPs).

The use of SOPs are gaining widespread usage due to their effectiveness at ensuring equipment is operated in a consistent and safe manner. However, if SOPs are not followed correctly, equipment damage or injury to personnel could result. Many procedures contain hundreds of steps which must be carried out in sequence. This poses a challenge to any operator, regardless of skill.

Some techniques for SOP use are demonstrated below, using the example of a simplified startup procedure for a centrifugal pump.

Using Sign-Offs

Some procedures have sign-offs at the end of each action step. Refer to Figure 8. The operator checks the box at the end of each step, to indicate that the activity has been completed. This helps operators to keep track of where they are in the sequence.

Figure 8 – Procedure Example with Check Boxes

1.	Close discharge valve.	☐
2.	Open suction valve.	☐
3.	Open recirculation valve.	☐
4.	Confirm pump is primed.	☐
5.	Close pump breaker.	☐
6.	Select pump hand switch to “ON”.	☐

Other procedures are formatted with sign-offs that require the operator to place their initial at the end of each completed step. This identifies the person who completed each activity. See Figure 9.

Figure 9 – Procedure Example with Initial Boxes

1.	Close discharge valve.	[ ]
2.	Open suction valve.	[ ]
3.	Open recirculation valve.	[ ]
4.	Confirm pump is primed.	[ ]
5.	Close pump breaker.	[ ]
6.	Select pump hand switch to “ON”.	[ ]

Using Place Keepers

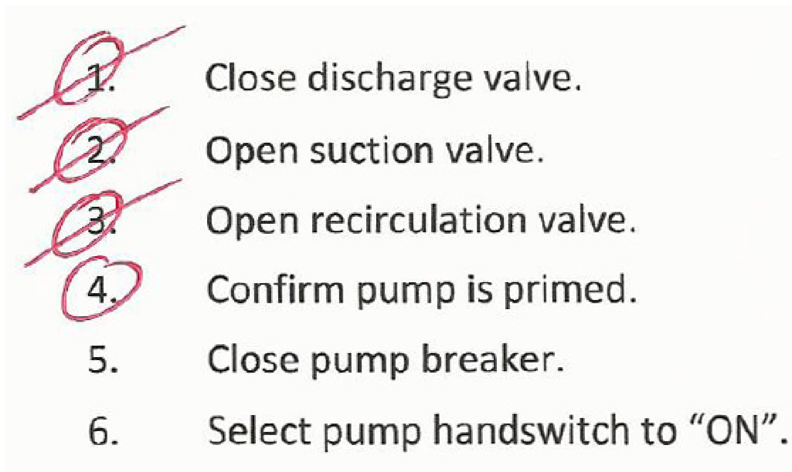
Although using a numbering system to keep sequence is common, the practice of sign-offs is not always used. Many procedures are not formatted with formal sign-offs. Regardless, there are tools for operators to help keep their place while following a procedure.

Circle/Slash Method

In this method of place keeping, the operator must circle the step currently being conducted, and put a slash through the circle when the step is complete.

Figure 10 shows such a method. The operator has completed step 3, and is currently performing step 4.

Figure 10 – Procedure Example Using Circle/Slash



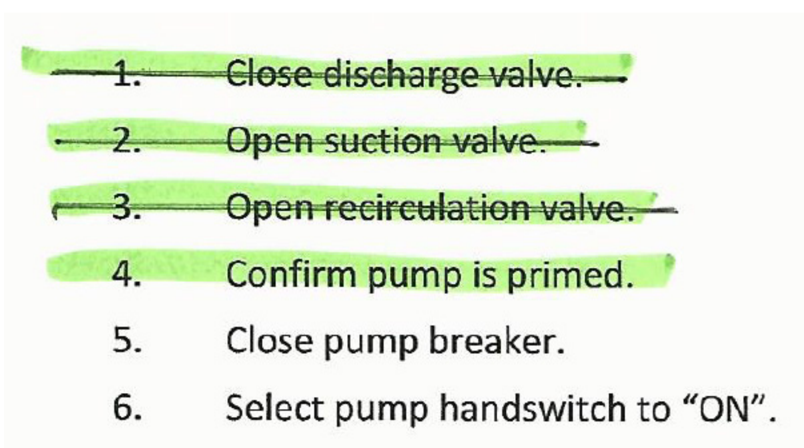
1. Close discharge valve.
2. Open suction valve.
3. Open recirculation valve.
4. Confirm pump is primed.
5. Close pump breaker.
6. Select pump handswitch to "ON".

Highlight and Cross Out

In this method, the operator highlights the step about to be performed, and crosses out the entire step once completed.

In Figure 11, the operator has finished step 3, and is currently conducting step 4.

Figure 11 – Procedure Example Using Highlight and Cross Out



1. ~~Close discharge valve.~~
2. ~~Open suction valve.~~
3. ~~Open recirculation valve.~~
4. Confirm pump is primed.
5. Close pump breaker.
6. Select pump handswitch to "ON".

Objective 5

Describe the need for boiler operating and maintenance logs, and the type of information that should be recorded.

The boiler room log is the official record of all activity in the boiler room. It serves as a legal document, and provides a historical record of operational performance, maintenance, and testing. This objective will introduce the requirements for keeping a boiler room log.

Side Track

The legal requirements and best practices for using log books and log sheets are covered extensively in **Part A, Unit 10, Chapter 3 Plant Communications**.

Boiler Operating and Maintenance Logs

Boiler logs must contain sufficient information to show that boilers are receiving appropriate care and attention.

For a boiler log to be a valuable tool, it must provide a continuous record of boiler operation (operating conditions, starts, and trips), testing, and maintenance. It is common practice to use a weekly or monthly log sheet to record routine operational checks, tests, and minor maintenance.

Qualified personnel should check the boiler and auxiliary equipment at regular intervals. Operating devices and protective equipment should be tested at sufficiently frequent intervals to determine that they are in working condition. These checks should be recorded in the boiler log book, or on the boiler log sheet.

The following are commonly recorded in a log book:

- Major maintenance jobs
- Auxiliary equipment testing
- Adjustment of controls
- Safety valve testing
- Instructions for operators

Figure 12 is an example of a low-pressure heating boiler log sheet. Boiler operators can develop similar log sheets and include all data relevant to their boiler plant.

Figure 13 is a sample page from a boiler room log book. It shows a few typical entries.

Under the relevant legislation, jurisdictions require that boiler room log books be maintained. The log book must be available for review by the Boiler Inspector at any time. The completed books must be stored for a prescribed period of time (usually seven years, according to jurisdictional requirements).

Figure 12 – Low-Pressure Heating Boiler Log

Low-Pressure Heating Boiler Log

Company ____________________

Building ____________________ Location ____________________

Boiler Make: ____________________ Boiler No. ____________________

Week ____________________ 20 ________

	Time	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Check and record	Steam pressure														
	Water level														
	Feed pump pressure														
	Feed water pressure														
	Flue gas temperature														
	Oil pressure														
Test	Low water cut-off														
	Feed pump control														
	Gauge glass + column														
Check	Feed water pump														
	Cond. Tank level														
	Burner operation														
	Fuel supply														
Test each shift	Dissolved solids														
	Alkalinity														
	Phosphate														
	Sulphite														
	Ph														
	Blow-off (seconds)														
	Make-up water														
	Water softener														
Test or clean at least once weekly	Safety valves														
	Water filter														
	Oil filter														
	Oil burner														
	Ignition														
Minor remarks only	Am remarks														
Use log book for extensive details	PM remarks														
	Operator's initials														

Figure 13 – Sample of Boiler Log Entry

DATE	REPORTS OF TESTS, INSPECTIONS, REPAIRS, ETC.
Mar 23	Replaced gage glass on #2 expansion tank J.C.
Mar 25	Tested flame scanners on #1 and #2 boilers P.J.
Mar. 26	Fuel Oil tank filled, 1800L. Clean oil filters S.P.
Mar 29	Shut #1 boiler down for internal cleaning and inspection
	Valves in supply and return lines closed, fuel valves closed,
	burner removed. Power off. P.J.
Mar 30	Drained #1 boiler, opened man-and hand
	holes. Washed out boiler. Opened doors, cleaned
	firetubes. furnace and reversing chambers. P.J.

Chapter Summary

This chapter covered many of the key duties of the Power Engineer on shift. When first coming on shift, operators must familiarize themselves with what happened on the previous shift. This helps to prepare for the upcoming shift. Rounds must be performed to ensure all the plant equipment is operating correctly.

Each area of the plant has specifics checks for the operator to perform while on rounds. These may include observing temperatures, pressures, flows, and levels. Pressure and level controls may be blown down. The operation of flame safeguards and programmed combustion controllers should be observed. Minor maintenance, such as tightening packing or valve leaks, may need to be performed while on rounds.

In addition, certain types of tests must happen on a regular basis. These include low water cut-off slow drain tests, safety valve manual try lever tests, and safety valve pop tests. Flame failure response checks are also conducted. Other boiler limits are tested for correct operation. These include the combustion air proving switch, high and low fuel pressure cut-offs, boiler pressure controls, boiler temperature controls, and boiler water flow limit switches.

The results of the rounds, tests, and checks performed must be logged. This provides a seamless shift handover, and satisfies legal requirements.

Review this material often. Though not comprehensive, it covered many of the critical checks and tests Power Engineers are responsible for while on shift.

CHAPTER 5

Shutdown Procedures

Learning Outcome

When you complete this chapter you should be able to:

Describe generic shutdown and layup procedures for different boiler types.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe hot water boiler shutdown procedures.*
2. *Describe steam boiler shutdown and lockout procedures.*
3. *Describe extended period layup requirements for steam boilers.*

Chapter Introduction

Boilers are shut down annually, for a variety of reasons. Boilers require annual inspection by jurisdictional and insurance inspectors. Boilers require scheduled repairs and maintenance, which can only be performed when the boiler is out of service. Large heating boilers may not be needed during the summer. Smaller "summer boilers" may not be needed during the winter. Some boilers are shut down but kept available for standby service.

This chapter presents general principles and procedures for shutting down and laying up hot water and steam boilers. The shutdown and layup procedures described in this chapter are important for safe plant operation, and for prolonging boiler service life.

It is important to have a good working knowledge of boiler plant equipment. An understanding of boiler components, startup, and operation are fundamental requirements for studying this chapter.

Objective 1

Describe hot water boiler shutdown procedures.

Removing Hot Water Boilers from Service

Hot water boilers must be periodically taken out of service for cleaning, inspection, or repair; or for layup at the end of the heating season. Before shutting down a hot water boiler, the overall status and condition of the boiler, plus its controls and its appurtenances, must be assessed, so that repairs can be made during the time the boiler is out of service.

CAUTION

Site-specific Standard Operating Procedures must be followed when taking a boiler out of service. Boiler manufacturer manuals and procedures must be adhered to. Review all procedures and recommendations before removing a boiler from service.

Follow all site-specific lockout/tagout procedures. Refer to **PanGlobal Fourth Class, Part A, Unit 4 Introduction to Plant and Fire Safety** to review lockout and tagout principles.

Below is a general procedure for taking a hot water boiler out of service:

1. While the boiler is still in operation, open the blowoff or drain valve on the bottom of the boiler. This will remove the sediment that may have collected. Close the valve when the water runs clear.
2. Check that the automatic make-up water system feeds the amount of water blown off in the previous step.
3. Observe the flame for irregularity. If unusually smoky, asymmetrical, or impinging on boiler surfaces, employ a certified burner service technician to adjust the burner prior to returning the boiler in service.
4. Test all operating and limit controls. These include:
    a) Low water cut-off
    b) High temperature cut-off
    c) High and low gas pressure cut-offs
    d) Flame scanner/flame failure detection devices
    e) Combustion air proving switch
    f) Any other control as specified by the boiler manufacturer
5. Perform a try lever test on the safety relief valve.
6. Test the water chemistry. Add chemicals, if necessary, to maintain the correct concentration required to protect the boiler and heating system. Consult a certified water treatment professional to determine which chemicals are necessary, and their appropriate concentrations.
7. Place the burner firing rate control to manual. Then, slowly reduce the firing rate of the boiler.
8. When the boiler is at minimum fire, turn the boiler control switch to "off."
9. Shut, lock, and tag the main and pilot manual fuel valves.

10. Open, lock, and tag the boiler control circuit breaker.
11. Open, lock, and tag the boiler draft fan circuit breaker.
12. If the heating system is being taken out of service, turn off the circulator pump. Lock its breaker open and tag it.
13. Close the stop valves in the boiler supply and return lines. Lock them and tag them.
14. Let the boiler cool down slowly.
15. In the log book, record the results of all limit tests, and the time the boiler went off-line.

Additional Steps to Prepare for Waterside or Fireside Inspection

CAUTION

Depending on the type of boiler and its physical size, waterside and fireside inspection may require confined space access. Follow approved site-specific confined space procedures before entering a boiler fireside or waterside. Refer to **PanGlobal Fourth Class, Part A, Unit 4 Introduction to Plant and Fire Safety** to review confined space procedures.

1. If the boiler waterside must be opened for maintenance or inspection:
   a) If the boiler shares an expansion tank with other boilers, close the valve in the line that connects the boiler with the expansion tank.
   b) After the boiler has completely cooled down, open the blowoff and vent valves to drain the boiler.
   c) After the boiler is drained, remove the manhole covers, handhole covers, and drain plugs.
   d) Wash the boiler out with a stream of high-pressure cold water.
2. Open the fireside access. Inspect the burner and refractory, according to manufacturer guidelines.

Boiler Layup

Side Track

The following information supports additional content found in **PanGlobal Fourth Class, Part B, Unit 5, Chapter 3 Boiler Maintenance.**

The boiler can be laid up after the boiler has been removed from service, inspected, and all required maintenance and repairs are completed.

Hot water boilers are usually kept full of water during a summer layup. It is beneficial to keep the heating system and boilers full of chemically treated water. This way, few impurities are introduced to the heating system, and chemical use is minimized.

Hot water heating boilers use very little make-up water. Often, there is sufficient chemical residual to prevent corrosion during the layup period. However, the need for proper chemical treatment during the layup is crucial. Prior to shutting off the boiler and the circulating pumps, accurate water testing and the addition of chemicals are critical.

The fireside can be left open during the summer months, or re-closed after the fireside is cleaned and inspected. If the fireside is re-closed, make sure the draft fan damper is shut. This will prevent humid air from passing through the furnace and up the chimney. Humid air could condense moisture on the fireside surfaces, and cause corrosion. After cleaning the fireside, some plants apply oil to protect the its surfaces. This should be done before closing up the fireside.

Objective 2

Describe steam boiler shutdown and lockout procedures.

Shutting down a steam boiler requires the operator to maintain stable steam system pressures, while simultaneously transferring load to other operating boilers. The shutdown procedure provides an opportunity to test safety interlocks without interrupting production. The following principles are general steps for shutting down a steam boiler.

Shutting Down a Steam Boiler

The following is a suggested procedure for removing a high-pressure steam boiler from service, for maintenance, inspection, or layup. Note that this procedure is for a high-pressure boiler on a shared steam header system. The steps for removing a low-pressure steam boiler from a shared header system are similar.

CAUTION

Site-specific Standard Operating Procedures must be followed while taking a boiler from service. Boiler manufacturer manuals and procedures must be adhered to. Review all procedures and recommendations before removing a boiler from service.

1. For several days before shutting down the boiler, increase the rate of continuous blowdown, and increase the frequency of bottom blowoff. Adjust the chemical feed rates to accommodate an increase in make-up water. This will discharge sediment and sludge that may have accumulated in the boiler, and make the waterside easier to clean.

On Track

Consult with a boiler water treatment professional to determine suitable chemical concentrations and boiler water conditions while preparing a boiler to come off-line.

2. Observe the flame for irregularity. If unusually smoky, asymmetrical, or impinging on boiler surfaces, employ a certified burner service technician to adjust the burner prior to returning the boiler to service.
3. Test all operating and limit controls. These include:
   a. Low water cut-off
   b. Combination feeder/cut-off control or pump control
   c. High-pressure cut-off
   d. High and low fuel pressure cut-offs
   e. Flame scanner/flame failure detection devices
   f. Combustion air proving switch
   g. Any other control as specified by the boiler manufacturer
4. Put the boiler steam pressure control in manual mode, and slowly reduce the firing rate. Monitor the main steam header pressure to confirm the other boilers have taken the load.
5. Isolate the boiler from the steam header, and perform a safety valve pop test.

6. With the boiler at minimum fire, turn the boiler control switch to "off."
7. Shut, lock, and tag the main and pilot manual fuel valves.
8. Open, lock, and tag the boiler control circuit breaker.
9. If the system has only a single boiler, turn off the boiler feedwater pump. Lock its breaker open and tag it.
10. Close the boiler non-return valve (main steam outlet stop valve) when the boiler stops supplying steam. This occurs when the boiler pressure drops to below main steam header pressure.
11. Isolate the boiler from the main header. Open the non-return valve drain and the steam line vent/drain, which is located between the non-return valve and the header. Lock and tag the header and non-return valve in the shut position. Lock or tag the non-return drain and the steam line vent/drain in the open position.
12. Close the stop valves in the boiler feedwater supply line. Lock and tag them.
13. Let the boiler cool down slowly.
14. Open the steam drum vent valve when the boiler pressure drops to approximately 20 to 35 kPa. This will prevent a vacuum from forming in the boiler.

On Track

Boilers are designed to withstand internal pressure, not external pressure. Allowing a boiler to develop a vacuum may cause damage to pressure retaining components.

CAUTION

It is dangerous to open a boiler manhole or handhole when the drum or shell is under vacuum. Never permit a boiler to develop an internal vacuum. Ensure drum vents are opened as the boiler cools. Make sure the drum vents are open before attempting to open a manhole or handhole.

15. In the log book, record the results of all limit tests, and the time the boiler went off-line.

If the boiler is going to be shut down for an extended period of time, it will need to be laid up.

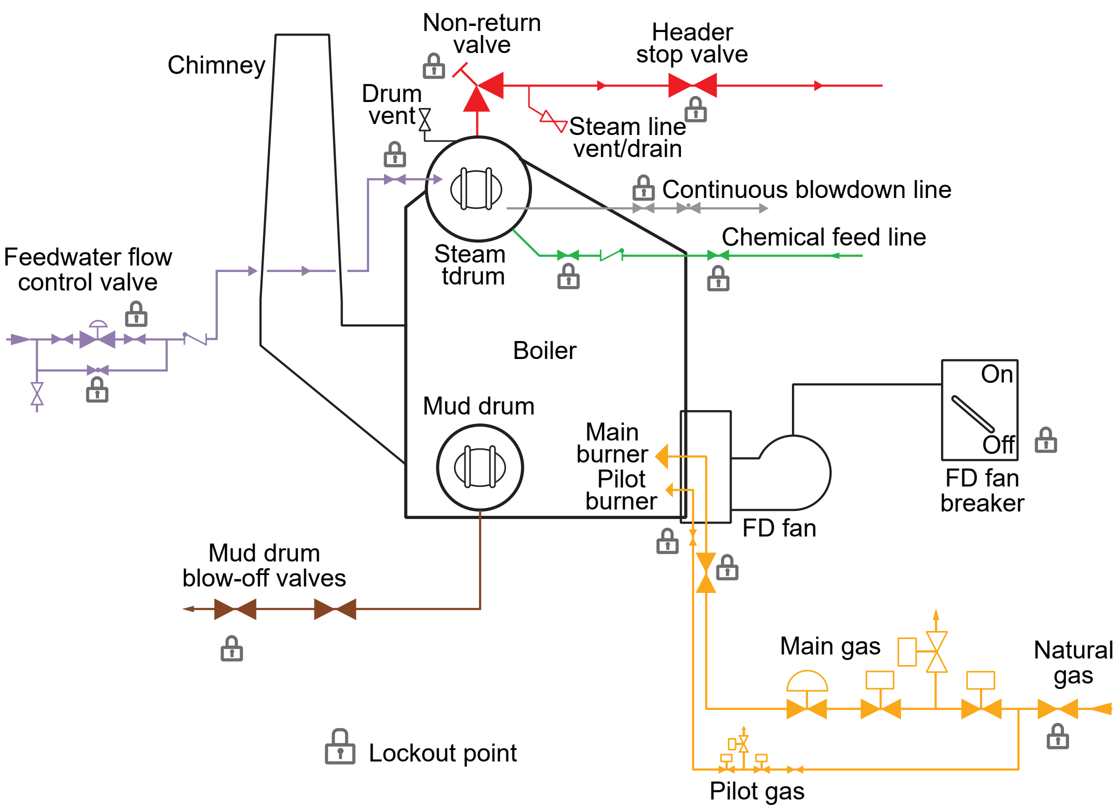
Locking Out a Steam Boiler

Figure 1 shows a typical high-pressure steam packaged boiler, indicating lockout points. Note that the complexity of a lockout varies depending on the complexity of the boiler system (number of draft fans, method of fuel firing, sootblowers, etc.). It may be useful to compare the lockout points shown in Figure 1 to those described in **Part B, Unit 5, Chapter 4 Boiler Cleaning.**

CAUTION

Follow all site-specific lockout-tagout procedures. Refer to **PanGlobal Fourth Class, Part A, Unit 4 Introduction to Plant and Fire Safety** to review lockout and tag out principles.

Figure 1 – Packaged Steam Boiler Lockout



When locking out a boiler, always follow site-specific lockout/tagout procedures. Only qualified operators are permitted to perform or verify lockouts.

The following describes how to apply a group lockout to the high-pressure steam boiler shown in Figure 1.

1. Follow the steps for shutting down a steam boiler, as outlined above.
2. Obtain a lockout sheet for the boiler. If the boiler is being locked out for the first time, prepare a lockout sheet using an approved template.
3. Obtain a lockbox and a set of numbered group lockout locks.
4. The operator performing the lockout places a lockbox lock on a lockout point. The number on the lock must be recorded at the lockout point.
5. The operator must initial the lockout point item listed on the lockout sheet to verify that it was done.

6. The operator proceeds to place a lockbox lock and tag on all of the lockout points. For a boiler, these points include:
   a) Main gas isolation valve
   b) Pilot test firing valve
   c) Main test firing valve
   d) Chemical feed isolation valve at drum
   e) Chemical feed isolation valve before check valve
   f) CBD isolation valve at drum
   g) Non-return valve
   h) Steam header isolation valve
   i) Feedwater isolation valve at drum
   j) Feedwater isolation valve downstream of regulator
   k) Feedwater bypass valve
   l) Blowoff valve
   m) FD fan breaker
7. The vent on the steam drum, and the vent between the stop valve and the non-return valve, should be open and recorded as open. It is best practice to lock them open, but in many plants considered unnecessary.
8. Double-check the lockout points to make sure that they are all accounted for.
9. A second qualified operator must verify that all the lockout points are locked, and that the various parts of the boiler are in a zero-energy state. This means that all isolation valves must be holding tight, and that all electrically operated equipment is de-energized.
10. Place the key for the lockbox set inside the lock box. All unused locks must also be put in the lockbox.
11. Seal the lockbox with a car seal. Record the seal number on the lockout sheet.
12. Sometimes, plants or jurisdictions require the chief or shift engineer to add an additional lock, called a supervisor or operations lock, to the lockbox. This is the last lock removed after work is complete and signed off. The supervisor or operations lock verifies that the lockout was performed correctly.
13. Contractors and plant employees place their personal lock on the lockbox when they work on the boiler. As well, they record their lock number on the lockout sheet, and sign when the lock is installed and when the lock is removed.
14. Record the lockout in the official Log Book.

Removing the Lockout

When the work on the boiler is complete, the lockout is removed.

1. Workers sign-off that their work is complete. All personal locks are removed from the lockbox.
2. The chief, shift engineer, or delegate removes the supervisory lock from the lockbox.
3. The car seal is broken. At this point, the lockout is no longer in effect.

4. The lockout key is removed from the lockbox. A qualified operator removes the locks, and restores valves and breakers to their previous positions. The operator records on the lockout sheet:
    a) The number of the lock removed.
    b) The final position of the restored valve or breaker.
    c) The date the lock was removed.
5. The operator records his or her initials beside each lock removed. All removed locks are placed back in the lockout box.
6. The chief engineer or safety officer may keep the lockout sheet for future reference.
7. Record the lockbox lockout removal in the official log book.

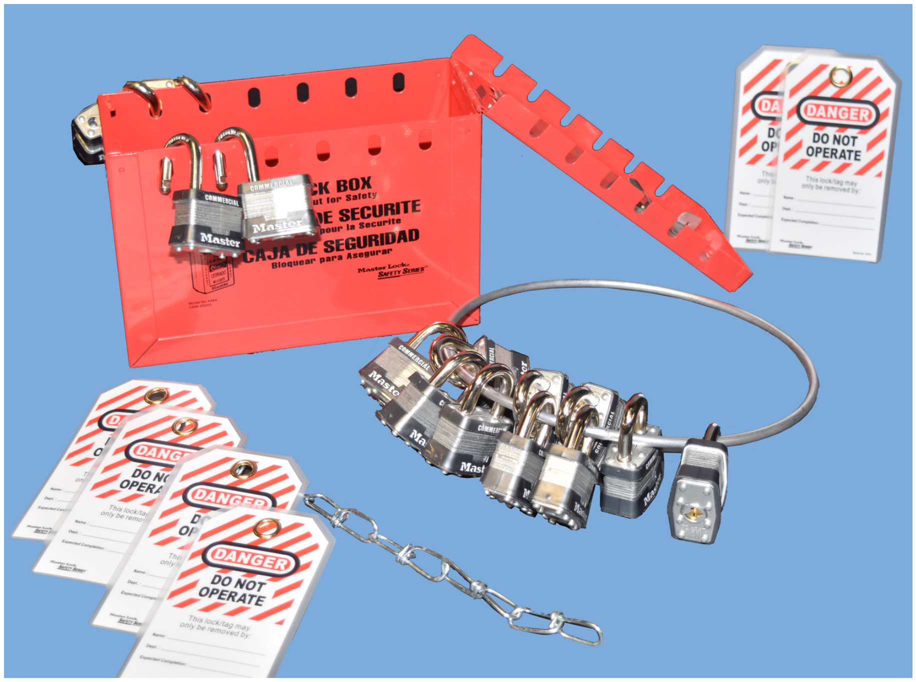
A typical lockbox lockout sheet for the above boiler may look like the one in Table 1. Note that in this case two trained operators are completing the lockout.

Table 1 – Sample Boiler Lockout Sheet

Lockout Master Sheet							
Title:	Boiler #3 Lockout						
Date:	August 1, 2017						
Qualified Operator(s) Performing Lockout:	Theresa Chan, Jim Brown						
Types and Number of Locks Used	13 green locks						
Car Seal Number	987654						
Lockout Points	Lock Installed				Lock Removed		
	Lock No.	Initial	Open/ Closed	Date	Initial	Open/ Closed	Date
1.Main gas isolation	1	TC	C	8/1/2017			
2. Pilot test firing valve	2	TC	C	8/1/2017			
3. Main test firing valve	3	TC	C	8/1/2017			
4. Chemical feed at drum	4	TC	C	8/1/2017			
5. Chemical feed before check valve	5	TC	C	8/1/2017			
6. CBD at drum	6	JB	C	8/1/2017			
7. Non-return valve	7	JB	C	8/1/2017			
8. Steam header valve	8	JB	C	8/1/2017			
9. Feedwater at drum	9	JB	C	8/1/2017			
10. Feedwater downstream of regulator	10	JB	C	8/1/2017			
11. Feedwater bypass	11	JB	C	8/1/2017			
12. Blowoff valve	12	JB	C	8/1/2017			
13. FD fan breaker	13	JB	O	8/1/2017			
14.							
15.							
Lockout Verified By:	Mark Stedenko						
Shift Engineer Signature:							

Figure 2 shows a typical isolation lockout box with locks and tags.

Figure 2 – Typical Lockout Box



Objective 3

Describe extended period layup requirements for steam boilers.

Proper storage of an out-of-service steam boiler is critical for maintaining its longevity. Many boilers have had their lifespans shortened due to improper layup.

There are several ways to layup a steam boiler. The expected duration and purpose of the layup will determine which method is used.

Side Track

The following information supports additional content found in **PanGlobal Fourth Class, Part B, Unit 5, Chapter 3 Boiler Maintenance.**

Dry Layup

The dry layup is the method most often chosen for:

- Long-term shutdown
- Shutdown of boilers that are not on standby
- Shutdown in freezing conditions
- When internal inspection or boiler entry is required

To perform a dry layup on a steam boiler, follow the steps for shutting down a boiler. After locking out, draining, and cleaning the boiler, dry it thoroughly. Air movers may be used to supply air to the mud drum or lower headers. This will force the air through the boiler and out the steam drum.

Once the boiler has been thoroughly dried, trays of moisture absorbing materials (such as quicklime, silica gel, or activated alumina) must be placed inside the shell or drums. If quicklime is used, **ASME BPVC Section VII** recommends the following quantities be used:

- 3.2 kg of **quicklime** for every 2.83 m^3 of boiler volume
- 3.6 kg of **silica gel** for every 2.83 m^3 of boiler volume

Desiccant must be placed in trays to catch the removed moisture. Then, the handholes, manholes, inspection ports, and all openings to and from the boiler must be closed and made leak tight.

Desiccant trays should be checked on a bi-weekly to monthly basis to assess if they should be replaced.

Wet Layup

Boiler wet layup is common for:

- Shorter duration shutdowns
- Shutdowns for boilers on standby
- Shutdowns when freezing conditions cannot occur.

In a wet layup, the boiler chemistry must be adjusted to account for long-term chemical needs. The chemicals must be added while the boiler is operating, to ensure they are thoroughly circulated through the shell or drums.

It is advisable to drain the boiler and clean its fireside and waterside prior to placing it under wet layup. The following procedure is for boilers being placed directly into wet layup, without being drained and cleaned.

1. Perform water tests as the plant procedures direct. Consult a certified water treatment professional to determine which chemicals are necessary, and their appropriate concentrations.
2. Adjust the pH of the water to 10, using the recommended alkali for the plant.
3. Adjust the sodium sulfite to 200 ppm to ensure a sufficient quantity of **oxygen scavenger** residual remains for the layup period.
4. Adjust all other chemical parameters to the recommended chemistry regimen.
5. Shut the boiler down. Depressurize and open the vents.
6. Fill the boiler until it overflows from the vents, and then close the vents.
7. Maintain approximately 40 kPa of pressure on the boiler for the layup period. This may be achieved with a head tank, a nitrogen blanket, or with a steam blanket.

Chapter Summary

This chapter discussed how to safely shut down and store hot water and steam boilers. Included were descriptions of necessary tests to perform, and conditions to observe, when taking a boiler out of service.

The lockout/tagout principles discussed in other chapters were applied to a typical packaged steam boiler. Short- and long-term storage of hot water and steam boilers was also touched upon.

This chapter emphasized the need to follow site-specific safe work procedures and manufacturer guidelines. This content supports material found in other Units in the **PanGlobal Fourth Class Edition 3.5**. Make sure to review the related materials in other units.

Chapter 6

Boiler Plant Monitoring and Reporting

Learning Outcome

When you complete this chapter you should be able to:

Describe the points and readings that need to be monitored and recorded in a plant.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Discuss recording requirements for operating and performance conditions.*
2. *Discuss the various systems required to conduct equipment repairs, and to manage the related maintenance records.*
3. *Describe the operational causes, consequences, and prevention of water hammer.*
4. *Describe the consequences and actions required for various equipment failures.*
5. *Describe the consequences, and actions required, in the event of boiler accidents.*

Chapter Introduction

Power Engineers are required not only to start, stop, and operate plant equipment, they must also monitor and report on plant conditions.

Once started, most boiler plant equipment operates automatically. While operating automatically, key operating and performance indicators must be monitored and compared to plant and equipment performance requirements. Along with monitoring comes documentation and reporting of observations.

Monitoring, documenting, and reporting:

- Informs the decisions of operators, thus ensuring optimum operating efficiency.
- Informs maintenance activities, thus ensuring optimum equipment life.

Equipment monitoring is an on-going process. Readings are taken while on rounds, or at designated times during the shift. Key operating parameters are compiled on reading sheets, which are updated from time-to-time.

Today, reading sheet entries are often transposed into spreadsheets, which may be shared between operation leads, maintenance leads, and engineering departments. Shift engineers and chief engineers review the reading sheets, and occasionally issue changes to key performance indicators (KPIs), as informed by trends in readings. Maintenance planners consult the readings to determine maintenance activities, and to anticipate and avert equipment failure. Engineering teams analyze data to ensure equipment is operating according to design specifications, or to optimize equipment installations.

This chapter identifies the typical monitoring and recording expectations for Power Engineers. As well, operator response to adverse situations is also covered.

To benefit from this chapter, boiler plant start-up, operation, and shutdown must be well understood.

Objective 1

Discuss recording requirements for operating and performance conditions.

Readings

Equipment that operates automatically may, unfortunately, be ignored. Complacent operators trust the control systems until adverse conditions arise. These conditions could be avoided by conducting regular rounds and by taking readings.

Taking power plant readings is a necessary, routine activity. These readings are required in order to compare current field conditions with the expected performance of the equipment. Taking readings encourages operators to:

- Familiarize themselves with the equipment for which they are responsible
- Assess operating conditions
- Diagnose problems
- Identify operating trends

If the operator notices that a reading is outside of the expected range, immediate action can be taken to resolve the situation. For example, if the lubrication oil temperature of a large boiler feed pump is higher than it should be, an operator can adjust the cooling water flow.

Field operators will usually be required to take readings while performing rounds. Such readings are taken from field instruments, a chart recorder, or a computer screen. An example of a reading sheet is given in Figure 1.

Readings that are recorded on a sheet can be stored and reviewed for historical data. For example, if a fan bearing has failed multiple times over a short period of time, reviewing the reading sheets could explain why. For these reasons, it is important that the Power Engineer remains diligent about recording information accurately while out in the field.

Figure 1 – Reading Sheet

Daily steam plant readings

Time	0600	1200	1800	2400		0600	1200	1800	2400		0600	1200	1800	2400		0600	1200	1800	2400
Utilities					Boiler 1 (on/off)					Boiler 2 (on/off)					Boiler 3 (on/off)				
Comp air press. (kPa)					Pressure (kPa)					Pressure (kPa)					Pressure (kPa)				
City water press. (kPa)					Fuel (G/O)					Fuel (G/O)					Fuel (G/O)				
O.A.T. (°C)					Steam flow ((kg/h)					Steam flow ((kg/h)					Steam flow ((kg/h)				
Supply gasr press. (kPa)					Fuel flow					Fuel flow					Fuel flow				
Oil tank level					Feedwater flow					Feedwater flow					Feedwater flow				
kW					Flue gas temp. (°C)					Flue gas temp. (°C)					Flue gas temp. (°C)				
Demand					CBD valve setting					CBD valve setting					CBD valve setting				

Time	0600	1200	1800	2400		0600	1200	1800	2400		0600	1200	1800	2400		0600	1200	1800	2400
Deaerator					**Boiler feed pumps**					**Condensate transfer pumps**					**Softener**				
Temp. (°C)					Pump 1 press. (kPa)					Pump 1 press. (kPa)					Brine level (check)				
Press. (kPa)					Pump 2 press. (kPa)					Pump 2 press. (kPa)					Salt level (check)				
Level															Totalizer (litres)				

Steam production				**Feedwater**			**Fuel**			**% Makeup**	
Steam flow	2400	0000	Total	2400	0000	Total	2400	0000	Total		
Boiler 1										**Boiler efficiency**	
Boiler 2										Boiler 1	
Boiler 3										Boiler 2	
		Plant total			Plant total			Plant total		Boiler 3	

Charts and Data Recorders

Both the control room operators and field operators must take readings, for the same reasons. Control room operations must oversee a multitude of plant parameters simultaneously. Monitoring current and historical conditions enables control room personnel to assess system performance, foresee problems, and take action.

To assist the control room operator, chart recorders are often installed in control rooms. These may be traditional circular or strip charts, or modern distributed control system electronic displays with data logging capabilities.

The electronic, computer-based displays can be configured to simultaneously show the conditions of any one of thousands of control parameters, including flows, valve positions, temperatures, levels, and pressures.

Mechanical chart or strip recorders require paper and ink. These have a defined length of time before the paper and ink need to be replaced. Circular chart recorders are renewed daily or weekly, depending on the type of the recorder mechanism.

Recorded trends may be dedicated to boiler plant equipment, or other process equipment. For example, bearing vibrations are often monitored in the control room. Operators can observe the bearing vibration over time to determine if, and when, a piece of equipment should be taken out of service for maintenance.

Side Track

Chart recorders and computerized trends are covered at length in **Part A, Unit 9, Chapter 3 Basic Controls and Instrumentation Components**. Refer to that chapter for more detailed information.

Objective 2

Discuss the various systems required to conduct equipment repairs, and to manage the related maintenance records.

Depending on the size of the plant, managing maintenance can be complex task. A plant that can more easily tolerate service interruptions is generally simpler to maintain. When there are many components to a plant, identifying maintenance requirements becomes more complex. In these larger plants, Preventative Maintenance (PM) systems schedule regular maintenance. These systems may also be used to predict equipment problems before they cause equipment outage.

Preventative maintenance encompasses all plant equipment. In many cases, preventative maintenance tasks are distributed between several work groups such as Operations, Mechanical Maintenance, Electrical Maintenance, and Instrumentation.

Preventative Maintenance

Preventative maintenance (PM) is necessary for continued plant production. A well-planned PM system will ensure equipment longevity, and protect against unplanned shutdowns.

PM systems may cover cleaning, lubrication, servicing, and monitoring of equipment. Many equipment readings are used as PM system data.

One goal of a PM system is to provide early detection of equipment problems. The PM system covers all plant equipment, with each item having specific required checks. By performing regular inspections, equipment health can be determined. Typical activities performed as part of a PM system include the following:

- Review of recorded operating parameters
- Vibration monitoring
- Equipment inspection
- Lubricating oil sampling and testing
- Equipment adjustment
- Bump tests
- Shaft rotation
- Instrument calibration
- Parts replacement
- Equipment duty swap
- Safety valve testing and calibration
- Operation of standby equipment (such as generators and fire pumps)

If a deficiency is found during a preventative maintenance check, the operator should create a work order so repairs can take place. Work orders notify the work-planning department of deficiencies. This department assesses each deficiency, and plans the required maintenance according to plant priorities.

The following looks at some of the preventative maintenance activities that are typically performed by Power Engineers and others.

Preventative Maintenance Checks

Oil Level Checks

Checking oil level is a regular activity, as part of operator rounds, and as a preventative maintenance task. Power Engineers must understand how to ensure that oil levels are correct. This will vary from machine to machine. It is also important to know what type of oil is required for a specific piece of equipment. Some of the characteristics that may differ include:

- Viscosity and viscosity index
- Flash point
- Pour point
- Floc point

Most plants have a lubricant index for selecting the proper lubricant. Before adding oil, the index must be referenced, and the correct lubricant type for the specific piece of equipment must be confirmed.

Air Station Blowdown

Air stations are located throughout each plant. Water entrained in compressed air will condense in the instrument air piping. This will cause damage to pneumatic instruments and control valves. Condensed water collects in low points of the control air piping, and must be removed. This is done by briefly opening and reclosing the low point drain valves.

CAUTION

Opening a valve in a compressed air system causes air to escape rapidly. This can be a noise hazard. Wear hearing protection while performing this task.

Never allow blasts of compressed air to contact the skin. Wear protective gloves to perform this task.

Standby Equipment Operation

Standby equipment must be maintained in a reliable, ready state. Periodic operational tests are required to ensure the standby equipment will work correctly when called upon.

The frequency of operation and inspection is determined by the level of reliability required. For example, standby fire pumps are critical equipment, and should be run weekly.

Operating standby equipment as part of a preventative maintenance program requires the date and time of operation to be recorded, as well as some operational data. This typically includes pressures, flows, temperatures, shaft speeds and capacities.

The following standby equipment needs periodic inspection and operation.

Emergency Generators

Emergency generators are commonly powered by diesel, gasoline, natural gas, and propane engines. The oil levels, fuel supplies, and governing controls should be inspected as part of their periodic test runs. The test run should include an assessment of the generator's loading capability. This requires the generator to prove it can power certain equipment, or a load bank.

NFPA 110 Standard for Emergency and Standby Power Systems states that emergency standby power systems and related components (such as automatic load transfer switches) shall be inspected weekly and exercised under load at least monthly.

For diesel driven generators, the monthly test must last at least 30 minutes. The load on the generator must be at least 30 percent of the generator nameplate kW rating, and the diesel engine must reach normal operating temperature.

Fire Pumps

Fire pumps are critical for plant safety and are generally test run on a weekly basis. The inspection and test run of a fire pump should include verifying oil levels and pumping capacity. Many plants have multiple fire pumps with either redundant or separate power supplies. This may include a separate pump and motor set, or the prime mover of the pump may be a diesel or gasoline engine. In the case of a diesel or gasoline engine driven fire pump, parameters such as battery voltage, fuel supply, crankcase oil level, and drive clutch should all be inspected.

NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems requires weekly "no-flow" tests of diesel and electric fire pumps, with some exceptions for electrically driven pumps. The pumps must start via the automatic start system. Diesel pumps must run for at least 30 minutes. Electric pumps must run for at least 10 minutes.

In addition to the no-flow test, all fire pumps require annual flow tests. Annual flow tests require equipment and instruments that most plants do not have. As well, most Power Engineers are not trained and certified to perform fire pump flow tests. Therefore, the annual flow test is usually conducted by a specialized testing firm under contract.

Side Track

Fire pump testing and operation is covered in **PanGlobal Fourth Class Part A, Unit 4, Chapter 5 Fire Extinguishing Methods and Equipment**.

Standby Feedwater Pumps

Standby feedwater pumps may be powered by electric motors, internal combustion engines, or steam turbines. Boiler feedwater pumps are critical to power plant operation. Therefore, they must be operated regularly, regardless of the type of prime mover.

It is common to run standby feedwater pumps on a weekly basis. If the pump driver is an internal combustion engine, parameters such as battery voltage, fuel supply, crankcase oil level, and drive clutch should be inspected as part of the test run. If the driver is a steam turbine, all the pre-start checks typical of a steam turbine should be completed. This includes warming up the turbine casing, draining condensate, and verifying adequate bearing oil levels.

Duty Swap

A duty swap of standby equipment should be performed as part of a preventative maintenance schedule. This distributes wear, and demonstrates equipment reliability. For example, it is not possible to perform vibration analysis, or to record operational data on equipment that is not operating. Duty swaps must be completed in order to retrieve this data.

To perform a duty swap:

1. Start the incoming piece of equipment (such as an alternate pump) while the in-service piece of equipment is still running.
2. Check the operating parameters to ensure they match that of the running piece of equipment. In the case of a pump, the checks include discharge pressure, flow, oil level, oil temperature, noise, and vibration.
3. When all of the operating parameters on the incoming equipment match that of the in-service equipment, or meet required parameters, shut down the in-service piece of equipment. In the case of the pump, the incoming pump now becomes the in-service pump, and the out-of-service pump becomes the standby.

Duty swaps are also commonly performed on boilers, boiler feed pumps, fuel oil pumps, condensate transfer pumps, air compressors, and refrigeration compressors.

Safety and Safety Relief Valve Testing

Safety and safety relief valve testing intervals are governed by preventative maintenance schedules. Safety valves require particular attention because they are critical safety items. Depending on which test is being performed, an authorized inspector, or representative of the jurisdiction, may need to witness the test.

Side Track

Details about safety valve construction, installation, and operation can be found in **PanGlobal Fourth Class, Part B, Unit 3, Chapter 1 Pressure Relief Valves**.

Testing of safety valves is covered extensively in **PanGlobal Fourth Class, Part B, Unit 4, Chapter 4 Operational Checks**.

Consult **ASME BPVC I, IV,** and **VII** in the **PanGlobal Academic Extract Volume 1** for detailed information about safety and safety relief valves.

Maintenance Records

Keeping maintenance records is as important as recording data. There are various methods to keep records. Some plants may use a paper system, or an electronic filing system. It is common to have a combination of both paper and electronic record keeping.

The Power Engineer performing rounds, or completing a task initiated by a PM schedule, will typically follow a paper copy of a log sheet, checklist, or a standard operating procedure. Once the monitoring is completed, the paper copy is submitted for review by a supervisor. It then goes to management or engineering personnel for data entry into the electronic data recording system. The system can then analyze current and historical equipment performance. It can also make predictions on reliability.

Side Track

Further information about maintenance management systems can be found in **PanGlobal Fourth Class, Part A, Unit 10, Chapter 3 Plant Communications**.

Objective 3

Describe the operational causes, consequences, and prevention of water hammer.

All steam plants are susceptible to the hazards of water hammer and its damaging effects. The results of water hammer are both dangerous and costly. This objective discusses how to identify, prevent, and respond to water hammer.

Identifying Water Hammer

Water hammer is recognizable as a series of loud noises, accompanied by the shaking of piping systems. The noises can be small pings or loud bangs, depending on the severity of the water hammer. Piping system movement can be slight, or quite dramatic in the case of severe shock.

Water hammer may occur when pumps stop, causing discharge check valves to close suddenly. It also occurs when steam is first admitted into cold steam lines or heat exchangers.

The consequences of water hammer can range from mild shockwaves to pipe failures. It is imperative that operators are familiar with methods of water hammer prevention.

Side Track

More details on water hammer, steam traps, and condensate removal can be found in **PanGlobal Fourth Class, Part A, Unit 7, Chapter 1 Introductory Fluid Handling Technology.**

Preventing Water Hammer

Water hammer can be caused by the sudden stoppage, or sudden acceleration, of fluid. Sudden stoppage is caused when:

- Manual valves are closed quickly
- Control valves (such as solenoid valves) close rapidly
- Swing check valves close suddenly when pumps stop or control valves closes quickly

Sudden fluid acceleration is caused when:

- Pumps start suddenly, with discharge valves fully open
- Manual valves are opened quickly
- Control valves (such as a solenoid valve) open rapidly
- Saturated steam and saturated water (condensate) co-exist in steam or condensate lines

Preventing water hammer can be accomplished by:

- Operating equipment carefully
- Redesigning piping systems
- Installing piping components that reduce or eliminate water hammer

Operational Solutions to Prevent Water Hammer

Operate manual valves slowly. A good rule of thumb is that it should take 5 seconds to fully open or fully close a valve, for every 25 mm of pipe diameter. Therefore, a manual valve on a DN 150 pipe should take 30 seconds to fully open or fully close.

For centrifugal pumps, slowly close the discharge valve before shutting off the pump.

For steam lines:

1. Repair or replace steam traps when a steam line is out of service, so that they function properly when the steam line is returned to service.
2. Inspect steam lines for broken or disconnected pipe hangers. Sagging pipes allow condensate to accumulate in areas that are not served by traps. Repair broken pipe hangers.
3. Inspect steam lines for damaged or missing insulation. Missing insulation creates more condensate for the traps to handle. Repair or replace insulation as required.
4. Regularly clean steam trap strainers.
5. Ensure all steam traps are in service before admitting steam to cold steam lines.
6. Many traps are not designed to handle the large amount of condensate that forms when equipment first warms up. Therefore, open all trap bypasses and manual condensate drains during the warm-up period.
7. Warm up steam lines using small warm-up lines, rather than main isolation valves. Do not open warm-up valves fully. This will limit the steam pressure in the cold steam line. Should water hammer occur, this lower steam pressure will create less severe water hammer.
8. Allow trap bypasses or steam line drains to blow until steam lines are warmed up. To prevent excess steam and water loss, these valves can be pinched off as the steam line warms.

Ensure correct boiler operations.

1. Make sure the water level is not too high.
2. Check the boiler water dissolved solids concentration. Foaming and priming will lead to carryover and water hammer.

Design and Equipment Solutions for Preventing Water Hammer

New or existing piping systems can be designed or modified to lessen the occurrence or severity of water hammer. Certain piping and system components can be upgraded to prevent water hammer. Below are some common design solutions to prevent or reduce the severity of water hammer.

For steam systems:

1. Identify low points in steam lines that should have traps, and install appropriate steam traps.
2. Ensure the installed steam traps are of the proper type and capacity for the application.
3. Install steam separators in longer saturated steam lines to help remove moisture from the steam.
4. Ensure steam and condensate lines are properly graded. Steam lines and condensate lines must be graded in the direction of flow.
5. Install warm-up valves around steam valves on steam lines larger than DN 50.

6. Ensure traps are installed in steam lines before control valves. This will remove condensate that builds up when the valve cycles off.
7. In heating systems, check the boiler Hartford Loop. Only close nipples should be installed between the condensate return connection and the Hartford Loop. Ensure the Hartford Loop connection is at the height recommended by the boiler manufacturer.

For other fluid-handling systems:

1. Install soft-start variable frequency drives to start, modulate, and stop centrifugal pumps.
2. Install slow-opening solenoid valves. These will not open and close suddenly.
3. Install no-slam design check valves.
4. Install surge arrestors downstream of pumps.
5. Redesign piping systems so that fluid velocities are lower.

What to do When Water Hammer Occurs

When Placing a Boiler On-Line

If water hammer or vibration occurs while the non-return valve is being opened, close the valve at once. Ensure the steam line between the header and the boiler is warm. Make sure that the drains between the header isolation valve and the non-return valve are open and blowing steam. Try opening the non-return valve again, but more slowly.

During Routine Operation

Water Hammer in the Boiler House

If water hammer occurs in the boiler house, immediately check the boiler water level. High boiler water level or priming can cause water hammer.

First, blow off the water column and gauge glass to make sure the water level is accurate. If the boiler water is high, lower it with the boiler blowoff valves. Follow proper blowoff procedure. Determine the cause of the high water level or carryover.

If the boiler is priming or foaming, open the boiler surface blowoff valve, to remove impurities from near the boiler water surface. Correct the boiler water conditions that are creating the situation.

In the case of severe priming and water hammer, turn off the boiler and close the non-return valve. Open the non-return valve drain, the header drains, and the trap bypasses. Check the feedwater for contamination.

Water Hammer in the Plant

Open steam trap test valves, or use other means to locate malfunctioning steam traps. Blow out the trap strainer to remove blockage. Place the trap on-line and recheck its operation. If it fails to pass condensate, open the trap bypass to relieve condensate from the steam system. Then, throttle the bypass valve to prevent excessive steam loss or water hammer in the condensate return lines. Isolate and remove the trap for repair or replacement. Follow plant lockout and tagout procedures.

Observe steam lines for sagging, missing insulation, and broken pipe hangers. Report these conditions to the shift engineer or chief engineer, and fill out a work request.

Objective 4

Describe the consequences and actions required for various equipment failures.

Despite the best efforts of operators and plant personnel, equipment failures occur, interrupting production. Sometimes, automatic controls do not operate as designed, and the operator must take manual control of the plant. Plants should have procedures for responding to adverse conditions. Power Engineers must know and practice these procedures so they can respond correctly should these conditions arise.

This objective explores some common equipment failures, and the general principles for how to deal with them.

Power Failure

An electrical power failure requires immediate and effective operator response. Plant operators must be well versed in plant blackout procedures, and follow them closely. As well, operators must know how electrical power failures affect plant equipment, and how to respond. Such considerations may include:

- The positions in which various control valves fail (open, shut, or last position).
- What equipment is fed by standby power, and what is not.
- What equipment is on uninterrupted power.
- How to manually start a standby generator if it fails to start automatically.
- How to manually operate an automatic transfer switch if it fails to operate automatically.
- Plant load shedding strategies.
- How to restart equipment when power is restored.
- The sequence for starting equipment after power is restored.

When a power failure occurs, all electrically powered equipment stops, unless connected to an uninterruptable power source (UPS). Some electrical equipment will restart when normal power is restored. However, most critical power plant equipment will not. Examples of equipment that will restart automatically include:

- Lighting and power receptacles.
- Pumps and fans that cycle on or off on a regular basis, such as small condensate return pumps and unit heater fans.
- Smaller air compressors, refrigeration compressors, and air dryers.

Electrical equipment that runs continuously when the plant is in service will likely require an operator to manually restart. This equipment may include:

- Fuel oil pumps
- Boiler feedwater pumps
- Chilled water pumps
- Condenser water pumps
- Boiler draft fans
- Condensate transfer pumps
- Large air compressors
- Refrigeration compressors and chillers
- Air handling unit fans

When a power failure occurs, valves go to a fail-safe position. Some valves fail open. Others fail shut or closed. Self-powered regulating and control valves continue to operate in response to their set point and the value of the process variable.

Control valves fail as follows:

- Heating system control valves (for heating coils, radiant heaters etc.) typically fail open.
- Fuel line safety shut-off valves fail closed.
- Fuel line bleed valves fail open.
- Boiler feedwater regulating valves (unless self-powered) fail closed.

For the operator, it is of primary importance to know that the fuel safety shut-off and the feedwater control valves fail closed. By design, the boiler fires should extinguish immediately, and the boiler feedwater should stop.

Immediately on power failure, the operator should ensure that the fire is extinguished. If the fire is not out, the fuel safety shut-off valves must be examined to determine why they failed to shut. The boiler must not be returned to service until the safety shut off valves are determined to function correctly. Regardless, the main and pilot test firing valves must be closed. This will prevent an unattended light-off when power is restored.

Firing solid fuel presents a different challenge. The fuel in the furnace can continue to burn, generating steam and lowering the boiler water level. This would require the operator to "bank" the fire. Banking involves smothering the fire by shutting down the forced and induced draft fans, closing the combustion air dampers, and closing the flue or stack dampers. It may also include covering the fire with green coal or ashes, or excluding oxygen by adding steam or other extinguishing medium.

Power plants vary in how well equipped they are at dealing with power outages. Simple plants may have no backup power. Larger plants have some sort of emergency power supply system. These systems may use standby generators or uninterruptable power supplies.

Plants without Backup Power

Plants that have no backup power remain "dead" until normal utility power is restored. In this case, if a power failure occurs, the job of the operator is to put the plant in a safe state until power returns.

CAUTION

Power Engineers should carry flashlights with them at all times. In the case of a power failure, power plants can get very dark, even in the daytime. Emergency lighting is not found throughout all areas of a plant.

Some of the tasks required are as follows:

a) Monitor the boiler as it cools down. Open drum vents once the boiler is depressurized. If a superheater is part of the equipment, open the vent to ensure flow through the superheater tubes to prevent overheating.
b) Isolate the boiler feed pumps.
c) Close the feedwater control valves.
d) Close the fuel line test firing valves.
e) Close the boiler steam outlet valves.
f) Open the boiler non-return valve drain.
g) Open the vents and drains on the steam headers.

Plants with Emergency Power Supply Systems (EPSS)

Plants equipped with Emergency Power Supply Systems (EPSS) have backup diesel engines, natural gas engines, or gas turbines operating standby generators. The generators are connected to automatic load transfer switches. The generators should start automatically when the normal power supply is interrupted. The automatic transfer switch should connect emergency power to critical equipment shortly after the generator starts.

An EPSS is designed to supply long-term power to essential loads. It is common to see generators connected to fuel storage systems with enough capacity for up to a week of operation. EPSS or generators are rated to carry a specified load rather than all plant equipment. When there is loss of power, it is important to open all breakers in an electrical distribution room. This will protect the EPSS bus from being overloaded. This is normally accomplished with automatic load-shedding equipment.

Essential loads are commonly:

- Control room panels and instrumentation
- Emergency lighting
- Feedwater control valves
- Fuel control valves
- Boiler feedwater pumps
- Condensate pumps
- Turbine seal oil pumps
- Turbine lubricating oil pumps
- Fire water pumps

Prior to the EPSS startup, there will be a period in which no power is available. This delay in power restoration will cause valves to fail safe and major equipment to stop. The equipment that stops will require restarting. However, certain critical equipment may be connected to uninterruptable power.

Plants with Uninterruptible Power Supply (UPS)

A UPS maintains power to critical equipment at all times through a system of batteries, rectifiers, power inverters, and automatic transfer switches. The batteries are charged when supplied with normal utility power. On a power failure, the automatic transfer switch connects the batteries and inverter to the critical loads, usually within 1/240th of a second. The inverter then supplies AC power to critical loads.

UPS powered equipment is typically short term which means their battery capacity is up to 6 hours. UPS systems are usually designed for low capacity loads, such as instrumentation and controls, computers, and lighting.

Side Track

More details on UPS systems can be found in **PanGlobal Fourth Class, Part A, Unit 8, Chapter 6 Electrical Distribution Circuits**.

Some plants have DC equipment fed from large battery banks. These automatically start on power failure. Examples include turbine lube oil pumps and generator seal oil pumps. The batteries supply enough power for the DC pumps to operate until the equipment they serve can be safely shut down.

Figure 2 shows a DC seal oil pump. Seal oil is used to keep hydrogen coolant inside large alternators. If a power failure occurs, hydrogen can escape, creating a severe explosion hazard. The pump starts on power failure, and runs until the hydrogen can be safely vented from the alternator.

Figure 2 – DC Seal Oil Pump

Loss of Water Level

A loss of water level could be due to a problem with the feedwater system or a problem with the boiler.

Feedwater System

A loss of boiler feedwater will result in a low water condition and a boiler trip before the water level reaches the lowest permissible water level. A loss of feedwater could be due to pump failure, control valve failure, or failure to return condensate to the plant.

In many plants, a low water alarm precedes the operation of the low water cut-off. This allows the operator to determine the cause, and take steps to restore feedwater flow before the boiler trips.

Feedwater Pump Failure

Feedwater pump failure could be due to:

- Electrical failure of the pump drive motor.
- Failure of the pump drive belt or coupling.
- Failure of the pump bearings, due to age, improper fitting, or improper lubrication.

A quick check involves observing the feedwater pump discharge pressure. The pressure should be higher than the boiler operating pressure, but not as high as the pump shutoff head pressure. If the pressure is at or near the shut-off head pressure, obstruction in the feedwater line is indicated. It may be that the feedwater valve has failed, blocking the feedwater flow.

In many plants, the standby boiler feedwater pump starts automatically when the on-line pump fails to provide adequate feedwater pressure. In other plants, the standby pump must be manually started. In all cases, the standby pump should be ready to start on short notice. The valves of the standby pump should be kept lined up for service. The pump must be vented and primed. Often, small amounts of hot feedwater are circulated through the standby pump to keep it hot.

If the boiler feedwater pump trips, make sure the standby pump starts automatically. If the standby pump is not automatic, start it manually. Then, observe that the water level in the boiler returns to normal.

It is good advice to start the standby feedwater pump even if the main pump is running. It is possible that internal pump damage could go unnoticed, and that standby pump operation is all that is needed to restore feedwater flow.

Feedwater Control Valve Failure

Control valve failure could be due to:

- Control instrumentation failure
- Compressed air failure
- Control valve mechanical failure

If the boiler feedwater pumps are supplying feedwater at the correct pressure, check the position of the feedwater control valve stem. If the stem shows the valve is fully open, suspect feedwater blockage downstream of the control valve. It is also possible that the valve has internal damage, preventing it from opening. For example, the stem may have separated from the valve plug.

If the valve stem shows it is closed, suspect the feedwater control system or the plant instrument air supply. Open the feedwater bypass valve. Observe whether the boiler water returns to normal. Then, modulate the bypass valve manually to maintain proper water level.

In this situation, if the boiler is to be operated for a prolonged period of time, an additional Power Engineer must be assigned to attend the bypass valve and maintain boiler water level. The feedwater control valve should be removed from service and repaired promptly.

Failure to Return Condensate to the Deaerator

If a condensate transfer pump fails, the deaerator can be pumped dry by the boiler feedwater pumps. This results in boiler feedwater pump damage and low boiler water. Deaerators are often equipped with low-level alarms to alert the operator of such a situation. As well, boiler feedwater pumps are often connected to deaerator low-low level cut-off switches. In the event of a low-low deaerator level, the boiler feedwater pump will trip off, and the standby pump will be disabled.

Check the condensate return tank level. If adequate, check the condensate transfer pumps. If the condensate transfer pump has tripped off, start the standby condensate transfer pump. Check that the deaerator level returns to normal.

If the condensate tank level is low, check the make-up water system. Make sure it is feeding make-up water to the condensate tank (or deaerator, according to the make-up system design).

If deaerator water level cannot be restored, shut down the boilers until the cause of the low deaerator level is determined and corrected.

Problems with the Boiler

Occasionally, boiler blowdown or blowoff valves may be accidentally left open, or may pass significant amounts of water even when closed. This may be due to debris lodged in a valve body, or mechanically defective valve plugs, gates, or seats. A quick scan of blowdown and blowoff lines can reveal these problems. These pipes should be relatively cool compared to the boiler shell. Check the temperature of the blowdown and blowoff lines with a handheld infrared thermometer. Hot lines indicate an undesirable loss of boiler water.

Damaged boiler tubes may also be a cause of low water. This damage could be from waterside corrosion, or from overheating due to excessive waterside scale accumulation. Look for water leaking from the front or rear doors of firetube boilers. Examine the flue gas for excessive moisture. Observe the flame for a disruption in its normal pattern, or for abnormal colour. Check all around and under the boiler for water. If a leak is suspected, the boiler should be removed from service, cooled, and thoroughly inspected.

Boiler Trips on Low Water

If the cause of low water cannot be determined quickly, and the water level restored, the boiler must trip on low water. After it trips, close the pilot and main test firing valves. When the boiler stops steaming, close the non-return valve and header valve, and open the non-return valve drain. The boiler should not be restarted until the cause of feedwater loss has been rectified.

On Track

The boiler low water cut-off must trip at, or before, the boiler water level reaches the lowest visible part of the gauge glass. This level is well above the lowest permissible water level of the boiler. Therefore, it is highly unlikely that a boiler with a correctly installed and functioning low water cut-off will sustain a damaging low water condition if a low water trip occurs.

Boiler Sustains a Low Water Condition

If an improperly functioning low water cut-off device fails to trip off the boiler, the fires will continue to operate. In this situation, metal surfaces can overheat and weaken. Trip the boiler manually, and shut the test firing valves. Then, isolate, cool, drain, and open up the boiler for internal inspection. If damage is suspected, or there are signs of overheated surfaces, notify the chief engineer and the jurisdictional boiler inspector.

No Water Level Indication

If the water level is outside of the visible portion of the gauge glass, the water level may be above the top or below the bottom of the gauge glass. In this case, blow down the gauge glass. This will reveal if the water level is above the top of the gauge.

Water Below Lowest Visible Part of Gauge Glass

If the boiler water level is below the lowest visible part of the gauge glass, shut the boiler down and let it cool slowly. DO NOT add water to the boiler to restore water level. This could rapidly cool any overheated surfaces, create metal stresses, and cause failure. As well, an influx of feedwater can rapidly evaporate, which will cause a pressure spike that may damage overheated metal surfaces. DO NOT operate the safety valve try lever.

If the boiler operated with its water level below the lowest visible part of the gauge glass, it should be isolated, cooled, drained, and opened up for internal inspection. If damage is suspected, or there are signs of overheated surfaces, notify the chief engineer and the jurisdictional boiler inspector.

On Track

Low water operation may or may not cause boiler damage. The lowest visible part of the gauge glass is still higher than the lowest permissible water level of the boiler. However, if the water level cannot be seen in the gauge glass, it is impossible to know how low the water is, or how low the level became before shutting off the burner. Therefore, it is highly advisable to take the boiler out of service, and thoroughly inspect it for damage.

Water Above Highest Visible Part of Gauge Glass

High boiler water level can cause severe and destructive water hammer.

If the boiler water level is above the highest visible part of the gauge glass, blow off the water column and gauge glass to make sure the water level is accurate. If the boiler water is high, lower the boiler water level using the blowoff valves. Follow proper blowoff procedure.

In the case of severe priming and water hammer, turn off the boiler, and close the non-return valve. Open the non-return valve and header drains, or trap bypasses. Check the feedwater for contamination.

Determine the cause of high water level before returning the boiler to service.

Flame Failure

Flame failure has a number of causes, including:

- An inadequate pilot flame during the ignition period
- Excessive combustion air supply
- An unstable main flame during the run period
- A defective flame detection device or flame safeguard control
- A fuel supply failure

Whenever a flame failure occurs, the combustion safeguard control (programmed combustion control) will signal "flame failure," usually with a light, an alarm, or a digital readout. Flame failure signals do not result from the action of a boiler permissive, such as a low water cut-off, fuel pressure switch, or pressuretrol.

When a flame failure occurs, the pilot and main test firing valves should be shut, and the cause of the failure should be investigated.

Once the cause of the failure has been determined and corrected, the operation of the flame safeguard controls must be carefully tested prior to restoring the boiler to service.

Side Track

Instructions for testing the operation of the programmed combustion control, and for performing flame failure tests, are covered in **PanGlobal Fourth Class, Part B, Unit 4, Chapter 4 Operational Checks**.

Inadequate Pilot Flame

During the pilot trial for ignition (PTFI) period, flame failure can occur if the pilot is of inadequate size to light the main burner. This may be due to a defective or improperly adjusted pilot fuel regulator.

ASME CSD-1 recommends that automatically fired boilers have an annual pilot turndown test. This test establishes the minimum pilot flame size that can consistently and safely ignite the main burner. A certified burner mechanic, such as a Class A gas fitter, must perform this test, and subsequently adjust the pilot flame.

An adequately sized pilot flame may fail if excessive combustion air is provided during the PTFI period. Modern damper drive motors have low fire start switches that must be satisfied before PTFI can occur. However, if a boiler with an older model damper drive does not have a low fire start switch, and fails in the high fire position, the pilot flame will likely be blown out.

If the flame fails during pilot ignition, contact a certified burner technician, or Class A gas fitter, to adjust the pilot to manufacturer specifications.

Unstable Main Flame

A main flame may be unstable due to:

- Excessive fuel pressure
- Inadequate fuel pressure
- Excessive combustion air
- Inadequate atomizing air or steam
- Dirty atomizer spray plate
- Defective fuel pumps
- Blocked fuel strainers
- Utility gas supply failure

Excessive Fuel Pressure

An improperly adjusted fuel pressure regulator can cause excessive fuel pressure. Before such a condition arises, the high fuel pressure cut-off switch should trip the boiler. However, if the cut-off is improperly adjusted or defective, the excess in fuel pressure will cause over-firing, lifting flames, smoky furnace conditions, and flame instability. The flame may be so smoky or unstable that the flame safeguard control trips off the burner.

Contact a certified burner technician, oil fitter, or Class A gas fitter to adjust the fuel pressure and the high fuel pressure cut-off to the burner manufacturer specifications.

Inadequate Fuel Pressure

Inadequate fuel pressure is often caused by an improperly adjusted fuel pressure regulator. Before such a condition arises, the low fuel pressure cut-off switch should trip the boiler. However, if the cut-off is improperly adjusted or defective, inadequate fuel pressure will cause flame instability. This will cause the flame safeguard control trip off the burner.

Inadequate fuel pressure could also occur because of failure in the utility fuel supply system. For oil burners, blockage in the fuel strainer could also be the cause. Check the fuel oil supply pressure. If the pressure is low and a dual strainer is installed, switch strainers and see if this helps. If there is only one strainer in the line, stop the pump and clean the strainer. Always follow plant procedures.

Inadequate fuel oil pressure can also arise if the fuel oil pump is defective. If changing the fuel oil strainer has no effect on the fuel oil pressure, suspect a faulty pump. Switch to the standby fuel oil pump, and see if the fuel supply pressure returns to normal.

Contact a certified burner technician, oil fitter, or Class A gas fitter to adjust the fuel pressure and the low fuel pressure cut-off to the burner manufacturer specifications.

Inadequate Atomizing Medium

For air or steam-atomized burners to function correctly, they require the proper atomizing medium pressure. If this pressure is inadequate, it can cause poor quality flames. The low atomizing medium cut-off switch should extinguish the burner before flame failure occurs. However, if the switch is defective or improperly adjusted, the poor quality oil flame will cause the flame safeguard control to trip the burner off.

Failure of Flame Detection and Flame Safeguard Controls

Flame scanners, flame rods, and thermocouples can, and do, fail. UV scanners last up to 40 000 hours before they need replacement. However, they will fail sooner if exposed to high temperature. Ensure flame scanners always have adequate cooling air while in service. Flame rods can warp and come out of alignment over time. If incorrectly aligned, they may fail to detect the pilot or main flame. Ceramic insulators can fail, and short out the flame rod. During annual burner maintenance, ensure the flame rods are clean, their ceramic insulators are intact, and they are properly aligned.

Flame safeguard controls (programmed combustion controllers and primary controls) can also fail. Fifty years ago, it was not unusual for Power Engineers to keep replacement flame amplifier tubes handy. Modern flame amplifiers, though, are solid-state. Still, these amplifiers fail on occasion. If all normal operating parameters are met (fuel pressure, combustion air, and all boiler permissives), and the boiler fails to light off or has repeated flame failures, a defective programmed combustion control or flame amplifier may be the problem.

Contact a certified burner technician, oil fitter, or Class A gas fitter to inspect the operation of the flame safeguard control system. Replace defective components, and retest the burner.

Side Track

More details on flame safeguard equipment can be found in **PanGlobal Fourth Class, Part B, Unit 3, Chapter 8 Combustion Safety**.

Forced Draft (FD) Fan Failure

Forced draft fans may fail due to failure of the electric motor, fan bearing, coupling, or fan belt. If a draft fan fails, the combustion air proving switch should open and extinguish the burner. If the switch fails to operate, the flame will become excessively smoky. Explosive conditions may arise in the furnace due to the presence of unburned fuel.

If an FD fan fails, and the combustion air proving switch does not shut down the burner, immediately shut the main and pilot test firing valves. Close the FD fan damper so that combustion air cannot enter the furnace and create explosive conditions. Follow the normal boiler shutdown procedure.

When the furnace is cooler, allow air to enter the furnace through the fan damper. This will sweep carbon monoxide and unburned fuel from the furnace.

The combustion air proving switch must be replaced, adjusted according to the burner manufacturer specifications, and tested prior to placing the boiler in service. Contact a certified burner technician, oil fitter, or Class A gas fitter to replace and adjust the combustion air proving switch.

When the cause of the FD fan failure is determined, and repairs are complete, thoroughly purge the furnace prior to beginning a normal restart.

Objective 5

Describe the consequences, and actions required, in the event of boiler accidents.

Overpressure Events

An overpressure event can occur if the safety valve fails to open when boiler pressure reaches the safety valve set point, or if a safety valve, while blowing, fails to stop the boiler pressure from rising excessively. **ASME BPVC Section I Part PG-67** states that:

> *The pressure relief valve capacity for each boiler … shall be such that the pressure relief valve, or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6% above the highest pressure at which any valve is set and in no case to more than 6% above the maximum allowable working pressure.*

To ensure the safety valve has adequate capacity, an accumulation test can be performed.

Side Track

Accumulation tests are covered in **PanGlobal Fourth Class, Part B, Unit 4, Chapter 4 Operational Checks.**

If an overpressure event occurs, shut down the boiler. Then isolate, cool, and drain it. Inform the boiler inspector. It is very important to determine the cause of the overpressure event before returning the boiler to service.

The vessel should undergo a thorough internal and external inspection. It is also recommended that the boiler undergo a hydrostatic test to determine the integrity of the pressure vessel. If the boiler shell and other pressure components are deemed acceptable to return to service, the safety valves should be removed, serviced, reset, and recertified by an approved agency.

If the installed safety valve capacity is adequate for the boiler, it is possible the boiler is being over-fired. A certified burner technician, oil fitter, or Class A gas fitter should determine the actual firing rate of the boiler, and adjust the firing conditions according to the boiler and burner manufacturer specifications.

Furnace or Pressure Vessel Explosions

Furnace explosions occur when an accumulation of combustible gases ignites and explodes within the furnace, or gas passes of the boiler.

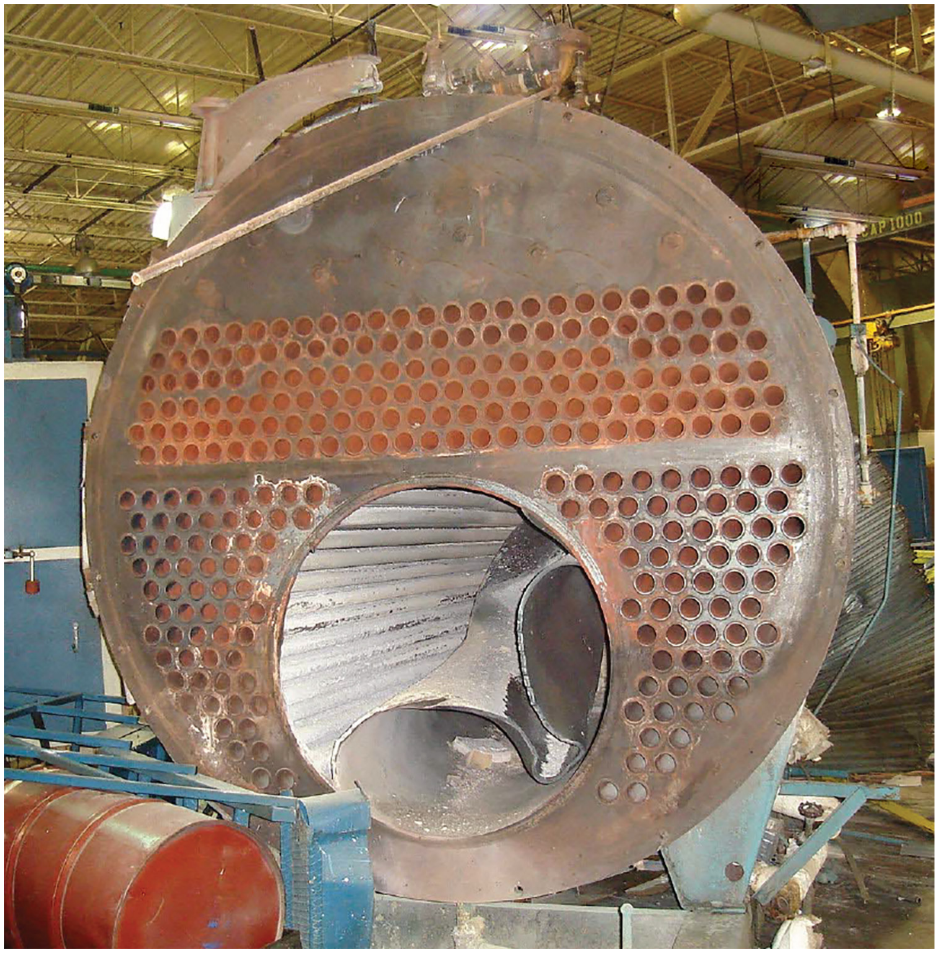
Pressure vessel explosions occur when a pressure part of the boiler, such as the shell, a watertube, or a firetube, bursts due to excessive internal pressure or structural weakening.

In most jurisdictions, prompt reporting is required following a furnace or pressure vessel explosion. For example, the **New Brunswick Boiler and Pressure Vessel Act** states:

> *When an explosion that causes damage to a boiler or pressure vessel occurs in connection with a boiler or pressure vessel, the owner or operator of the boiler or pressure vessel shall report it immediately to the Chief Inspector by telephone or telegraph, and, within 24 hours after its occurrence, shall send a report on it by mail to the Chief Inspector, stating the exact place at which the explosion occurred, the number of persons, if any, killed or injured by it and any other information required by regulations.*

After experiencing a pressure vessel explosion, the boiler shown in Figure 3 did not pass inspection.

Figure 3 – Boiler After Low Water Condition



Chapter Summary

Boiler plant monitoring is complex and requires great attention to detail on the part of the operator. There are many dynamic elements to power plant operation, which require skilled, diligent operators.

This chapter covered the need to observe, monitor, record, and interpret plant conditions. These records help inform operating decisions and maintenance practices.

Adverse conditions, such as power failure, water hammer, low water, flame failure, combustion air failure, and explosions were also discussed. Appropriate operator response to these conditions cannot be emphasized enough.

Unit Summary

This unit covered many of the major operational elements common to most boiler plants. These authentic industrial situations included:

- Boiler plant startup
- Boiler startup
- Boiler operation
- Operational checks
- Boiler shutdown procedures
- Monitoring requirements

This unit progressed much like a boiler plant operational cycle.

Before starting a boiler, its auxiliary systems must first be proven ready, and then brought online. For example, a boiler cannot be fired until the feedwater system has been started and proven operational. A boiler must be fired and then carefully monitored by the operator. If equipment does not operate as expected, the plant operator recognizes and corrects the situation.

When a boiler is on-line, the operator performs many tasks, including safety device checks, blowoffs, and routine monitoring.

When a boiler plant is to be shut down, Power Engineers know there is more involved than just turning a boiler off. These operators take great care: cooling boilers slowly, and laying them up to preserve their longevity.

This unit provided a high-level overview of typical processes and procedures. In order for Power Engineers to develop competency, they must understand all aspects of boiler operation. The level of complexity of each plant is different. Operating time, and continued reference to the guidelines in this unit, will raise a nervous neophyte operator to the level of skilled and competent plant operator.

A self-assessment tool is available on MyPower LMS. Login using the unique user ID and password found on the inside front cover of Unit 1.

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UNIT B-4

Knowledge Exercises and Unit Glossary

Knowledge Exercises – Chapter 1

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. What steps must be taken if leaks are found when walking down a fuel oil system?

Objective 2

2. Identify four combustion controls that must be verified during a plant startup.

3. During a boiler start, the forced draft fan fails in operation. Which safety device responds to the fan failure and causes the boiler to trip?

Objective 3

4. Why should plant personnel always walk around, and not step over, rotating equipment?

5. Define the STAR principle.

Chapter 1 (Cont.)

Objective 4

6. How long must a hot water heating system high-point be vented? Explain why.

Objective 5

7. What must be done, as general startup preparation, for a steam boiler that is not done for a hot water boiler?

Objective 6

8. What is housekeeping, and why is it important?

Knowledge Exercises – Chapter 2

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. Why are cold boilers warmed up on low fire? Name three reasons.

Objective 2

2. When starting a hot water boiler, why must the boiler be attended until it reaches its temperature limit cut-out?

3. What is meant by the term “cutting in”?

4. List four log book entries operators should make after placing a boiler on line.

Objective 3

5. For a single boiler steam plant, state the two methods of warming up the boiler and plant piping. Which method is preferred by **ASME VI**?

Chapter 2 (Cont.)

6. Why are drain valves open during steam plant warm-up?

7. Why is the boiler drum vent open during the boiler warm-up period? When should it be closed?

Objective 4

8. Explain the process for cutting in a boiler equipped with a non-return valve, when the interconnecting piping is warmed with steam from an energized steam header.

9. Why are non-return valves only opened 25% when warming up steam lines?

Objective 5

10. Why are some automatic gas valves arranged in a double block and bleed arrangement?

Chapter 2 (Cont.)

11. Why must a supervised main test firing valve be shut during a furnace pre-purge?

Objective 6

12. Name and explain two post-start inspections for a hot water boiler, and two post-start inspections for a steam boiler.

Knowledge Exercises – Chapter 3

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. What causes a hot water heating system to lose water?

2. Describe how to drain and refill a bladderless expansion tank.

3. Describe how to check the air charge of a bladder-type expansion tank.

4. A hot water boiler has a safety valve set to 518 kPag. What is the maximum pressure that the boiler should operate at?

5. Name three conditions that may lead to higher than normal flue gas temperature.

Chapter 3 (Cont.)

Objective 2

6. Name three kinds of tests performed on low water cut-offs.

7. How often should an operator check the low water cut-offs of a power boiler in steam service?

8. Why are float cages, low water fuel cut-offs, water columns, and gauge glasses blown down regularly?

9. A power boiler in steam service has a safety valve set to 2070 kPa. What should the maximum operating pressure be for this boiler?

Objective 3

10. What conditions may lead to a low water level in a boiler?

11. What should an operator do if the boiler water level is not visible in the gauge glass?

Chapter 3 (Cont.)

12. What are the two main types of boiler explosion?

13. Name the main causes of boiler pressure vessel explosions.

14. Name the main causes of boiler furnace explosions.

Chapter 3 (Cont.)

15. What steps should an operator take if the boiler water level is too high, but is still visible in the gauge glass?

Objective 4

16. What operating condition may arise from a weak or defective flame detector? What should be done about the flame detector?

17. A burner continues through a pre-purge, but does not ignite the pilot. What are the possible causes?

Knowledge Exercises – Chapter 4

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. The thermometer of a deaerator reads 130°C. What should the pressure gauge read? Assume atmospheric pressure is 101.1 kPa, and that the deaerator is operating correctly.

2. While on rounds, condensate return tanks are checked.

   a) What condition may indicate a defective steam trap?

   b) What condition may indicate a tripped return pump breaker?

3. Name the water tests that can be performed on condensate, and explain why are these tests performed.

4. Name three water softener checks that can be made while on rounds.

Chapter 4 (Cont.)

5. The safety valves for a hot water heating system lift whenever the boiler fires. What is the most likely cause?

6. Describe, in general terms, the indications of a proper burner flame.

7. What are the routine checks performed on a plant compressed air system?

8. Should a standby diesel generator be cold to touch? Why or why not?

Chapter 4 (Cont.)

9. With the aid of a diagram, describe the steps in performing a water column/gauge glass blowdown. The water column is equipped with isolation valves.

Chapter 4 (Cont.)

Objective 2

10. Describe the procedure for checking the main flame failure response.

11. Ultraviolet flame scanners have a lifespan of ____________________ hours.

12. Explain how to test a low gas pressure cut-off switch.

13. What is the name of the safety valve test that determines its popping and reseating pressure?

Chapter 4 (Cont.)

14. After a safety valve try-lever test, the valve does not reclose tightly and simmers. What should be done?

15. A high-pressure steam boiler safety valve is set to 1725 kPa. The valve lifts at 1780 kPa and reseats at 1690 kPa. Is this valve operating correctly? Explain.

16. During an accumulation test on a low-pressure steam heating boiler, the boiler pressure rises to 140 kPa. Does the safety valve have adequate relief capacity? Explain.

17. According to code, what boilers use flow switches instead of low water cut-offs?

18. Explain a procedure for testing the high-pressure cut-off of a steam boiler.

Chapter 4 (Cont.)

19. What check should be performed daily on the low water cut-off of a high-pressure steam boiler?

Objective 3

20. Is it okay to tighten the packing gland on a valve under pressure? Explain.

Objective 4

21. Explain the circle/slash method of place keeping while carrying out a procedure.

Objective 5

22. What information should be recorded in a boiler room log book?

Knowledge Exercises – Chapter 5

Name: ______________________________ Date: ________________________________

Instructor: ___________________________ Course: ______________________________

Objective 1

1. Name five hot water boiler operating controls that should be checked before taking the boiler off-line.

2. List the additional shutdown steps to prepare a hot water boiler for waterside inspection.

Objective 2

3. Why are boiler safety and operating limits tested before taking a boiler out of service?

4. Name six steam boiler operating controls that should be checked before taking a boiler off-line.

Chapter 5 (Cont.)

5. Name two reasons why a steam boiler vent needs to be opened on boiler shutdown?

6. A lock box contains 25 red locks, and 14 are used in a boiler lockout. Where are the remaining 11 red locks stored?

7. A boiler is being returned to service after a lockout. What is the last lock removed from the lock box?

Objective 3

8. When is a dry layup used?

9. When is a wet layup used?

10. Why is silica gel placed inside a boiler shell?

Knowledge Exercises – Chapter 6

Name: ______________________________ Date: ________________________________

Instructor: ___________________________ Course: ______________________________

Objective 1

1. How often are circular charts renewed?

2. List seven boiler operating parameters that may be found on a reading sheet.

Objective 2

3. In a power plant, which work groups are involved in performing preventative maintenance tasks?

4. How often should a standby diesel generator be test run? How long should it run under test?

Chapter 6 (Cont.)

5. How often are "no flow" tests performed on diesel and electric fire pumps? How long should they run under test?

6. Why is duty swap performed?

Objective 3

7. A DN 100 valve must be opened. To prevent water hammer, how long should it take an operator to fully open the valve?

8. Why is it important to inspect steam mains for broken or missing pipe hangers?

9. With regard to water hammer, why should steam lines be well insulated?

Objective 4

10. Name five pieces of common power plant equipment that do not typically restart when power is restored.

Chapter 6 (Cont.)

11. Name five essential loads connected to emergency power supply systems.

12. State a reason why a deaerator low-level alarm may be activated.

13. A boiler trips off on low water. How likely is it that the boiler has sustained damage?

14. What should be done if the water level cannot be seen in the gauge glass?

15. What is a "pilot turndown" test?

16. Who is qualified and certified to adjust the operation of a boiler burner?

Chapter 6 (Cont.)

Objective 5

17. A boiler shell has a maximum allowable working pressure of 2415 kPa. The safety valve installed on the boiler has a set point of 2070 kPa. During an accumulation test, the boiler pressure stabilizes at 2200 kPa. Does the safety valve have adequate capacity? Explain. Show all calculations.

Unit B-4 Glossary

Term	Definition
Accumulation test	A method of determining boiler safety valve capacity, by shutting off all steam discharge outlets from the boiler, and forcing the fires to the maximum.
Aqua-stat	A hot water boiler fitting that starts and stops the burner by sensing the temperature of the water. The term “AQUASTAT™” is a trademark of Honeywell International, Inc., originally filed in 1923.
Ash	The non-combustible product of combustion left from the burning of solid fuel.
Atmospheric burner	A device for burning gaseous fuels, where combustion air is delivered to the burner at atmospheric pressure, with no additional mechanical means.
Blowdown	With regard to boiler waterside operations, the continuous removal of a portion of boiler water for the purpose of reducing dissolved solids concentration.
Blowoff	With regard to boiler waterside operations, the intermittent removal of a portion of boiler water to discharge sludge.
Boil out	To remove greasy contaminants from the waterside of a boiler by first adding caustic or basic chemicals to the boiler water and then adding heat.
Carryover	The entrainment of water droplets in the steam leaving the boiler drum.
CBD	See *continuous blowdown* (CBD).
Coalescing filter	A filter used to remove water and oil aerosols from compressed air, by causing smaller particles to come together to form larger particles.
Combustion air opening	An opening from a mechanical room where combustion equipment is housed that provides the fresh air required for satisfactory combustion of a fuel, including excess air.
Condensate	Fluid formed when steam is cooled to below its saturation temperature.
Continuous blowdown (CBD)	The continuous removal of concentrated boiler water from a boiler. This reduces the total solids concentration in the remaining water
Cutting in	The activity of adding a previously non-operating piece of equipment, such as a boiler, into a system that is already in operation.
Day tank	A local supply of fuel oil for boilers, emergency generators, or other oil-fired equipment.
Dew point	The temperature at which the water vapour in the air is saturated; the temperature at which water vapour begins to condense out of the air.
Dilution air	The ambient air that is admitted to a venting system at the draft hood, draft diverter, or draft regulator, to cool combustion products.
Draft fan	A mechanically driven fan used to either blow combustion air into a furnace, or to draw combustion gases from a furnace and expel them out the chimney.
Draft hood	A draft control device installed on natural draft appliances. It is designed to: a) Ensure the ready escape of flue gases from the combustion chamber in the event of either no draft, or stoppage downstream from the draft hood. b) Prevent a backdraft from entering the combustion chamber of the appliance. c) Neutralize the effect of stack action of either a chimney or a vent upon the operation of the appliance.

Term	Definition
Dry run	A trial exercise to check that equipment operates correctly prior to placing the equipment on-line. Dry runs are conducted with precautions in place to prevent damage to equipment or personnel if the equipment malfunctions during the exercise.
Electrolyte	A liquid or paste that conducts electricity as a result of the presence of positive or negative ions.
Expansion tank	A tank that permits changes in the water volume of a hot water heating system, as it changes in temperature. The tank allows the system to be filled with the proper amount of water when cold, without excessive system pressure occurring as system temperature increases.
Feedwater	Water introduced into a boiler during operation. It includes make-up and return condensate.
Flame failure	The time between a primary safety control flame failure detection device sensing a flame is out and de-energizing the fuel system.
Flame scanner	A device that monitors the pilot and main flame of a furnace.
Float cage	A large hollow chamber used to house a level sensor (such as a float) external to a process vessel. Float cages dampen the effects of surface agitation and, when equipped with isolation valves, permit servicing of the level sensor without draining the attached process vessel.
Foaming	The continuous formation of bubbles with sufficiently high surface tension, so they remain as bubbles above the disengaging surface. This interferes with the natural steam disengagement process and can result in priming.
Gauge glass	A fitting used to give a visual indication of the water level in a boiler or other vessel.
Handhole	An access opening in a boiler or pressure vessel, usually less than 150 mm in its longest dimension.
Header	A chamber that collects or distributes fluid to or from multiple parallel flow parts.
Heating boiler	A low-temperature, low-pressure hot water or steam boiler, designed in accordance with **ASME BPVC Section IV**.
Internal water treatment	The softening, deaeration, and conditioning of water inside the boiler shell or drum, through the addition of chemicals.
Ion-exchange softener	Equipment used to soften water, using the principles of ion exchange.
Low fire start	The requirement for a burner to have its fuel and combustion air flows at their minimum respective settings prior to ignition. Burners with proven low fire start use interlock switches to prevent ignition if the fuel and air are not in low fire position.
Low water fuel cut-off (LWCO)	A safety device that will shut off a boiler if its water level becomes too low.
LWCO	See *low water fuel cut-off* (LWCO).
Magnetic latching ssov	A valve that automatically shuts off the supply of gas when de-energized by a combustion safety or safety limit control, but must be opened manually.
Main test firing valve	A quarter turn manual shut-off valve that is located downstream of all safety shut-off valves on the main valve train, and as close to the burner as is practicable.
Make-up water	The water added to a boiler system to compensate for water lost through exhaust, blowdown, blowoff, leakage, and others.
Manhole	A circular or elliptical opening through which a person may enter a boiler or pressure vessel, in order to conduct maintenance, inspection, or repair.

Term	Definition
National board of boiler and pressure vessel inspectors (NBBI)	An organization comprised of chief boiler and pressure vessel inspectors from most North American jurisdictions, whose purpose is to promote greater safety to life and property through uniformity in the construction, installation, repair, maintenance, and inspection of pressure equipment.
NBBI	See *National board of boiler and pressure vessel inspectors* (NBBI).
OS&Y	See *outside screw and yoke* (OS&Y).
Outside screw and yoke (OS&Y)	A manually operated valve with a screw and a yoke outside of the valve body or bonnet.
Oxygen scavenger	A chemical added to boiler water that combines with oxygen, to prevent oxygen-induced corrosion.
Packaged boiler	A boiler that is entirely shop-fabricated and tested, complete with all required auxiliaries, such as burners and controls, and sold as a package.
Permissive	In control instrumentation, one or several conditions (such as flow, temperature, level, or pressure) that must be satisfied for a process sequence to proceed.
pH	Unit of measure of the acid or alkaline condition of a substance.
Pilot burner	A small burner used to ignite a large burner.
Pilot trial for ignition	The step of a burner start sequence during which the pilot flame is established and detected.
Post-purge	Air that blows through a furnace to remove any unburned fuel that may be present after the combustion process stops.
Power boiler	A high-temperature, high-pressure hot water or steam boiler, designed in accordance with **ASME BPVC Section I**.
Power burner	A burner supplied with combustion air by a mechanical device, such as a fan or blower.
Pre-ignition interlock	A safety device which must be satisfied by the process condition it measures, prior to the commencement of a burner ignition sequence.
Purge	Air that blows through the furnace to remove any unburned fuel that may be present prior to lighting up.
Priming	With regard to boiler operation, an undesirable condition, in which excess quantities of water are carried along with the steam to the steam outlet.
Programmed combustion control	A digital controller that monitors the startup sequence (limit switches, timed purge, pilot, and main flame) and operation of a burner system.
Proof of closure switch	A factory-sealed switch incorporated into a safety shut-off valve that includes at least one set of contacts. The switch closes only after the valve port is closed, and opens prior to the opening of the valve port.
Quicklime	Calcium Oxide (CaO)
Rising stem valve	A gate or globe valve whose handle or stem changes in position when operated from fully closed to fully open.
Safety relief valve	An automatic pressure-relieving device characterized by rapid opening or pop action, or by gradual opening proportional to the pressure increase, depending on the application. It may be used either for vapour or liquid service.
Safety shut-off valve (SSOV)	A fast-closing valve that automatically and completely shuts off the fuel supply. This is in response to an operating limit or a safety limit.
Safety valve	An automatic pressure-relieving device actuated by the static pressure upstream of the valve. It is characterized by full-opening pop action. It is used for gas or vapour service including steam.

Term	Definition
Safety vent valve	A solenoid operated gas valve used to bleed gas pressure from between safety shut-off valves in a double block and bleed system.
Scale	A deposit that forms on tubes, reducing heat transfer efficiency.
Schrader valve	A small spring-loaded check valve, used in combination with an air chuck, commonly used for adding compressed air to containers such as pneumatic tires and expansion tanks.
Sealed combustion system	A system whereby burners housed in a sealed furnace draw combustion air directly from the outside and vent the products of combustion directly to the outside. In the case of sealed combustion, the burner, combustion air and combustion products cannot communicate with the air inside the mechanical space.
Silica gel	A silicon oxide that readily adsorbs moisture, used as an air-drying agent.
Simmer	In a pressure relief valve, the audible or visible escape of fluid between the seat and disc, at an inlet pressure below the popping pressure of the valve.
Sodium zeolite softener	An ion-exchange softener that uses cation exchange resin, regenerated with sodium chloride.
Soot	Carbon dust formed by incomplete combustion.
Soot blower	A mechanical device for discharging air, steam, or water to clean the fireside of boiler heat transfer surfaces.
SSOV	See *safety shut-off valve* (SSOV).
Steam trap	An automatic valve that drains condensate from a steam-containing enclosure while remaining tight to live steam, or if necessary, allowing steam to flow at a controlled or adjusted rate. Most steam traps will also pass non-condensable gases while remaining tight to live steam.
Superheater	A group of tubes which absorb heat from the products of combustion to raise the temperature of the steam passing through the tubes above its saturation temperature.
Supervised cock	In a fuel train, a test firing valve equipped with a proof of closure switch
Test firing valve	A quarter turn manual shut-off valve that is located downstream of all safety shut-off valves on the pilot or main fuel valve train and as close to the burner as is practicable.
Trap bypass	A bypass valve installed in a condensate system parallel to a steam trap. It helps release condensate from the condensate line at high rates during warm-up periods.
Tridicator	A gauge used on hot water heating systems that indicates water pressure, water height or "head", and water temperature.
Walk down	A tour of a power plant or power plant system to discover adverse conditions prior to starting the plant or plant system.
Water column	A chamber connected at top and bottom to the steam and water spaces of a boiler respectively, and to which the gauge glass, high and low level alarms, and low water cut-offs may be connected.
Water hammer	A sudden increase in pressure of water due to an instantaneous conversion of momentum to pressure.
Windmilling	A term used to describe the rotational movement of a fan or turbine that is not receiving power. Examples include the rotation of a gas turbine that is created by wind, or the rotation of a fan in a heating duct, due to airflow.

Additional Workspace

Additional Workspace

Additional Workspace

Additional Workspace